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Microgrids & District Energy: Pathways To Sustainable Urban Development

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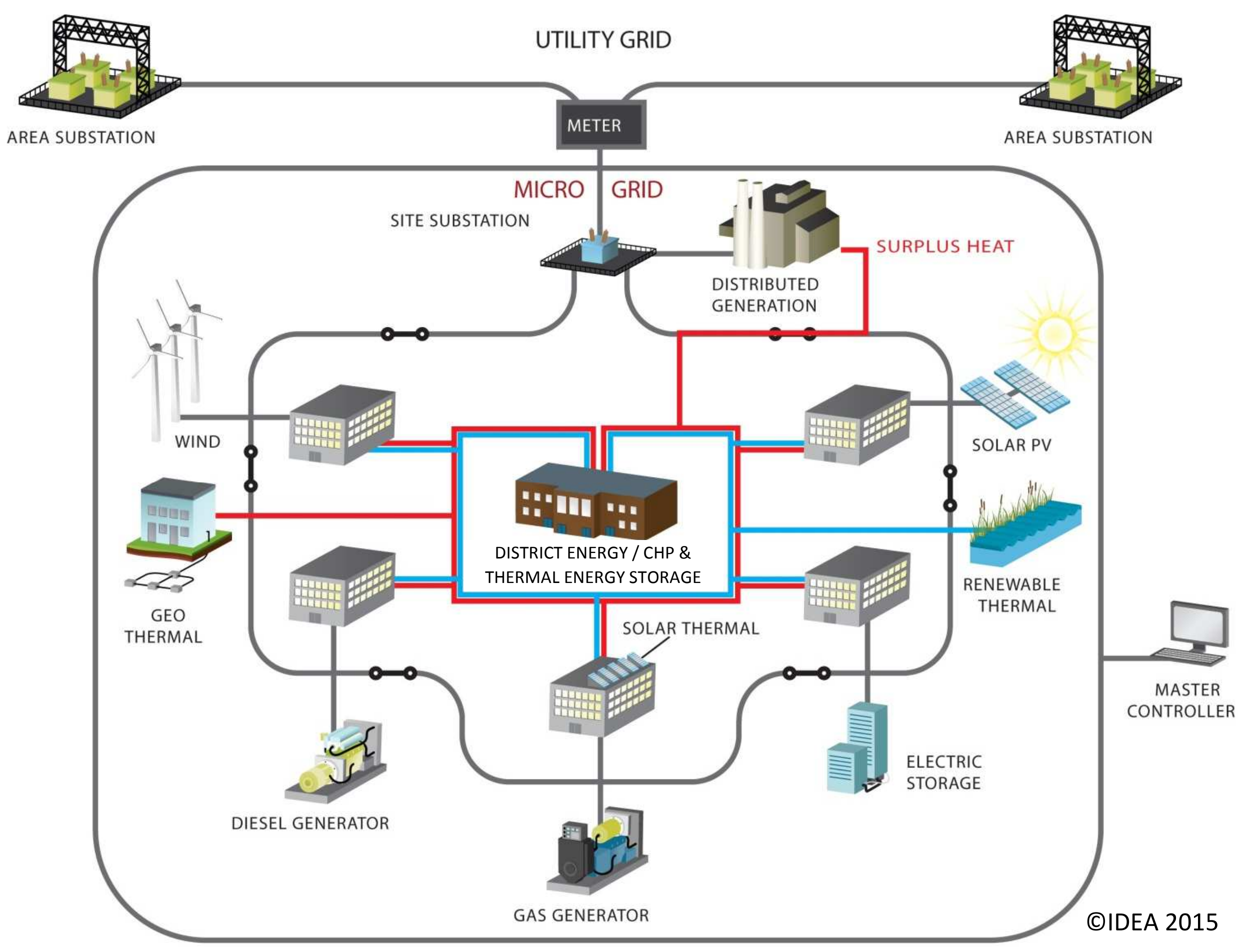
CONTENTS

1 Introduction

A microgrid is an energy system specifically designed to meet some of the energy needs of a group of buildings, a campus, or an entire community. It can include local facilities that generate electricity, heating, and/or cooling; store energy; distribute the energy generated; and manage energy consumption intelligently and in real time. Microgrids enable economies of scale that facilitate local production of energy in ways that can advance cost reduction, sustainability, economic development, and resilience goals. As they often involve multiple stakeholders, and may encompass numerous distinct property boundaries, municipal involvement is often a key factor for successful implementation.

This report provides an introduction to microgrid concepts, identifies the benefits and most common road blocks to implementation, and discusses proactive steps municipalities can take to advance economically viable and environmentally superior microgrids. It also offers advocacy suggestions for municipal leaders and officials to pursue at the state and regional level. The contents are targeted to municipal government staff but anyone looking for introductory material on microgrids should find it useful.

Many microgrids are built within the property boundary of a single owner such as a hospital or university campus. However this document focuses on microgrids that serve more than one entity. It outlines the various goals that microgrids help advance, describes their technical composition, and enumerates guidelines for identifying promising candidate sites. Given recent and ongoing technological advances in sensors, controls, and distributed generation the hurdles to microgrid development are less due to technical and engineering constraints and more often thwarted by legal, regulatory and financial challenges. The below graphic illustrates a microgrid with a variety of energy resources. Most microgrids will only use a subset of the methods shown.



2 The Case for Microgrids

The initial stimulus for microgrids has largely come from state and local governments and policymakers desiring a more effective public sector response to the social, economic, and environmental disruptions caused by widespread and long-term power outages. College, university, and hospital campuses are analyzing microgrids as tools to reduce energy costs, achieve environmental and sustainability goals, and ensure that the power is on when it is most needed. Utilities and their regulators are exploring opportunities for strategically sited, designed, and operated microgrids to substitute for costly electric distribution system capital expenditures, lowering costs for all ratepayers.

"As the microgrid market evolves from the single owner campus and critical public infrastructure models, more complex multi-party constructs built around economic development, area redevelopment, and resiliency as an enhanced private sector service are beginning to emerge. The promise of microgrids to provide this multi-faceted set of benefits drives the current enthusiasm for these systems as cities and communities strive to remain economically competitive, environmentally responsible, and energy resilient.

Campuses are commonly treated as a single electric meter, so it's easy to account for resiliency and efficiency benefits when you bundle in renewables or CHP. However, Business Improvement Districts can be 500 individual electric meters, which makes qualifying for, accruing, and distributing monetary benefits very complicated. Regulatory, statutory, and financing innovations are required to achieve the technology transfer of campus scale energy systems into districts of privately owned buildings, forming Multi-User Microgrids (MUMs). Whereas 20th century regulation enabled the grid to scale up into regional networks, 21st century regulation will help ratepayers to benefit from clean and resilient, locally-deployed generation and storage technology.

Compared to single-owner campuses, Multi-User Microgrids (MUMs) face many challenges including:

- There is no industry standard business model that accounts for retail level electricity sales
- Incumbent utilities are likely to perceive accelerated renewables integration as eroding their rate base
- There is often no regulatory or statutory support to realize revenue streams or formally recognize microgrids
- Real estate developers and property managers are generally unaware of the opportunities and risk averse to joining new district systems
- The energy planning process typically does not include municipal government or district scale stakeholder engagement

In 2007, the Connecticut legislature passed an act that attempted to ameliorate these challenges. Under the legislation, municipalities are empowered with expanded financing options, tax exemptions and franchise authority through the formation of Energy Improvement Districts (EIDs). Although the EID concept has been implemented, market activity to date has been minimal.[1]"

2.1 Energy Savings, Efficiency, Economic Competitiveness and Grid Support

Appropriately designed, operated, and sited microgrids can create economic benefits for both users and non-users of the microgrid. Microgrids may incorporate a suite of distributed energy resources ("DER") including energy efficiency investments, electric generation technologies utilizing combined heat and power ("CHP"), solar photovoltaic (PV), energy storage, optimizations algorithms, and intelligent energy management. This integrated local energy portfolio can directly create benefits by significantly reducing the overall energy costs for the microgrid users compared to purchasing energy from the main grid, deliver power and heat resiliency to the site and indirectly reduce costs for all grid users by lowering peak load on the entire electric system.

The direct economic benefits of microgrids emanate primarily from improving overall energy efficiency—whether by reducing energy consumption or using energy more intelligently. Whole-building energy efficiency measures can reduce overall energy consumption and costs as well as reducing the necessary size of the microgrid's generation sources. CHP can provide continuous base load power at a lower cost than the main grid by utilizing the waste heat from electricity generation for purposes such as space and water heating and absorption cooling. Intelligent energy management software, communication and controls can shape load profiles, optimize onsite energy production and consumption, and shift energy demand in response to price signals.

These technologies can create economic savings as measures within single buildings, but combining them into a larger system with multiple technologies and loads via a microgrid can create synergistic effects that further improve economic, reliability, and grid system benefits. For example, a CHP system that jointly serves multiple users with complementary usage (see section 3.5.4 Complementary Energy Users) may enable significantly larger energy cost savings than separate systems that serve each building individually. Consider one user with a large and consistent demand for thermal energy, but little demand for electricity, paired with a nearby user with the opposite usage pattern. By combining such complementary loads, a single CHP system will have a marked improvement in efficiency and utilization rate, thereby creating a far more economically viable, and environmentally superior system than operating each individually. While it's rare to find such perfectly complementary partners, the different load profiles of each can still offer a great deal of load "smoothing" to the overall system.

When sections of the electric grid become congested due to demand growth, utilities need to make significant investments to upgrade the system by replacing old or installing additional infrastructure. Microgrids are able to provide grid support as they decrease the overall load on the main grid by reducing onsite energy consumption and self-generating a large portion of the demand. When microgrids reduce this strain, the utility can defer or avoid these costly investments, as well as avoid additional investment in other generation sources, thus further reducing the entire grid's energy costs. For distribution only utilities, this results in lower costs for procuring energy and capacity.

2.2 Sustainability

Microgrids have proven to be a cost-effective approach to achieving sustainability and environmental goals, by reducing harmful air pollutants such as greenhouse gases. Incorporating energy efficiency and renewable generation sources such as solar PV or wind will provide emission-free energy. Microgrids enable greater economies of scale for renewable energy while allowing multiple users to share the environmental benefits produced by these measures. Intelligent energy management and storage can also be utilized to operate the microgrid in the cleanest way possible—shifting energy demand to when the cleanest sources are available, for example.

Microgrids incorporating CHP systems that run on natural gas can also have significant sustainability benefits. For the same reason that they reduce energy costs, they also reduce air pollution by significantly improving fuel efficiency as compared to the main grid. Because CHP systems are designed and sized to operate continuously as opposed to intermittently, they can produce much greater net emissions reductions than other forms of generation like solar PV and wind. For perspective, the CO_2 emissions from a 5 MW natural gas-fired CHP system are approximately half the CO_2 emissions compared to separate heat and power with the same energy output.[2]

2.2.1 Emissions Comparison Table[3]

"The below table compares the annual energy and CO_2 savings of a 10 MW natural gas-fired CHP system over separate heat and power with the energy and CO_2 savings from utility-scale renewable technologies and natural gas combined cycle (NGCC) systems producing power only. This shows that CHP can provide overall energy and CO_2 savings on par with comparably sized solar photovoltaics (PV), wind, NGCC, and at a capital cost that is lower than solar and wind and on par with NGCC."

Category	10 MW CHP	10 MW PV	10 MW Wind	10 MW NGCC
Annual Capacity Factor	85%	22%	34%	70%
Annual Electricity (MWh)	74,446	19,272	29,784	61,320
Annual Useful Heat Provided (MWh_t)	103,417	None	None	None
Footprint Required (sqft)	6,000	1,740,000	76,000	N/A
Capital Cost ($M)	$20	$60.5	$24.4	$10
Annual Energy Savings (MMBtu)	308,100	196,462	303,623	154,649
Annual CO_2 Savings (Tons)	42,751	17,887	27,644	28,172
Annual NO_x Savings	59.9	16.2	24.9	39.3

The values in the above table are based the baseline value of CHP, PV, Wind, and NGCC electricity displacing National All Fossil Average Generation resources (eGRID2012) – 9,572 Btu/kWh, 1,743 lbs. CO_2/MWh, 1.5708 lbs. NO_x/MWh, 6.5% T&D losses, CHP thermal output displaces 80% efficient on-site natural gas boiler with 0.1 lbs./MMbtu NOx emissions

2.3 Reliability, Resiliency, and Business Continuity

Recent widespread power outages of long duration have galvanized interest in new approaches for improving society's capacity to respond to and recover from natural or man-made calamities. Hurricanes, snowstorms, flooding, and icing have exposed the inadequacies of current approaches to mitigating the impacts of power outages that are so often a consequence of these events.

A key impetus for microgrid development is enhanced energy reliability, resiliency, and business continuity. Microgrids provide this service through the ability to disconnect and operate independently from the grid—otherwise known as islanding. This functionality allows microgrids to continue to provide energy services even when the main grid is down. Maintaining some level of energy services during main grid outages is important for businesses and organizations that place a premium on high-quality and reliable power.

A Department of Energy report estimates that for every hour of power disruption credit card and brokerage operators can lose up to $2.5 million and $6.5 million respectively.[4] The below table shows estimated interruption costs per event, average kW, and unserved kWh, in 2013 USD by duration and customer class.[5]

Interruption Cost (2013 USD)	Interruption Duration					
	Momentary	30 Min	1 Hour	4 Hours	8 Hours	16 Hours
Medium and Large Commercial & Industrial (Over 50,000 Annual kWh)						
Cost per Event	12,952	15,241	17,804	39,458	84,083	165,482
Cost per Average kW	15.9	18.7	21.8	48.4	103.2	203.0
Cost per Unserved kWh	190.7	37.4	21.8	12.1	12.9	12.7
Small Commercial & Industrial (Under 50,000 Annual kWh)						
Cost per Event	412	520	647	1880	4690	9055
Cost per Average kW	187.9	237.0	295	857.1	2,138.1	4,128.3
Cost per Unserved kWh	2,254.6	474.1	295	214.3	267.3	258.0
Residential						

Cost per Event	3.9	4.5	5.1	9.5	17.2	32.4
Cost per Average kW	2.6	2.9	3.3	6.2	11.3	21.2
Cost per Unserved kWh	30.9	5.9	3.3	1.6	1.4	1.3

The promise of reliable power can also attract additional economic development. If microgrids can offer reliable power at a competitive price, firms that value this service may be more likely to locate at sites that are either part of a microgrid or microgrid-ready.

Operating through extended grid outages is *extremely* important for critical infrastructure. Natural disasters such as hurricanes, earthquakes, and tornados may render the main grid inoperable by knocking down distribution and transmission lines or disabling other parts of the grid. As the name suggests, it is at precisely these times that critical infrastructure facilities are most needed. Microgrids are self-sufficient systems possessing local power generation sources, with less exposed infrastructure and so are less prone to disruptions and damage during such events. Therefore, critical infrastructure within a microgrid will be much more likely to maintain power and continue operating during emergency events that affect the surrounding macrogrid. Ensuring continuity of power supply at nursing homes and assisted living facilities keeps vulnerable populations safe in place. Supplying power, heating, and cooling to multifamily apartments, condos, and co-ops during outages reduces the number of people that may otherwise require assistance. Providing centers of refuge that offer temporary safe shelter for those who can't stay at their residences is an essential tool for disaster recovery.

2.3.1 What is Critical Infrastructure

The Department of Homeland Security defines critical infrastructure as "those assets, systems, and networks that, if incapacitated, would have a substantial negative impact on national security, national economic security, or national public health and safety."[6] In the context of microgrids, states have defined critical infrastructure in the process of developing incentive programs for microgrids serving such facilities. In New York, the NY Prize—a competitive solicitation to fund microgrids—will only consider microgrids that incorporate at least one of the following users:

Wastewater Treatment
Hospitals
Facilities of Refuge / Shelters
Police Departments
Fire Stations
Emergency Medical Services

2.3.2 Emergency Generators: Why CHP is a Better Choice

Traditionally, the ability to operate throughout grid outages has been provided by the use of onsite emergency and backup generators sized to meet the critical loads of a single building. Experience has demonstrated that backup generators are inferior to continuously operating power sources on both economic and operational grounds. For example, emergency/backup generators:

- Are only run when the grid is down or for infrequent maintenance and testing
- Are dead assets sitting unutilized most of the time; tying up scarce financial resources locked into the generator
- Are not providing value while idle
- Are more prone to failure in their time of need due to lack of familiarity under operating conditions and less rigorous maintenance as an idle asset
- Do not provide the cost offsets of avoided thermal energy consumption that's available from CHP systems

Systems with CHP can operate on a continuous basis, particularly when paired with the load aggregation capability of district energy systems. The benefit is in the form of consistent and reliable energy cost savings and reduced emissions. Emergency generators typically operate on locally stored liquid fuels. During outage events of longer duration it may be infeasible to transport fuel in to replenish depleted storage tanks. Additionally, while diesel generators were once exempted from certain pollution controls, this is no longer the case.[7]

2.3.3 Cost Premium for Resiliency

The ability to operate islanded from the main grid requires additional infrastructure to allow the microgrid to disconnect safely from the main grid and afterwards maintain service to critical loads throughout the duration of the disconnection. These requirements can vary greatly from site to site but ultimately will add an additional cost layer to microgrids when compared to systems not built for resiliency.[8] Depending on the characteristics of the microgrid, these additional costs will have an impact on the overall savings obtained from increased energy efficiency. For sites that require a degree of energy reliability that exceeds that of traditional distribution system service, it's essential to consider the value that energy resiliency and business continuity provides—especially in comparison to other means of providing this service.

3 Design Criteria

This document assumes that the reader already has a general familiarity with the technologies of distributed generation (solar, wind, etc.) so these will not be discussed in detail. A key design aspect one should bear in mind: in order for microgrids to provide resiliency, especially thermal resiliency, combined heat and power (CHP) must be a central component. This technology will be discussed in detail along with several other key technical considerations.

3.1 Energy Efficiency

The cheapest and cleanest energy choice of all is that of unused energy. Such reductions in energy consumption have been nicknamed "*nega*watt" hours. A recent report by the ACEEE found that the average cost of saving a kilowatt hour (KWh) is 2.8 cents via energy efficiency programs as compared to typical charges on the electricity U.S. grid which average roughly 10 cents per KWh (plus distribution charges). [9]

Energy efficiency measures, whether retrofits or new building standards, should be implemented in conjunction with the microgrid (if not before). With this in mind, it often makes sense to explore opportunities for microgrids and district energy systems in tandem. Steps can be taken to ensure future development or retrofits are compatible with existing or planned community district energy assets, such as district energy-ready (DE-R) design. See section 6.9 Planning for District Energy-Ready Buildings for more detailed information.

While reducing energy costs and emissions by reducing overall energy consumption, energy efficiency also ensures that the microgrid design is appropriately sized from the outset. Designing a microgrid without first pursuing energy efficiency can significantly increase overall capital and operating costs by requiring the purchase of larger capacity generation systems which consume more fuel than would otherwise be needed.

3.2 Combined Heat and Power

CHP is the simultaneous production of useful thermal energy and electricity. Waste heat from the production of electricity is captured in the form of hot water or steam that can be used for space and hot water heating, cooling in combination with thermally activated chillers, or other types of process heat applications. CHP is far more efficient than the traditional energy system configuration that draws electricity from the main grid and heating from an onsite boiler or furnace. CHP systems can achieve efficiency ratings of more than 80%, while generating heat and electricity separately is typically no more than 45% efficient. Note that CHP can also be used in warmer climates where space heating is rarely, if ever, needed. The "waste heat" from electrical generation can also be converted for cooling applications through use of a well-established technology: absorption chillers.

It's also worth noting that a CHP plant will need a "storm resistant" fuel source. On site storage is one path, though a connection to a natural gas pipeline may also be sufficient. For example, during Super Storm Sandy in New York City, short of localized damage to the gas pipeline by things like uprooted trees, virtually all gas customer's service continued to work. But fuel considerations should be a part of the risk profile being evaluated.

There are several reasons for CHP's crucial role in the microgrids currently being designed:

- Without heat recovery, the cost of on-site electric generation will almost always be more costly than purchasing electricity from the grid
- CHP provides reliable power day and night and throughout emergency events. Natural gas supplies are rarely disrupted while other energy sources such as PV or wind can only provide intermittent energy
- Machines such as elevators and water pumps need a significant surge of power when their motors first start up. This surge power can be provided by CHP systems while presenting challenges for other energy sources like batteries

GHG savings per kW of capacity is far greater for a CHP system than for an equivalently sized PV or wind installation due to the higher capacity factor of the CHP system (see section 0

- Emissions Comparison Table)
- Without CHP the microgrid cannot provide any heat resiliency without significant additional investment. Your buildings may be lit, but they will be unheated

3.3 Renewables: Solar and Wind

With current technologies, CHP will likely continue to be a central part of microgrid projects if heating and critical electrical loads are to remain online during a grid outage. Solar and wind generation can and do play an increasing role in on-site electrical generation for many microgrids. As things currently stand, the general mix of microgrid energy supplied tends to be roughly 80% CHP and 20% renewables in mixed generation deployments. As the cost of renewables declines they will likely take a progressively larger share of the electrical generation mix. They have the obvious advantage of not needing fuel delivery but their generation is also intermittent. Also, they are not able to provide resiliency on their own without a large amount of on-site electrical storage.

3.4 Storage

A microgrid where all electrical needs are met through renewables generation, with storage, is technically attainable. So too are those where all energy needs, thermal energy included, can be accomplished with renewables only. Storage prices have been dropping over the last several years and all indications are that they will continue to do so. However, they have not yet reached the point of cost viability to support all the loads required by a typical microgrid and will likely not do so for at least the next several years. The current role of storage is primarily to smooth the intermittency of renewables generation and, in a few areas, to smooth a customer's load profile during the day to help reduce demand charges from grid purchased power. Storage can also be used to participate in ancillary services and other wholesale markets.

It's not clear exactly when the inflection point of cheaper battery storage will enable more widespread and substantial deployment. But it's a definite possibility. One thing that local governments can do to help prepare for this it to keep abreast of technological developments, such as new battery chemistries and other storage technologies, and help ensure that local building codes, fire codes, and other ordinances allow for their implementation.

3.5 Site Selection[10]

An ideal microgrid site would combine all of the following attributes:

- High demand users with consistent and non-coincident peaks in electric, heating, and cooling needs
- Critical infrastructure and/or end user that places a high value on power quality & reliability
- Access to plenty of solar insolation, wind exposure, or onsite biofuels
- A site that is already engaged in another major construction process that has its own financing
- A current or imminent need to replace, upgrade or install heating, cooling and power equipment onsite
- Existing high energy prices
- An existing steam or thermal loop on the site, or planned excavation that offers the opportunity to lay electric and thermal distribution networks

In reality, few sites meet all of these criteria. Several important tools and processes, however, can help municipalities identify those sites with the best mix of these attributes to achieve their goals.

3.5.1 Energy Planning Process[11]

While community-wide energy planning is not necessary to find the optimal project sites for microgrids, undertaking an energy planning process can help secure the attention of high-level officials, coordinate activity across different municipal agencies, and integrate microgrid efforts into the community's broader development goals. In an energy plan, communities can better answer the following questions:

- Where and how is energy currently used today in the community, and how is that expected to change?

- Where does the community expect development to occur in the future? Would microgrid infrastructure installation at these sites be most economical as part of the larger development?
- What type(s) of economic activity does the community want to attract and can a microgrid be an economic development driver?
- What critical infrastructure is vulnerable to regional power outages?
- How does the community want to address its carbon footprint?

A successful energy planning exercise will answer these questions and then follow-up with coordinated studies that engage business leaders, local government agencies, and key affected parties to identify the right project sites.

3.5.2 Integration Into Capital Planning

Incorporating microgrid development into capital planning can help identify good candidate sites. Sites with planned or needed infrastructure upgrades can be good candidates for microgrid development for several reasons. First, planning and executing other infrastructure upgrades with a microgrid development can save time, materials, and overhead. Additionally, installing CHP to replace traditional boiler plants and other HVAC equipment at or near the end of their useful lives allows for the associated capital expenses to be viewed as a marginal cost increase from a traditional "replacement in kind" rather than as a simple stand-alone expenditure. Finally, if potential sites implement significant infrastructure upgrades prior to microgrid consideration, viable designs may be "locked-out" of consideration for years due to sunk investments.

3.5.3 Anchor Energy Users

Successful microgrid projects typically require an anchor energy user, a site with significant energy demand that will likely remain at the same location for many years in the future. Such a site, at the heart of a microgrid, can help insure its long-term viability. Microgrids are capital assets with very long service lives. Therefore perceived project risks are diminished when centered on a core user who will be there for the microgrid's useful life.

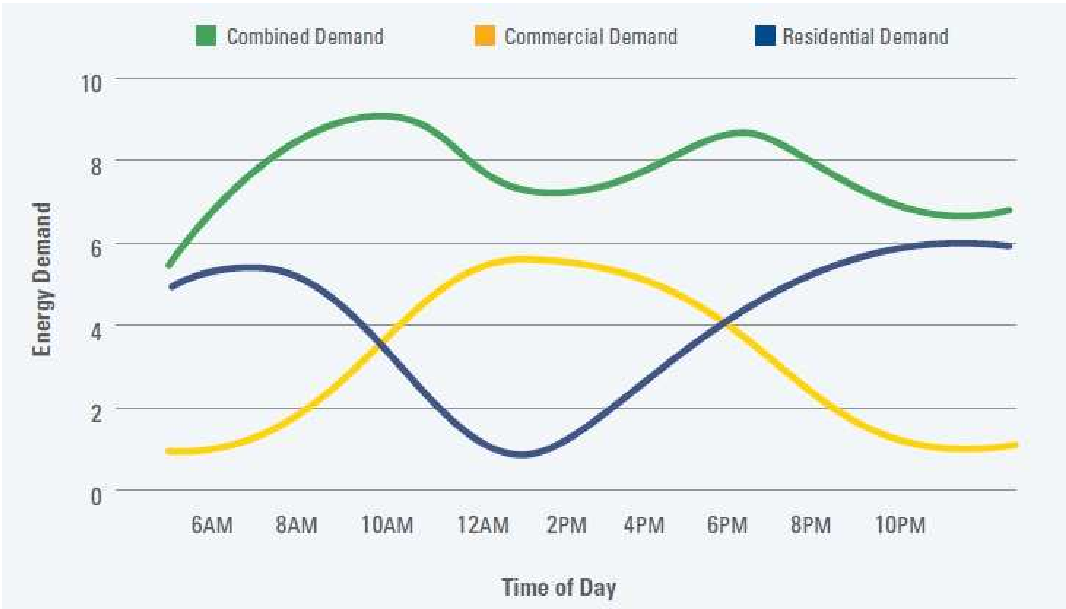
These users are likely to have larger and more stable energy demand, and significant concurrent requirements for the waste heat from electricity production that is an important component of an economically viable microgrid. There are typically scale economies up to a certain size. Larger generators tend to be more efficient than smaller ones as the fixed costs (engineering, design, permitting, financing, etc.,) do not increase proportionally with energy generation capacity. Provided that they have the right energy demand characteristic, the incremental economic value of attaching proximate sites may be significantly higher than the incremental costs associated with a small increase in the network distributing that energy. A microgrid where the energy generation and distribution assets are used at a high capacity factor and asset utilization rate for a large proportion of the hours of the year is characteristic of a preferable value proposition.

The anchor user can also foster microgrid development by taking the lead in negotiating financing for the system. This is particularly the case when a primary end user can use its credit capacity, access to tax-exempt or other forms of low cost capital, or its own financial strength to secure a more advantageous project cost of capital that is extended to other parties in the development. Examples of such tenants include municipalities, hospitals, universities, convention centers, industrial parks, commercial centers, and prisons.

3.5.4 Complementary Energy Users

Instead of, or preferably, in addition to incorporating a single anchor user with a stable energy demand, microgrids can become more economical when they target complementary energy users that when joined together present a *sizeable*, *constan*t and *concurrent* energy demand. Just like an anchor user, when multiple users combine to provide a relatively constant energy demand on a daily, weekly and seasonal basis, microgrid assets are more fully and economically utilized. This circumstance makes microgrids advantageous by allowing multiple users to jointly and economically produce and consume, whereas they may not have been able to self-generate energy in a cost effective manner on their own.

"Consider the example of a commercial center next to a large residential area. As illustrated in the below figure, the commercial building is used intensively between the hours of 8 AM and 5 PM, with demand increasing and decreasing quickly during the morning and evening, respectively. The adjacent residential area complements this load profile because it demands more electricity during early mornings and late evenings. The pair of users provides a combined daily demand profile that is far steadier. This complementary demand profile can be paired with a generator such as a CHP unit and ensure that the generator's capacity will be utilized consistently."[12]



3.5.5 Recognizing Underdeveloped Locations

In addition to the right sets of users with the right energy demand, communities could also look for physical locations with untapped potential, such as:

- Existing sites with generation that can be cost-effectively reconfigured or expanded to serve a microgrid
- Sites already slated for significant development, like brownfield redevelopment areas, new mixed use development, or multi-building commercial/industrial/residential redevelopment where microgrid infrastructure can be cost-effectively installed simultaneously with planned development
- Sites that already generate substantial waste heat that can be recovered to serve a microgrid

To take one example: On the site of a former brownfield in Atlanta, GA, Atlantic Station represents a good example of how to save money by building community energy in the midst of a larger capital project. Atlantic Station used Brownfield Tax Allocation District dollars to fund a 7,500 ton chilled water plant with two-mile network of distribution pipes, providing cooling to an already-planned 140 acre mixed-use development where a steel mill once operated. When excavation is occurring for some other reason (e.g. roads, sewer, gas lines, etc.,) it's prudent to investigate the future value of installing district energy infrastructure, as it may be added at such a time for a much smaller marginal cost.

3.5.6 Offsetting Utility Capital Investments

The initiation and planning of large-scale private and public-private development projects is a fortuitous time for assessing microgrids. In certain circumstances, the new load growth associated with development may present an opportunity to reduce utility costs and benefit all ratepayers. Costly utility investment in new substations, transformers and other distribution assets can be avoided or deferred by onsite distributed energy resources. If this is the case, the utility should be engaged in a partnership to best determine how the microgrid could be designed, configured and operated in a manner that works to the advantage of all parties.

3.5.7 Rights of Way

If a microgrid needs to cross a right of way (e.g., public street, railroad), additional technical constraints and/or planning or legal procedures may need to be addressed. While the need to cross a right of way should not exclude a potential site from consideration, a site with similar promise and absent the complexities of right of way issues should be considered a preferable choice. See section 7.3 Rights of Way and Franchise for more details.

3.6 Wiring for Resiliency

Microgrids are typically designed to provide only a portion of the electricity requirements for their participants, since local generating capacity for the entire electrical load typically is cost prohibitive and unnecessary for meeting the objectives of most projects. Consequently some electricity will need to be drawn from the grid. How much, and at what periods of the day this occurs, is a matter of the microgrid's specific design characteristics. For example, solar panels may produce an excess of power during the day but obviously they cannot function at night.

Microgrids by definition are capable of operating separated from the grid in the event of a grid outage. Resiliency is often a primary impetus for the project. Resiliency can be secured by powering (and heating) loads that have been identified as critical. The control system must have the ability to shed non-critical loads with a rapid enough response time to insure that the power supply and power demand are kept in balance on an instantaneous basis.

Load shedding generally takes one of two forms. Either an entire building is electrically cut off from the microgrid (thermal connections could be unaffected) or buildings are wired in such a way so that a subsection of electrical power is provided to critical systems only. For example, if a large multifamily building were wired for critical loads, the system might allow for the operation of a single elevator, minimal common area lighting, water pumps, the boiler plant, and perhaps several outlets in the lobby for charging mobile phones. This would leave the building "livable" but residents would be without power in their apartments. Though not ideal from a quality-of-life standpoint, it would keep the building habitable and allow for heat and running water.

Retrofitting buildings to separate critical from non-critical load does incur some cost, but with the smarter metering and controls that have been introduced over the last few years, especially those using power-line communications, this retrofit can now be accomplished without having to rewire the building's entire electrical system.

4 Financing the Microgrid

The development plan for a technically feasible and economically viable microgrid often falters at the point of financing. Except for the lifetime cost of energy, the cost of financing is often the largest single component of total project cost. Successfully moving from project concept and design to completion and operation hinges, in large part, on securing financing at a price that enables an economic return that will support the investment.

In the first section of this chapter we summarize the revenue sources that are the foundation for project success. We encourage communities to include in their analysis revenues that might be available from sales of energy, capacity and/or ancillary services in wholesale energy markets.

The following section addresses a variety of different financial mechanisms that might be utilized. These instruments are not all relevant to the circumstances of every project. The purpose is to highlight a range of alternatives, alerting the reader to instruments and combinations thereof that might otherwise be overlooked.

For completeness we add brief sections covering ongoing maintenance, ownership structure, and financial phasing. Each of these three topics is an important consideration in the overall design and assessment of the project financial plan.

Microgrids are in the earliest stages of market development. As projects proliferate and the financial community gains a much deeper base of information for analysis, we can expect an evolution in financial products, services, and terms. This section concludes with observations on key areas where progress might be made.

4.1 Microgrid Profitability Considerations

What enables microgrids to succeed as a profitable investment is the extent to which the revenues over the project's lifetime exceed the costs. With a larger difference (lifetime revenues less lifetime costs, or net revenue), the impetus for investment will be greater, and the potential pool of interested financiers will also be greater. When the net revenue over time is small, investment may be attractive to a smaller set of project sites with a long-term investment time horizon and financing sources willing to accept lower returns and/or longer periods of capital recovery (e.g. 15 or 20 years).

While seemingly an obvious statement, it's critical to focus on the sources of project returns, the expected value or riskiness of each source of return, and how the value of these expected benefits are analyzed by different financiers.

4.1.1 Economies of Scale

Perhaps the largest benefit of microgrids is that they enable load aggregation, economies of scale, and, with CHP, the productive utilization of waste heat in a manner that may be significantly more efficient at the multi-building level than within individual buildings. This results in several areas of cost reduction:

- Larger equipment deployments (boiler plants, CHP) are generally more efficient than smaller deployments. This means a higher output of useful energy per unit of fuel and lower fuel costs
- Aggregation of *concurrent* electrical and thermal loads:
    - Smooth demand resulting in an increased base load for on-site CHP (this means greater efficiency) as well as lower demand (KW) charges from the utility
    - Enables a larger portion of the electricity from intermittent renewable sources (wind, solar) to be used onsite, thus boosting their payback period. This effect is even higher in areas with less generous, or non-existent, net metering policies
- Concentration of boiler plants and generators into a central location:
    - Allows maintenance staff to conduct more of their normal maintenance in one location that reduces productive time lost in travel between buildings
    - Reduces the costs of storm hardening critical equipment

- Standardization of equipment:
  - Reduces costs for training and spare parts
  - Homogenizes operational and maintenance procedures
  - Allows for cheaper implementation of equipment redundancy (N+1) thus providing lower probability of downtime or other reductions in service
- On site electrical generation can enable buildings to remain powered on in the event of a grid outage. This enables critical infrastructure (police, fire, hospitals, emergency services) to continue functioning, and helps avert safety issues. It also has obvious benefits to quality-of-life in residential deployments and helps avert loss of income to commercial facilities (data and critical transaction losses, forfeited sales, food spoilage, manufacturing, and commercial downtime costs)

Where cogeneration/tri-generation can be utilized, it is possible to increase the energy efficiency of the block, campus, or neighborhood by more than 50%. This reduces money spent purchasing electricity from the grid. Of critical importance is productive use of waste heat that saves the cost of purchased fuels (natural gas, or oil) that would otherwise be necessary for space heating, hot water heating, and other uses of heat and/or steam at the site. In the summer, the waste heat can provide heat-driven cooling that reduces the need to purchase and run chillers for cooling. This further lowers the site's electric energy and demand charges. It also provides for "resilient thermal energy" for the site, ensuring that during extended interruptions in grid power supply some or all heating needs are met during cold winters, that more cooling is available during hot summers, and that hot water service is retained during an emergency.

4.1.2 Measurement and Verification

Microgrids will most likely require an on-going measurement and verification (M&V) protocol. Usage must be measured and/or metered, the cost of service calculated, and customers billed appropriately. When multiple separate entities are connected, transparent cost determination and equitable apportionment will be essential. An outside (i.e., impartial) contractor will likely be needed in such situations.

There will also need to be M&V even for "single customer" microgrids such as those of a university or hospital; departmental budgets will have to track energy costs. Rigorous monitoring of usage at the most granular level feasible has proven to be the cornerstone of maintaining performance and cost savings over the long run. In such cases the facilities management group may be the one to provide M&V, but there should be an additional staffing and training component if done internally rather than by an outside contractor.

4.2 Cost Offsets and Ancillary Income

The economic viability of a microgrid project is significantly enhanced if the project includes a well-designed, high efficiency combined heat and power or district heat and power system. As noted previously cost savings from onsite power generation and productive use of waste heat for heating and/or cooling provides the foundation for an attractive investment.

There are other value streams that should be considered in assessing microgrid development opportunities. The contribution they're likely to make to the "value stack" may be markedly less than total energy (and capacity) cost savings from CHP and efficiency investments, but when available and appropriate, these sources of income should not be ignored.

Demand Response:[13] FERC defines demand response as "changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized."[14] Microgrids can enable participation in these programs.

Renewable Energy Credits (REC) / Carbon Reduction: Local generation can reduce a site's carbon footprint through use of renewable energy, energy efficiency, and/or lack of macro grid transmission loss. Such carbon reductions can be sold on secondary markets. Third party M&V will likely be required for this.

Ancillary Electricity Grid Services: There are a number of inherent issues with any large-scale electrical grid such as voltage control, reactive power, and frequency regulation. There are existing and emerging business models in place in parts of the US that allow DER's to be compensated in wholesale power markets for helping to alleviate these issues[15]. At the distribution system level, the REV proceeding is examining new products, services and transaction mechanisms to compensate DERs for providing services to the grid. Microgrids, if appropriately designed, configured and operated could be well suited to providing ancillary services in wholesale power markets, and in the future, at the distribution level, once these markets are established.

Utility Distribution System Cost Reductions: Local generation reduces the load on the utility's electricity grid. Such reductions could also mean deferred or avoided capital expenditure for the utility. New York is experimenting with a series of pilot projects designed to test the viability of strategically sited and operated DER's, as a substitute for distribution capital expenditures[16]. These experiments and new market designs that may emerge from the pilots could offer a new source of income for Microgrids that are situated in the right geographic areas and operated in a manner that predictably and reliably reduces requirements in that location.

Insurance: If the microgrid offers power or heat resiliency, such backup capacity could result in lower insurance premiums.

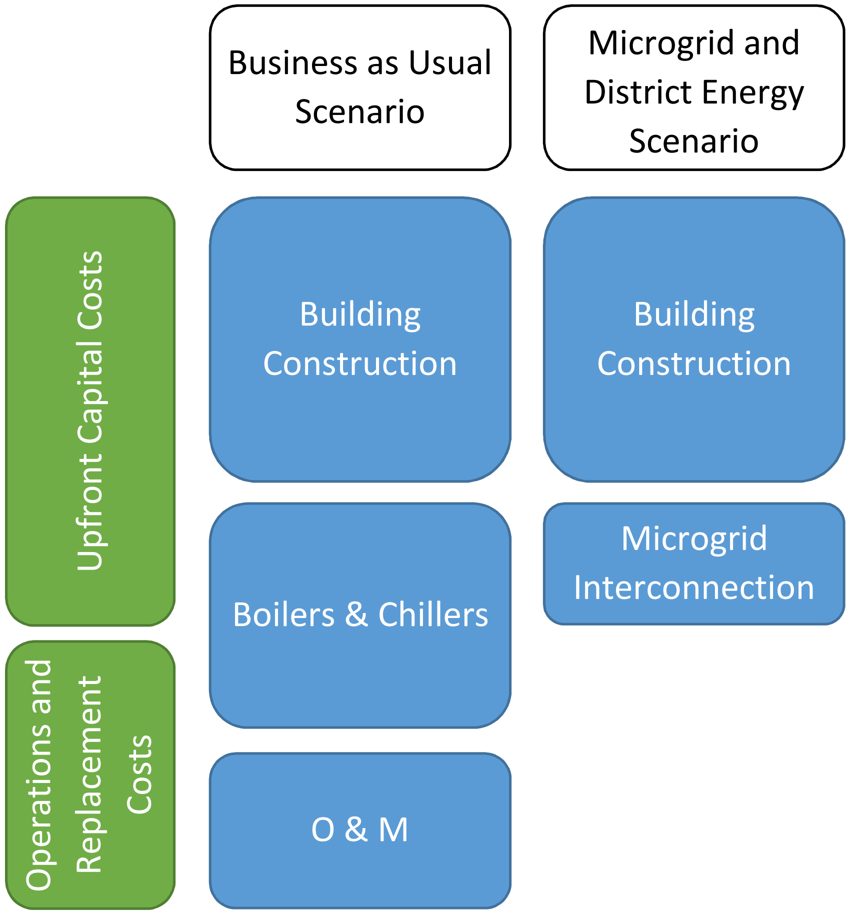
By their very nature microgrids are likely to have more than one stakeholder. It's not uncommon for different stakeholders to approach their investment and participation with differing strategies. Microgrid models are readily adaptable to hybrid financing. Individual stakeholders might also choose to make use of several different financing mechanisms just for themselves.

Potential customers should take a holistic view of total cost of ownership when structuring any deals. Include financial incentives *and penalties* wherever possible that align the interests of all stakeholders, especially for long-term contracts. Of key consideration should be the long term risk factors. Engagement of a third party subject matter expert (SME) by customers is *strongly* recommended to represent their interests during design and contract negotiations.

Microgrids may create significant and tangible benefits for non-users of the microgrid as well. Societal and electric grid system benefits of microgrids can include enhanced resiliency of critical infrastructure and reduced capital and operating costs in the generation and delivery of electricity. Furthermore, to the extent that microgrids incorporate low or no emitting distributed energy resources, such as high efficiency CHP, renewable energy, storage, and energy efficiency, they can deliver deep reductions in emissions of greenhouse gases and criteria air pollutants.

Presently, these benefits are not captured by the owners and users of the microgrid, and thus go uncompensated. When those who assess an investment in microgrids are unable to monetize, in part or in whole, the value streams from public and grid benefits that they create, they may be deterred from going forward with the project. In those instances where the sum of private and public benefits are significantly greater than total costs, society and utility ratepayers will be worse off by the failure of markets and policies to account for total benefits.

Building owners benefit from interconnecting to district thermal systems associated with multi user microgrids. This interconnection obviates the need for boilers and chillers inside the building, freeing up space for more leasable floor area and rooftop space. Interconnected buildings also eliminate operations, maintenance and replacement costs associated with boilers and chillers.



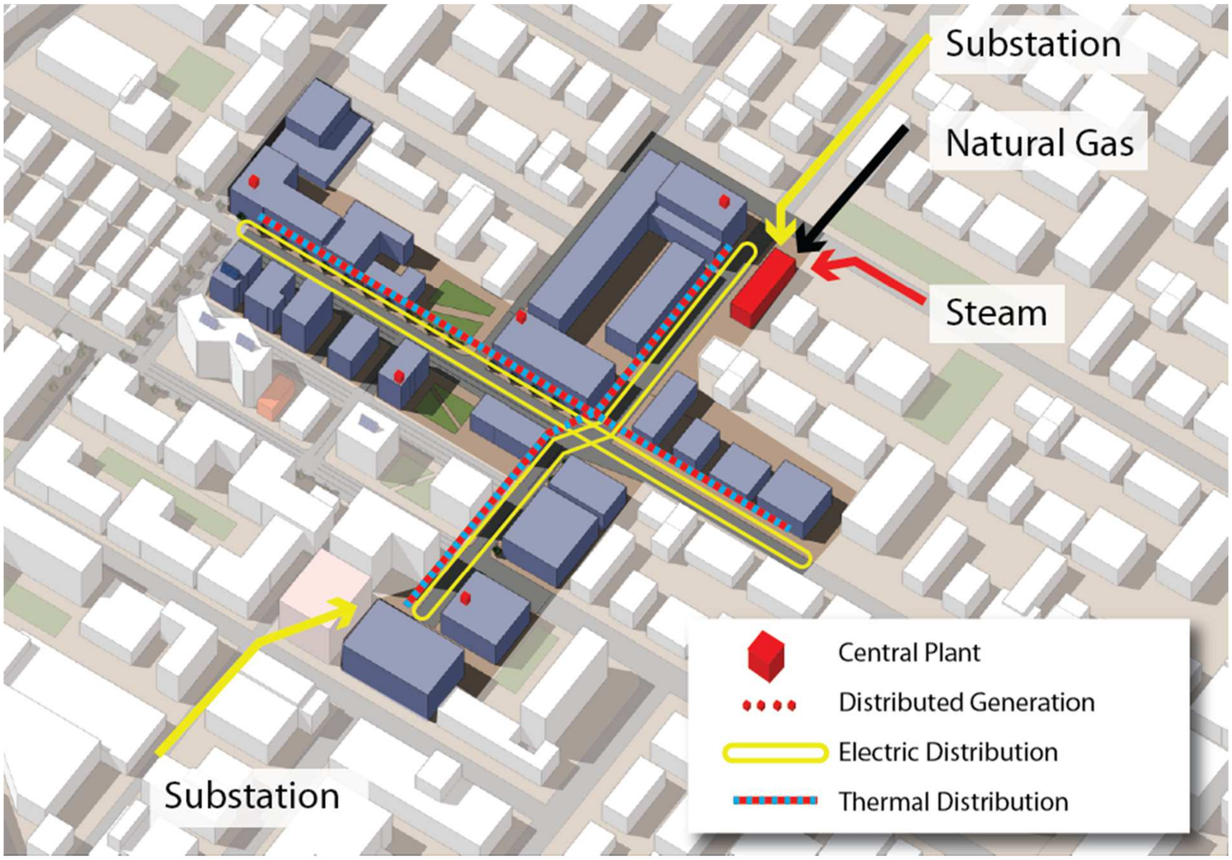
4.3 Scalability and Financial Phasing

One of the benefits of a microgrid is that it can be constructed in phases and scaled out over time. The cost implications, both immediate and longer term, need to be part of the planning process.

Consider the example of a microgrid created by a municipality for district thermal and electrical services. It will connect several dozen buildings in their downtown mixed-use district that will include municipal buildings, privately held commercial stores, and some multifamily housing. For simplicity, we'll assume that generation will be solely from CHP and rooftop solar and that the CHP equipment will be housed in a new structure that will be specially built for that purpose. There are two general choices in the initial design: design and build for the existing loads (buildings set to be connected immediately plus some margin for error) or design and build for future expansion.

If the latter option is chosen, it might be best to include several additional elements in the initial build out such as:

- A larger footprint for the CHP equipment building (central plant) to allow for additional units to be added in the future
- Larger pipes for thermal distribution and larger capacity electrical transmission wiring and controls
- More linear feet of pipe and electrical conduit laid into the ground near future customers or areas slated for development, or additional underground excavation/tunneling with placeholder conduit



While these additional measures can save a great deal of future costs, they still need to be funded in the short term. The plan for this funding can take several forms:

- The entire cost can be "baked in" to the project's price tag and funded as part of the original scope. This means that initial users are essentially subsidizing expansion to future customers
- The municipality can have the design engineers determine the marginal cost difference between a standard build out (for current scope) and the additional scalability enabling measures. This portion of the cost could then be financed separately (perhaps at the municipality's expense) while the remainder is then incorporated into the cost of service, PPA, etc.
- Vendors (those involved in construction and/or maintenance), energy services companies, or other investors may wish to fund this capability if they are granted a share of future revenues
- Landowners on the periphery of the microgrid may be willing to provide funding so as to facilitate their future participation when their own buildings become ready

The project planners should be certain to carefully address the costs, benefits and implications of phasing and funding issues, when formulating the long term vision for the microgrid.

4.4 Construction Financing and Own, Operate, Maintain Options

When examining financing options and conducting benefit-cost analyses it's important to examine *marginal* cost considerations and not just the *gross* cost. For example, consider a conventional boiler plant that is past its useful life where a like-for-like replacement would cost $4M. If the cost of installing a comparable combined heat and power (CHP) system and connecting it to the microgrid is $6M then the *marginal* cost for the additional benefits (lower electricity costs, redundancy, etc.) is $2M. In order for this measure to recover its costs, it only needs to generate an additional $2M in benefits, not the $6M of the entire upgrade's price tag. This is a much lower threshold to meet and the benefits to costs ratio (BCR) should be calculated with this in mind.

An additional option is the bundling of energy efficiency projects with one or more microgrid components. Energy efficiency upgrades (e.g., lighting, insulation, high efficiency motors and drives, smarter controls) often have very attractive payback periods. When combined with other projects that have longer payback periods the overall financial performance of this portfolio may allow for better financing terms.

4.4.1 No Financing

Energy improvements are often eligible for financing well below typical market rates. One should not exclude the possibility of financing without a holistic examination of one's cost of capital. Also, some financing mechanisms such as an energy performance contract may require a *partial* cash commitment.

If a participating entity has sufficient funds (positive fund balance, retained earnings) or access to attractive capital re-imbursement formulas, then the project may be financed, in whole or in part, by internal sources. The use of internal funds raises the ownership stake of the entity, thereby increasing its claim on the share of the microgrid's ongoing financial benefits. Internal funding bypasses some of the costs and constraints of taking on outside equity or debt investors. However, internal funding is not costless and when analyzed this approach should set a price on the use of internal capital that represents the "opportunity cost", or the return on the next best investment that could be made with these funds.

4.4.2 Equity Financing

In an equity financing arrangement, investors contribute to the project and acquire an ownership stake that entitles them to a share of the returns arising from the profits and increase in economic value generated over time by the project. Note that investors need not be participants in the microgrid. The equity investor takes on more risk than does the debt investor. Equity financing in most instances will be more expensive, sometimes markedly more expensive, then debt financing.

4.4.3 Power Purchase Agreements (PPA)

PPAs are used by energy services companies (ESCOs) for financing the build-out of power generation assets (e.g., photovoltaics, CHP, fuel cells). Typically they are structured to involve little to no upfront capital cost for the customer(s). The cost of installation is recouped through the sale of energy back to the customer at a pre-set rate. Note that "pre-set" does not necessarily mean fixed. Some, or all, of the rate may be tied to variables such as natural gas prices or the cost of electricity from the local utility.

PPAs often include long-term maintenance agreements and agreements for the operation of the system. O&M agreements are typically priced on a cents per kWh basis, and added to the PPA's other cost components (e.g. return of capital, return on capital, etc.). One source of risk for customers is that PPAs might have built in escalation charges and these should be evaluated. To help mitigate such a risk, linking the price of energy from the assets to an objective measure (say a published price of electricity in the local market or the price of natural gas) can help ensure a favorable cost for customer even when energy prices fluctuate.

Contracts also typically include nonperformance clauses for both sides. For the customers, it may mean that they are required to purchase some or all of the energy produced, with potential minimum thresholds. PPAs can be an instrument providing a good risk/reward tradeoff for customers. For those with capital constraints PPAs are designed so that the user incurs no upfront costs. Institutions may wish to preserve limited debt capacity for investments that are central to their mission. In such instances a PPA can be structured to be off the balance sheet of the host site. It's essential that the seller's economic interest is aligned with the buyer. Contracts should be structured so that the seller is incentivized to keep their assets running at peak efficiency: the more energy they produce, the higher their profit, and when the system is down (and the buyer is incurring a loss) the seller should shoulder a significant share in the risk of losses from outages and poor capacity factors.

For example, consider a PPA for rooftop solar panels with no cost to the customers that offers electricity at 2 cents per KWh below grid rate each month. If the solar panel's output is below the customers' needs then they'll be buying all of the electricity produced. The more that's produced, the more the customers save and the higher the income for the ESCO. The ESCO is incentivized to keep the panels running well, conduct proactive maintenance, and repair any damage quickly.

If the assets can be connected to a microgrid then this could allow for an even larger set of distributed energy assets to be acquired. The same model outlined above would apply but the customer base has now been extended to the entire microgrid site.

4.4.4 Tax Exempt (Municipal or Authority) Bonds

This type of financing may be available to help lower total financing costs of the project when municipalities, hospitals, universities or other non-profit entities are participating in the project. Bear in mind that a municipality's participation could take several different forms such as an energy customer, energy provider, managing agent, and/or as an infrastructure provider (by constructing or operating the electrical and thermal connection assets for example). Examples include municipal bonds, industrial development authorities, state health and educational facilities finance authorities.[17]

4.4.5 Energy Performance Contracts (EPC)

These contracts are somewhat similar to PPAs (see above). Whereas PPAs are typically tied to generation assets EPCs can encompass other measures and services such as building retrofits or boiler plant operation. Some or all of the upfront costs for energy improvements are borne by the ESCO and the building owner is able to pay back the loan through energy savings. EPCs typically involve a third party for M&V that provides reporting for on-going costs and energy savings.

EPCs are sometimes structured with the ESCO sharing a stake in both the risks and rewards of the project. For example, the ESCO may receive a fixed amount of the savings but any amount beyond that may be shared between the ESCO and the property owner. This helps align incentives between the two.

4.4.6 Property Assessed Clean Energy (PACE)

PACE programs, where available, can be extremely advantageous as they allow a private landowner to receive a loan from the state or local municipality for energy improvements to their property. This is essentially an energy performance contract from a government source. Projects are scoped so that the energy savings from the resulting projects are greater than the amount needed to service the new debt. Payments are levied by the local municipality by adding a line item on the property tax bill. This debt is senior to any mortgage.

The distinguishing feature of PACE loans is that they're connected to *property* and not the *owner*; so contract obligations are transferred upon sale. This mitigates the risk in situations where property owners are reluctant to pay for energy projects if they envision a possible sale before reaching that project's payback period.

One drawback of PACE loans is that they are sometimes unavailable to two sectors: municipal and small residential. Municipalities don't typically pay property taxes and so such an arrangement wouldn't apply; much as municipal bonds don't typically apply to the private sector. As of July 2015, there remains an outstanding issue for small residential: in July 2010, the FHFA released a Statement on Certain Energy Retrofit Loan Programs, which dampened residential PACE programs by advising Fannie Mae and Freddie Mac to avoid buying mortgages with PACE assessments.[18] The issue remains unresolved. Note that this restriction does not apply to medium and large multifamily structures (whether rental or owner occupied) as mortgages for these properties are not under FHFA's umbrella.

4.4.7 Qualified Energy Conservation Bond (QECB)

A QECB is a bond that enables qualified state, tribal, and local government issuers to borrow money at attractive rates to fund energy conservation projects. A QECB is among the lowest cost public financing tools because the U.S. Department of the Treasury subsidizes the issuer's borrowing costs. These are taxable bonds—meaning that investors must pay federal taxes on QECB interest they receive. Issuers may choose between structuring QECBs as tax credit bonds (bond investors receive federal tax credits in lieu of interest payments) or as direct subsidy bonds (bond issuers receive cash rebates from the U.S. Department of the Treasury to subsidize their net interest payments).[19]

4.4.8 On-Bill Financing

Some utilities have programs in place for on-bill financing (OBF) of energy improvements. OBF allows utility customers to invest in energy efficiency improvements and repay the funds through additional charges on their utility bills. It is most commonly structured as a loan or tariff, but could also be structured as an energy service agreement or lease. Utilities tend to look for projects that are “bill-neutral,” meaning that energy savings are sufficient to cover the monthly payments for the financing so that the total monthly charge on the utility bills is less than or equal to the pre-investment amount.[20]

Because OBF tends to favor bill-neutral arrangements, they’re usually paired with energy efficiency projects. The high capital costs of some microgrid components means that few, if any, projects can be exclusively financed this way. However, this type of funding may still have a role to play in the financing mix since energy efficiency measures and retrofits can and should be one of the first phases of any microgrid project.

4.4.9 Design, Build, (Own), Operate, Maintain (DBOOM)

A DBOM/DBOOM contract (ownership is optional) is typically a combination of several of the above financial mechanisms and essentially turns the entire project into an outsourced solution. It means that the builder will need to approach the project from a complete lifecycle perspective rather than a “one-off” construction contract. The two largest advantages are a significant reduction in customers’ management efforts for both construction and operations as well as a very good alignment of incentives. External management of facilities allows customers to focus on their core services. If the same firm designs, builds, and operates the facility, the firm is better incentivized to make choices in design that reduce the total cost of ownership. Its time horizon is now measured in decades rather than just a couple of years.

Third party ownership also offers advantages to private sector customers: the possibility of qualifying the project for tax-exempt purchasing and financing, and the ability to hold their stake in the assets off their books.

Of course, just because a project is outsourced and competitively bid does not mean there aren’t risk factors. As with any such contract, customers should hire subject matter experts to represent their interests.

4.4.10 State Green Banks

Some state governments have established agencies to issue and oversee debt for clean energy projects. These are intended to be niche players that typically only fund proposals that cannot be funded normally. Green Banks are not usually intended to compete with commercial lenders. Their mandate may include projects that have technologies that are too new for banks to feel comfortable with, where transaction costs are too high under current conditions, or where traditional lenders are looking for a loss prevention alternative.

4.5 Ongoing Maintenance

Any building that connects to an electrical or gas utility will have some line of demarcation for maintenance of the physical connections. This may occur at the property line, on the customer side of the meter, or some other point.

Ensure that maintenance for all sections of the microgrid has been planned for. Any microgrid infrastructure that is “behind the meter” will typically not be maintained by the utility company. This could mean the entire microgrid depending on the specific implementation. Any distributed energy resources, interconnection equipment, cabling, conduit, or other behind the meter sections not covered by either a PPA or DBOOM contract (see previous section) will have a maintenance component to them. Ensure that an inspection and maintenance plan is in place for every aspect of the microgrid, and that an appropriate cost-sharing plan is in place for the common components.

There are often third party contractors available to cover such work. Conduct a complete benefit-cost analysis for in-house vs. contracted maintenance. Ensure that labor management costs are part of that equation. Also consider the lifecycles of the various components. Generation assets may have a lifecycle of 10-20 years but well maintained underground piping lifecycles are typically much longer than that.

4.6 Ownership Structure

It may be desirable to have some or all of the microgrid under the umbrella of an ownership structure different from one or more of its customers. It could take the form of a publically-owned municipal entity, corporation, non-profit, or public-private partnership (PPP). Each locality will a have a different set of financing, tax, and incentive considerations. All of these should be taken into account when deciding what ownership model(s) to use.

For example, municipalities cannot make use of PACE Financing, section 179 tax credits, or accelerated depreciation, while private companies cannot issue tax-exempt bonds. Municipalities may also be constrained by certain staffing models that don't mesh well with the management of a microgrid.

5 Coalition Building

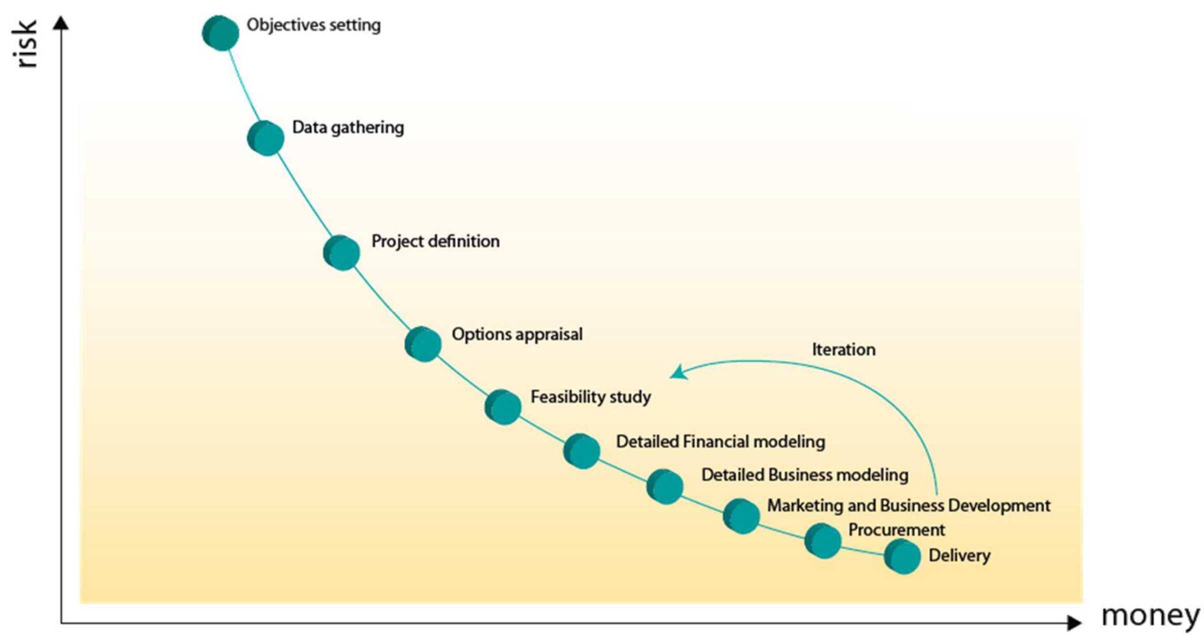
Community microgrids and district energy systems provide stakeholders, service providers, and end-users the means to achieve specific objectives such as:

- Energy efficiency and cost savings
- Economic competiveness derived from sustainable residential, commercial, and institutional assets
- Carbon footprint reduction and energy security
- Use of local resources and sustainable community development
- Reliable and resilient local energy infrastructure that enables business continuity

A dedicated "champion" is key to the success of a microgrid/district energy project and its journey from concept to completion. The champion has the longer-term vision and the determination to leverage resources and stay the course. Ideally, this is a paid staff position whose job description is clearly allocated to this effort. Volunteer or other unpaid staff can often find it difficult to stay engaged over the long gestation period that's typical of these large-scale developments.

While a champion often works tirelessly to address and overcome the hurdles involved, coalitions create the means of achieving a coordinated approach to pool expertise and resources. They can develop effective ways to help achieve the outcomes and objectives of the project and also create opportunities for collaboration and public/private partnerships.

Coalitions provide the project and the champion with the right partners needed at various phases of decision-making during the projects flight path (see the below figure[21]). Risk decreases over time as it becomes possible to collect more detailed information and firm up project costs as the project progresses through its development stages.



In order to reap the benefits of the coalition, it is important to recruit the right people and devise a set of objectives and activities that provide the motivation for members of the coalition to participate effectively. While the specific partners in a coalition may vary by project, the following list provides potential candidates for the coalition:

- Community/City Planning, Energy, Economic Development and Sustainability Staff
- Elected Officials – Mayors, City/County Managers, Governors
- Urban Planners, Architects & Engineers
- Building Facility Managers
- Local District Energy Providers
- Local Utilities
- Potential Developers including:
  - Local governments
  - Campuses and institutions (university, hospital, industrial parks)
  - Other public sector developers such as housing authorities
  - Property developers, landowners and building managers
  - Private sector developers

Each member of the coalition can provide expertise and information such as strategic plans, business models, technical know-how, climate action plans, sustainability guidelines, planning documents, and energy use data. It is important that the governance structure be transparent and clear and that the coalition moves the project forward on its intended path.

6 Municipalities and Urban Policy

Municipalities can serve as the catalyst for launching and sustaining environmentally superior and economically viable microgrids. They can be active partners in the microgrids (direct stakeholders) or play an indispensable role as a facilitator of multiple interests, a conduit to resources and economic incentives and as a source of advocacy.

This section will discuss specific measures that a municipality has available to spur microgrid project development and includes examples of district energy/microgrid zones already created. Zoning is one powerful tool at the municipality's disposal. Municipalities can offer additional development rights (higher densities, more floors) in exchange for the development of low energy buildings and neighborhoods.

6.1 Strong, Resilient Cities

Municipal and business leaders are focusing attention on improving the energy resiliency of their towns and cities. Communities are facing growing economic, social, and sustainability challenges and elected officials are increasingly interested in local energy production as a means of addressing them. The resilience of energy infrastructure in the face of extreme weather events is of particular concern. As community leaders are delegated ever more responsibility for addressing these matters they are looking to local energy projects; such as microgrids and district energy systems with CHP, as an effective response.

6.2 Energy and City Planning

Energy production, delivery, and use is a significant driver for the health and welfare of residents, the growth and development of business, as well as energy stability for cities and communities of all sizes. Until recently, for a majority of property owners, businesses, and local governments, energy has been viewed as little more than a bill to pay. Similarly, land-use planners and property developers not necessarily focused on the energy requirements of tenants, residents, and building owners. But a growing recognition of the ability of alternatives to manage energy costs, concern about national and local energy security, and threat of climate change are increasingly focusing attention on local energy opportunities.

In a number of states and local jurisdictions, access to low-cost, long-term capital, and other energy and environmental policies have opened up unprecedented opportunities to make money, restore budget cuts to core missions and activities, and put assets to more productive use, while meeting wider social and environmental objectives. To take advantage of these benefits, many municipalities and other public sector organizations, as well as businesses and landowners, are actively considering becoming energy producers as well as consumers by developing energy projects themselves, or by forming partnerships with the private sector to develop more sustainable properties and communities.

The potential to reduce emissions and energy costs can play an important role in city building, guided by growth and development decisions, as well as broader community objectives associated with sustainability and economic development. In these settings, communities can describe areas where there are opportunities to locate thermal energy facilities close to potential users and link them. Linking sources and users through a community energy network can improve capital efficiency, conserve space, improve operating efficiency through better load management, and create opportunities for community-scale resource conservation and energy efficiency. By doing this the subscribers to the community energy services can experience both health and financial benefits compared to traditional generation and delivery of energy. For example, manufacturing facilities may generate excess heat that can be supplied for the benefit of others in a district energy network. Similarly, large occasional-use facilities such as convention centers, stadiums, and arenas may allow the redirection of under-utilized energy capacity to surrounding buildings.

Many communities already have Climate Action Plans, and revisiting those to integrate microgrids and thermal energy considerations can open up a range of new opportunities. In cities that have a comprehensive plan, or a plan for new development, or redevelopment of a specific area, municipal leaders may be able to consider that plan in the context of local energy generation potential. Many cities are planning new development areas and revitalizing aged industrial areas by undertaking urban renewal or brownfield projects that would benefit greatly from a community based energy system.

Assessing the potential value and impacts of local energy in order to become a project champion, sponsor, or developer requires a general understanding of the opportunities. A perceived lack of skills, money, or understanding of the project development process can seem like daunting obstacles. Crucially, public project managers will need to adopt the commercial approach of a private developer. Land-use planning has a role to play in supporting project proponents in the early stages by mapping energy opportunities, sourcing, and providing data.

6.3 Energy Mapping

An energy map is a tool that can be used to organize/present data as the basis for defining energy character areas as part of an energy planning process. Energy maps are commonly used in planning departments across Europe as part of a broader community energy planning (CEP) initiative, and have recently begun to gain traction in North America. While energy maps are not a prerequisite to project development, they can help:

- Identify opportunities for new energy projects
- Determine suitable technologies and approaches to energy generation, distribution, and supply
- Highlight opportunities to link to other projects or share energy centers
- Aid decisions about prioritizing projects

Energy maps provide evidence for moving forward with a community based energy project and the basis for rational decisions to support planning policies. They also provide information for local infrastructure plans. Project proponents can choose to use one as a starting point for energy strategies for new developments and/or revitalization projects, and to highlight possible or priority projects.

Energy maps can also be used to define energy character areas, where the particular characteristics of an area are used to define the appropriate energy solution or planning policy. For example, mature residential suburbs are usually lower-density areas with little mix of use and many owners. These areas may be most suitable for micro-generation technologies (small, often building-integrated technologies, such as solar power). In contrast, city center locations have a higher density of buildings with a mix of uses including offices, shopping centers, hotels, and public buildings. While there still may be many different building owners, they usually have standardized decision-making processes for procuring energy services. Areas such as these can develop large-scale heating and cooling networks served by CHP plants, with islanding capability.

In this way, energy maps can illustrate energy character areas and help project proponents make good investment decisions and plans, whether at the single-building, neighborhood, or city scale. Energy maps can be an overlay to zoning and use-planning so that appropriate uses are targeted and concentrated.

Most energy maps are based in a Geographic Information System (GIS) platform, and are often prepared at the local or municipality scale. An energy map might be used in a variety of ways:

- Energy strategy: a map could form the starting point for the energy strategy for a development by identifying energy options
- Identifying energy solutions: a map can identify likely energy solutions, such as implementation of a district energy network, as part of an urban renewal project
- Priority projects: the map might point to possible investment opportunities for a project proponent
- Inform growth options: maps provide information that can aid decisions on the allocation of development sites
- Exclude inappropriate areas: for example, where nature conservation or landscape character are concerns

There is no single defined process for preparing an energy map. The project proponent will determine the level of detail necessary. For a given area, a map might include:

- An assessment of existing building energy demands and energy installations as a baseline
- Projected locations of new development at different stages in the planning pipeline, and an assessment of how this will affect energy demands over time
- The availability of potential local and renewable fuels
- A heat map, showing the location of large public buildings and other anchor loads

See "Power Play: an Energy Map of New York City" for one interactive example.[22]

6.4 Planning Policy for Microgrids and Community Based Energy Systems

The planning process has a significant influence over a community's ability to develop successful community based energy systems. Accounting for the conservation of energy in land use is imperative for achieving local, regional, and provincial goals associated with infrastructure, the environment, and energy resource management. Planners have a suite of tools at their disposal to shape and guide nodes of development, urban form, density, and land use as a means to support the development and expansion of district energy systems.

6.5 Factors Influencing the Built Form of Cities

Historically, the built form of many North American cities has been influenced by abundant, low-cost energy. Low-cost energy supply has prompted many middle-class North Americans to move away from the urban core, accepting longer commute times in exchange for lower housing prices. This has left a mark on the built form of many communities, developing regions of scattered single-detached, single-use development. Dispersed, low-density development makes providing frequent transit service difficult and increases the use of private automobiles. Another factor influencing the shape of North American cities has been the prevalence of large-scale, centralized energy production.

Energy planning in the 20th century was typically the responsibility of government agencies, particularly at the state level. Large-scale generation facilities were viewed favorably, on the assumption they would achieve economies of scale through centralization and large capital investments. The result has been a monopolistic procurement model, where decision-making around energy planning is removed from energy end-users and centralized in the hands of a few large-scale producers and government agencies. This energy model has allowed consumers to locate at almost any distance from a generator, with regulation keeping electricity prices low and removing the need to consider proximity from homeowners and businesses. More recently, energy price volatility, as well as vulnerability associated with weather related events, has alerted producers, consumers, and decision-makers to the implications of energy scarcity in meeting local demand.

6.6 Shaping the Urban Environment for Community Based Energy Systems

In contrast, urban environments with their higher density, compact, urban form, and mixed land use represent the greatest potential for the development and expansion of community-based energy systems. Major urban centers are now encouraging concentrated development and increased density within existing urban boundaries to protect productive agricultural and environmental lands outside city limits, while maximizing infrastructure investment.

Planners influence the location, form, density, and uses of future development, and can therefore shape the city building process to maximize the potential for microgrids and district energy systems. In particular, they should take a proactive position in the early identification of nodes of activity which could support community-based energy systems. Municipalities should try to incorporate the development of community-based energy assets in their official plan documents. More detailed direction can be provided within neighborhood-specific or secondary plans. Local officials, developers, and industry should collectively identify opportunities to concentrate urban form and leverage sources of waste heat. Infill and intensification efforts can be used for community based energy system development by requiring new development applications to undertake a study to determine the feasibility of energy asset connection, such as district energy, within a serviced area. In some cases, identifying a single, large thermal user can act as a catalyst for microgrid and district energy development. Encouraging compact development will improve the efficiency of community based energy systems while reducing capital costs.

6.7 Planning Tools for Community Based Energy Systems

Municipalities have a number of tools and resources available to encourage the development of community-based energy systems. Official plans provide the authority for municipalities to implement specific policies through the review and processing of development applications. Zoning bylaws capture potential land uses within a municipality. Planners can zone for, dedicate, and/or assemble lands for energy facilities. Community improvement plans, zoning activities, and powers of subdivision offer the opportunity to review community energy proposals. Achieving energy planning considerations in the development review process often requires the official plan to provide an energy vision based on objectives outlined in supporting legislation, accompanied by a zoning bylaw that specifies targets for development approval.

6.8 Bylaws and Regulations to Encourage Community Based Energy Systems

Several communities across North America have developed “district energy zones” – areas or neighborhoods with an existing or planned district energy service that require new developments to connect. For example, the City of North Vancouver requires all new development applications in excess of 1000 m^2 to connect to the Lonsdale District Energy Corporation system.[23] In exchange for connection and increased efficiency, developers receive a density bonus to increase saleable floor area. In some cases, mandating connection may not be possible. In these instances, district energy pre-feasibility studies can be required as part of the site-plan approval process. Municipalities can also designate local improvement areas, with a specific levy added to property tax to offset part of the district energy system capital costs.

Any sort of bonus permissions or incentives should be acknowledged upfront in the official plan and/or zoning bylaws. The permissions must be in place and vetted through a public process for acceptance, to avoid creating an unfair development advantage. Engaging stakeholders early on in the development process regarding the opportunity for a district energy or other community based energy system is critical. In order to capitalize on potential opportunities for connection, timing must be considered with respect to the development of the new energy asset, age of existing equipment, and connections to new services.

Depending on the jurisdiction and project objectives, some or all of the following planning policies and tools may be applicable:

- Establish dedicated district energy zones or service areas and consider mandating connection to the system within these zones. At a minimum, require a district energy connection feasibility study as part of the site-plan approval process for all new developments larger than 1000 m^2. Interconnection to district energy and CHP systems should be predictable, consistent and transparent
- Ensure zoning bylaws, site development/application process, subdivision and new development approval processes support the development of district energy systems. For example:
  - Use energy mapping, zoning bylaws, and site-plan approvals requirements to locate heat sources near identified heat sinks, and concentrate density in dedicated district energy service areas
  - Reduce permit fees and expedite approval for projects that meet community energy priorities
- Incorporate consideration for GHGs and energy demand into the land-use planning and development processes. Provide tools to assist municipal governments with the measurement and evaluation of GHG emissions
- Targets for energy efficiency or GHG reductions might be measured by achieving an energy density expressed as J/m^2 or MWh/hectare

- Require total cost assessment of new developments and adjust development charges to account for all new infrastructure expansions (typically intended to recover costs for maintenance of roads, water services etc.)
- In some jurisdictions, additional capital costs for infrastructure can be recovered through supplementary charges on property taxes
- Provide cohesive integration of land use, energy, and transportation into all planning documents, identifying nodes of planned development with density and floor space thresholds that could support district energy
- Remove policies that compromise the ability to advance district energy systems, such as restrictions on mixed-use developments in urban environments

See the sample zoning language from Vancouver[24] for an example.

6.9 Planning for District Energy-Ready Buildings

In many cases, it makes sense to explore opportunities for microgrids and district energy systems in tandem. Various steps can be taken to ensure future development is compatible with existing or planned community-based energy assets.

Currently housing developers are largely focused on provisions in building design, whereas district energy is more about energy demand and servicing. Heating systems based upon natural gas (forced air) or electricity (baseboard heaters) are well established, and installing them in new buildings have become the default options for developers. If district energy infrastructure is not already in place, it requires a greater degree of upfront evaluation.

6.10 Encouraging District Energy-Ready Buildings through Planning

Planners have a number of tools to encourage district energy ready (DE-R) buildings by ensuring proposed building design and systems are compatible with district energy:

- Green building or neighborhood standards. New buildings in a specific district energy zone could be required to demonstrate at least 25% energy efficiency improvement over the building code. A standard that sets an electricity conservation target will discourage the use of electric heaters. A renewable energy target will discourage the use of natural gas forced air, although such a target alone will not be effective if the source of electricity is hydro (renewable) or if the district energy system is gas fired
- Where the development of a district energy system is planned or anticipated, all new buildings or retrofits to buildings larger than 1000 m^2 or approximately 10,800 ft^2 (this may vary according to local conditions) should incorporate the following DE-R elements:
  - Hydronic HVAC system
  - Centrally located domestic hot water system in lieu of point-of-use heaters
  - Space allocated for an Energy Transfer Station (ETS)

DE-R building design can be negotiated and established through:

- Development agreements (e.g. Dockside Green, Victoria, British Columbia)
- Standard land-use covenants
- Prescriptive requirements for the site, such as energy conservation performance targets
- Development permit area guidelines with process requirements, such as DE feasibility studies or development permit checklists requiring site-level DE infrastructure

DE-R building design can be encouraged or incentivized through:

- Reductions in development cost charges or community amenity contributions
- Tax revitalization exemptions

- Streamlined approval processes
- Development permit area guidelines encouraging or incentivizing hydronic heating or cooling infrastructure within buildings

Once a system is operational, a service area bylaw can require buildings to connect. It is recommended that the municipality own a majority portion of the community-based energy system or heat source when establishing a service area bylaw. Some municipalities have offered financial assistance to developers to help cover the “premium” associated with installation. This may be reduced substantially if a building also requires cooling.

7 Legal & Regulatory

Microgrids will be required to comply with a variety of existing municipal, state, and federal requirements. In many jurisdictions, the exact regulatory requirements are uncertain and this uncertainty creates a hurdle for microgrid development. However, as the value proposition of these and other distributed energy resources becomes known around the country, more and more regulators are looking at new frameworks that minimize regulatory uncertainty regarding microgrids. This section will survey existing legal and regulatory frameworks surrounding microgrids, while also noting some areas where a more favorable regime can be pursued.

7.1 Interconnection

In order to interconnect with the wider electric grid, a microgrid will require an interconnection agreement with the incumbent utility. An interconnection agreement will typically state the technical requirements for the microgrid to operate in parallel with the utility's system, and often assess costs to the interconnecting customer-generator to pay for any upgrades that are necessary to the utility's system in order to safely accommodate the customer's system.

Various states have set out different interconnection rules and procedures. A typical interconnection standard prescribes:

- What a customer must put into the application for interconnection
- How long the utility has to review that application
- What kinds of studies can be required upon various showings of necessity
- How to assess the costs of those studies
- How to assess the costs of any utility system upgrades those studies justify

Another common feature of interconnection standards is incorporating the technical standards established by a third party agency, such as the 1547 series of standards adopted by the Institute of Electrical and Electronics Engineers (IEEE), so as to avoid legislatively prescribing technical requirements that may change or be sensitive to precise interpretations. Across the United States, forty-five States have different interconnection standards or guidelines. Some jurisdictions have adopted streamlined interconnection procedures for distributed generation projects below a certain capacity threshold. For example, New York has adopted Standardized Interconnection Requirements (SIR) for distributed generation projects with a capacity below 2 MW.

Interconnection standards and processes may change in the future as understanding of microgrids advances. New York, for example, is in the process of reviewing interconnection standards through the Reforming the Energy Vision (REV) proceeding and intends to raise the SIR threshold to 5 MW. The IEEE standards are also being reviewed to develop more closely tailored rules for microgrids.[25]

7.1.1 Advocacy: Interconnection

Microgrid developers would benefit from standardization, clarity, and cost control in the interconnection process.

Standardization

Standardization benefits developers in at least two ways. First, by knowing the technical requirements for interconnection before designing the microgrid, developers face less risk that a utility will require a costly redesign in order to connect. Second, and relatedly, by meeting the technical requirements for interconnection as part of the design, the developer reduces the need for a costly and time-consuming engineering analysis of the microgrid as part of the interconnection process.

Clarity

Generally speaking, interconnection becomes more complex in the microgrid context, and existing interconnection processes may not capture the full range of that complexity. To ensure safe operation with the macrogrid, the utility may require more information on the microgrid's internal controls, or visibility into its performance, than is typically required in the case of a single customer-generator.

The anti-islanding provisions of many interconnection requirements may also benefit from greater clarity, considering their application to microgrids that intentionally island a whole section of the utility's distribution system. Local interconnection procedures should be reviewed at the level at which they are issued – i.e., State legislature, regulatory commission, or utility – and appropriate application and review procedures established. Due to the varied nature of how these standards are promulgated, it is impossible to issue a uniform recommendation on the actors or procedures that should be targeted.

Cost Control

The cost of interconnecting a microgrid will depend on what upgrades are required of the utility's system to accommodate the microgrid's DER. These costs may vary based on where the microgrid is being built. Minimizing them may be possible by building a microgrid capable of providing services to the distribution system. Two types of effort may be helpful:

- Utilities may be required to provide certain grid information to developers to allow them to identify areas where interconnection costs are likely to be smaller. This effort could be accomplished by appealing to the regulatory authority and requesting a ruling to this effect
- A utility may be able to minimize the costs of grid upgrades where a developer can guarantee maintaining certain operational parameters (e.g. implement demand response and load following to keep power import/export within a certain range, or utilizing DERs that can provide distribution-level ancillary services like voltage regulation)

Developing microgrid-specific interconnection processes that identify these opportunities may help control interconnection costs in the future.

7.2 Power Export

Once interconnected, there are various means by which excess power in the microgrid may be exported onto the wider grid, and correspondingly, different ways in which a microgrid may be compensated. For example, a microgrid could enter into a PPA with the incumbent utility. In this case, the rate for excess energy provided to the wider grid could be either the retail rate, the wholesale rate, or something in between. In the case that a microgrid qualifies as a "Qualifying Facility" under the federal Public Utility Regulatory Policies Act ("PURPA"), then in general, the incumbent utility will be required to purchase the excess energy from the microgrid unless the microgrid has nondiscriminatory access to the wholesale electricity market.[26]

Alternatively, in some jurisdictions, a microgrid can export excess electricity under a net metering regime, where excess electricity exported onto the grid will typically be credited to the customer-generator's next utility bill at a rate that reflects all or some portion of the retail cost of that electricity. Various net metering rules often distinguish between different types of generation so that, for example, solar generation may receive a more beneficial credit rate than a combined heat and power (CHP) system. Alternatively, some types of generation may be ineligible to receive net metering credits at all. These discrepancies may tend to make exporting power from a microgrid with several different types of generation sources problematic. One solution may be to independently meter the different sources of generation so that they can be accounted for separately, with output of the specific generation type "mapped" to the relevant net metering policy. How to resolve this tension so that microgrids with multiple types of generating resources straddling different regulatory statuses will not be excluded from participating in net metering is an open question in many jurisdictions. In addition, in some jurisdictions net metering is not available to some types of regulated entities. For example, in Massachusetts, net metering is not available to any entity regulated as an electric company, generating company, aggregator, supplier, energy marketer, or energy broker.[27]

Net metering policies exist in forty six States across the country. Most of these States have a uniform policy, though some States like Texas permit individual utilities to adopt policies while the State itself has no policy as a whole. Many of these policies also apply only to investor-owned utilities, and not to municipal utilities or electric cooperatives. These policies permit a variety of different generating resources to participate with a variety of types of compensation. For example, twenty States permit combined heat and power systems to net meter. In those that don't (and some that do), a feed-in tariff may also provide financial incentive for on-site CHP, such as California's CHP FiT.[28]

7.2.1 Advocacy: Power Export

Microgrid developers may benefit from net metering policies that:

- Allow microgrids to utilize all forms of distributed generation without discrimination in the form of net metering eligibility or differing credit rate
- Set the credit at retail rate
- Set the credit at a similarly beneficial value-based rate[29]

Typically, net metering policies will be either legislatively prescribed or promulgated by the State's utility regulator. Lobbying efforts for these policies should be targeted at the appropriate authority.

7.3 Rights of Way and Franchise

In some jurisdictions, utilities are granted monopoly rights in their service territories, so-called "franchise" rights. In these territories, non-utility entities are prohibited from delivering electricity. The form of this prohibition varies by jurisdiction. In some jurisdictions, a non-utility entity is prohibited from delivering electricity, in the engineering sense, across a public right-of-way. In these jurisdictions, there is little, if any, limitation on electricity service on private property. In other jurisdictions, however, non-utility entities are prohibited from transferring ownership and control of electricity, irrespective of whether such transfer occurs across a public right-of-way or on private property.

Exceptions to a utility's monopoly are also highly jurisdictional dependent. In New York, for example, a municipality can typically issue a competing franchise or other consent in a utility's service territory which would allow a microgrid to cross a public right-of-way;[30] in Massachusetts, by contrast, only the utility itself can consent to a microgrid that infringes on the utility's franchise.[31] Franchise issues may be avoided in cases where the microgrid utilizes existing utility infrastructure to wheel power between microgrid users. Note that use of a utility's existing infrastructure may impact the microgrid's ability to operate in island mode. Be sure to investigate this and weigh it accordingly in any benefit-cost analysis. In such a case, the contractual and service relationship between the utility and the microgrid users may adopt many forms: a microgrid "wheeling" charge, a net metering arrangement that shares credits among all sites, etc.

7.3.1 Advocacy: Franchises

The most effective markets for microgrids will develop where utilities do not have an effective veto over projects that implicate their franchise rights. The grantors of a franchise, a competing franchise, or a lesser consent are typically at the municipal level. These local authorities should be approached to ascertain the type of consent required to operate a microgrid that distributes powers over public rights of way, and involve the utility to the extent necessary to either negotiate for consent or modify the utility's franchise to make it nonexclusive.

7.4 Standby Tariffs and Exit Charges

Standby rates are utility rates that a customer pays to interconnect with the utility system while producing its own power. They are often set utility by utility, though several jurisdictions have State-wide policies, and are designed to compensate the utility for the cost of fixed transmission and distribution assets that the customer might not otherwise pay for but must nevertheless be maintained for the customer to use the grid as its "backup." The cost of standby delivery *strongly* affects the economic viability of the DG technology in instances when the customer does not completely disconnect from the grid, as is the case with most microgrids.

Generally, a utility customer will pay a tariff in the form of a monthly demand charge. This is an additional fee to any electrical generation charges for actual electricity used. Some utilities require a customer to contract for the measured peak electrical output of the customer's onsite electrical generator, which can inequitably affect the economics of a project that might shed load in the event it switches to grid power. Other utilities may fix the charge based on a customer's peak demand. In the microgrid context, where all of the customers served by the microgrid can interact as a single controllable entity to the grid, it is important that the coincident peak of all customers be measured, and not the aggregation of their individual peaks, which may not coincide.

Microgrid developers would be benefited by standby rates evolving towards a comprehensive valuation mechanism that bases cost and compensation on performance, taking into account the diversity and redundancy of supply built into the microgrid.[32] Reformation of these rates should take place at the level at which they are issued, which varies jurisdiction.

7.5 Emissions

Microgrids are required to comply with federal and state environmental laws, including laws and regulations related to air pollution. The Federal Clean Air Act requires pre-construction environmental permitting of new stationary facilities in order to meet the goals of the National Ambient Air Quality Standards (NAAQS) program. The "criteria pollutants" regulated under this program that are of greatest relevance to DG are nitrogen oxides (NOx) (as a precursor to ground level ozone or smog), carbon monoxide (CO), sulfur dioxide (SO2), and particulate matter (PM). NOx is the primary (and often the only) criteria pollutant that significantly affects most DG projects.

Although the permitting process is established and regulated under federal law, it is administered, in most cases, by the States. This leads to a high degree of variability in implementation, ranging from no control requirements to extremely stringent levels of control.

Air permitting and emission control requirements can be divided into four general categories: major source permitting, state minor source permitting, *de minimis* exemptions, and emergency generators. Unless a source qualifies for an exemption, a permit is required. The need for a permit will depend on the unique features of a project, including its location (i.e. whether it is located within a "non-attainment" area under the Clean Air Act) and emissions levels. Emission levels will be measured by a source's "potential to emit," or the source's maximum possible emissions if operated at full capacity for 8,760 hours per year.

- "De minimis exemption" refers to the fact that most states have a threshold below which units are either too small or emit a small enough amount that they do not have to apply for a permit of any kind. The requirements and conditions for these exemptions vary by state, but most states allow some kind of de minimis exemption. Sources that are not exempted must obtain a permit
- Sources that fall in between the de minimis and the major thresholds are generally subject to state minor source permitting. Both the minor source permit and the major source permit are likely to require some kind of emission limitations or controls. These control requirements could be anything from raising the stack height of a unit to installing the most stringent control technologies available. The permitting process also can range from a simple application to a complex cost-based technology evaluation. The requirements vary depending on the state and the type of unit proposed
- New or modified sources that exceed certain potential emissions thresholds are called "major sources" and are subject to the federal New Source Review program. This level of preconstruction permitting will require the application of either "Best Available Control Technology" or the "Lowest Achievable Emissions Rate"

In addition, greenhouse gas emissions may be regulated in the Northeast under the Northeast States' Regional Greenhouse Gas Initiative, or in California under the State's Cap-And-Trade program.[33] The applicability of these requirements depends upon the capacity of the distributed generation source and the technology it employs.

7.6 Building and Fire Codes

Code development and enforcement is a patchwork of state and local regulations. There tend to be few provisions in existing standards, codes, and building construction regulations that address either traditional or emerging distributed generation technologies. This limitation, combined with a lack of familiarity on the part of many local code enforcement officials, can create significant additional cost for a developer through cumbersome site-specific testing, evaluations and approvals.

Issues likely to affect a microgrid include:

- **Zoning and building codes:** While many permutations of zoning concerns are possible, common ones include overly restrictive rules dictating where generation can be sited, height restrictions, lot coverage limitations, and setback requirements that may not allow for the placement of solar panels or small wind installations on existing rooftops or building sites. Silence in "permitted use" sections of a zoning code that can, in effect, prohibit on-site generation or storage. Municipalities should review applicable zoning codes and local homeowners' associations' covenants and consider removing or altering those that unintentionally impede microgrid development within the municipality's jurisdiction. Municipalities can also create a variety of incentives to encourage microgrid development including conditional zoning variances (e.g., floor and area ratio bonuses for incorporating various DER), flexible building standards (e.g., granting points in a green building standard for incorporating DER), and streamlined permitting processes. These actions can help make microgrids more economical and the development process more straightforward
- **Mechanical/plumbing codes:** Many localities will not allow a gas-fired unit to be installed unless it is listed as a gas appliance by an approved agency. Subsequently, exemption must be sought through the use of a "Registered Professional Engineer who will submit a report declaring the installation meets all applicable standards and is in safe operating condition"
- **Fire codes:** Under many fire codes, an analysis of the fuels flammability and combustibility must be performed for many generation sources. The fire department will need to know where a unit is located and how to disconnect the unit in case of a fire. The installation of a fire suppression system may be required[34]

8 Appendix A – For Further Reading

8.1 Community Microgrids: Smarter, Cleaner, Greener

An introductory report on community microgrids and the many benefits they offer. It lays out a roadmap for communities considering microgrids from setting goals and identifying the vision for a project to choosing sites, completing analyses, acquiring financing, and getting approval to build. The report also considers the regulatory environment for microgrid development and offers recommendations for making the region friendlier to microgrids. This document should be read by municipal and community leaders, state and local government and regulatory officials, emergency managers, large business owners, and any other individuals interested in resilient, affordable, and clean energy.

http://energy.pace.edu/sites/default/files/publications/Community%20Microgrids%20Report%20%282%29.pdf

8.2 Community Energy: Planning, Development & Delivery

Aims to support mayors, planners, community leaders, real estate developers and economic development officials who are interested in planning more sustainable urban energy infrastructure, creating community energy master plans and implementing district energy systems in cities, communities and towns. The new guidebook provides an overview of the local energy project development process, in a form that is accessible to lay readers, to assist them in making informed decisions on the analysis, planning, development and delivery of district energy systems. IDEA engaged UK-based district energy specialist Michael King, author of the UK guidebook by the same name, to revise Community Energy: Planning, Development and Delivery for the U.S. market to reflect relevant national energy and environmental policies and incorporate current U.S. market conditions and policy drivers on a federal, state and local level.

http://www.districtenergy.org/community-energy-planning-development-and-delivery/

8.3 District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy

Argues that modern district energy is the most effective approach for many cities to transition to sustainable heating and cooling, by improving energy efficiency and enabling higher shares of renewables. Provides concrete policy, finance and technology best-practice recommendations on addressing the heating and cooling sectors in cities through energy efficiency improvements and the integration of renewables.

http://www.unep.org/energy/portals/50177/DES_District_Energy_Report_full_02_d.pdf

8.4 US Department of Energy – Technical Assistance Partnership

The DOE's TAP provides a variety of support resources for CHP projects including free first level technical assessments.

http://www.energy.gov/eere/amo/chp-technical-assistance-partnerships-chp-taps

8.5 Qualified Energy Conservation Bond Case Study

Public Building Upgrades: Reducing Energy Bills in the City of Philadelphia

http://energy.gov/sites/prod/files/2014/06/f16/public-building-qecb.pdf

8.6 Powering District Energy Projects at the Eco-Districts Summit

http://ecodistricts.org/powering-district-energy-projects-at-the-ecodistricts-summit/

8.7 BC Hydro: Sustainable Communities Program

https://www.bchydro.com/powersmart/business/programs/sustainable-communities.html

9 Appendix B – District Energy/CHP Microgrid Case Studies

Ten District Energy/ CHP case studies have been selected to illustrate the multiple dimensions of Microgrids with CHP and District Energy. These are summarized below and will be attached as a separate document.

Location	Description	Country
Princeton University Princeton, NJ	Super resilient and islandable Campus District Energy/CHP/Microgrid with 5MW of integrated Photovoltaics. Leverages New Jersey Cogeneration Law to allow for wheeling of electricity across utility-owned wires to buildings also served by thermal energy from central plant.	USA
Coop City Bronx, NY	Privately owned 40 MW microgrid supplying power and thermal energy to mixed-use community of over 60,000 residents. Maintained 100% operation during Super Storm Sandy and back fed Con Edison electric grid during extended regional outage.	USA
Markham District Energy Markham, Ontario	Municipal utility providing hot water, chilled water and power to support economic development, mission-critical healthcare and new urban real estate development.	Canada
University of Massachusetts Medical School Worcester, MA	Mission-critical healthcare campus has expanded CHP capacity to provide power, steam & chilled water for enhanced resiliency. Recent project expansion was supported by grant from local utility and features significant emission reductions under MA Green Communities Act.	USA
New York University Manhattan, NY	CHP/district energy/microgrid provides primary energy, including thermal and power, to support urban oasis in lower Manhattan. Central plant maintained operations during Super Storm Sandy to prioritized campus buildings.	USA
District Energy St. Paul St. Paul, MN	Microgrid with renewable Biomass fueled CHP and District Heating and Cooling systems were financed by long-term municipal revenue bonds secured by long-term contracts with initial customers. Recent integration of renewables includes photovoltaics and solar hot water systems.	USA
Marine Corps Air Ground Combat Center Twenty-nine Palms, CA	Utilizing third party ESCO strategy, the largest Marine Training Base in the world integrated CHP and renewables to deliver highly-reliable energy for critical mission operations.	USA
Veolia Energy North America Boston-Cambridge, MA	New owner has invested in CHP to transform independent power producer asset into base load, low heat rate CHP to provide power and district heating to Cambridge/Boston thermal grid.	USA
Hamilton Community Energy Hamilton, Ontario	This geo-exchange based district energy system sits on a former brownfield site in Hamilton. It was designed, built and is operated by Hamilton Community Energy, a District Energy subsidiary of the City owned Hamilton Utilities Corporation	Canada
Helen Ltd. (Helsingin Energia) Helsinki	A for-profit company owned by the city of Helsinki, which supplies electric energy to nearly 400 000 customers in Finland and covers over 90% of the heat demand of the capital city with district heating. The power grid connection is self-healing and provides enhanced reliability and uptime through active feeds from two substations.	Finland

10 About the Authors

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All links are valid as of June 15, 2015

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[7] US News and World Report: Federal appeals court blocks EPA rule that exempted backup generators from pollution controls http://www.usnews.com/news/politics/articles/2015/05/01/appeals-court-overturns-rule-on-backup-generators. Full court opinion: http://www.cadc.uscourts.gov/internet/opinions.nsf/2E87E0199203E71B85257E3800500091/%24file/13-1093-1550129.pdf
[8] Systems designed without the ability to island safely from the main grid are required to shut down when the main grid is down to avoid back-feeding energy onto the grid and energizing infrastructure that utility maintenance may be repairing.
[9] The Best Value for America's Energy Dollar: A National Review of the Cost of Utility Energy Efficiency Programs; March 25, 2014; Research Report U1402; http://www.aceee.org/research-report/u1402
[10] Pace Energy and Climate Center - Community Microgrids: Smarter, Cleaner, Greener at http://energy.pace.edu/sites/default/files/publications/Community%20Microgrids%20Report%20%282%29.pdf
[11] Id.
[12] Id.
[13] FERC Order 745, approved in 2012, calls for wholesale-market operators to pay the full market price, known as the locational marginal price, to economic demand response resources in real-time and day-ahead markets as long as dispatching DR is cost-effective and helps operators clear the market. In May 2014, the U.S. Court of Appeals in Washington, D.C. vacated the Federal Energy Regulatory Commission's Order 745 in a 2-1 decision after a challenge from the Electric Power Supply Association. Possible rule changes as well as challenges to this decision are still on-going as of March 2015. State demand response programs may still be available for microgrids.
[14] http://www.ferc.gov/industries/electric/indus-act/demand-response/dem-res-adv-metering.asp
[15] See for example the Princeton Microgrid which receives payments for Ancillary Services in the PJM market, and MIT in the NE-ISO market. Similarly the Konterra project in Maryland is a business model that combines PV and battery storage, in a scheme that includes PJM market revenues.
[16] Con Edison's Brooklyn Queens Demand Management (BQDM) is one example of an attempt to avoid additional spending on distribution networks
[17] See for example the members of the National Association of Health and Educational Facilities Finance Authorities (NAHEFFA) at http://www.naheffa.com/index.html
[18] For background information see: http://www.pacenow.org/bring-back-residential-pace/ and page 58 of this document: http://energycenter.org/sites/default/files/docs/nav/policy/research-and-reports/PACE_in_California.pdf
[19] http://energy.gov/eere/slsc/qualified-energy-conservation-bonds
[20] On-Bill Financing for Energy Efficiency Improvements; American Council for an Energy Efficient Economy (ACEEE), Washington DC
[21] IDEA Community Energy: Planning, Development & Delivery http://www.districtenergy.org/assets/pdfs/Community-Energy-Dev-Guide-US-version/USCommunityEnergyGuidehi.pdf
[22] http://blogs.ei.columbia.edu/2012/02/13/power-play-an-energy-map-of-new-york-city/

[23] In accordance with Bylaw 7575, as amended periodically, any new building larger than 1,000 square meters is required to connect to the district heating system for heating purposes unless it is determined by the City's Director of Finance that the cost to the City for providing the service would be excessive. http://www.cnv.org/City-Services/Lonsdale-Energy/Standards-and-Requirements-for-Developers

[24] http://vancouver.ca/files/cov/neighbourhood-energy-design-guidelines.pdf

[25] See, e.g., IEEE Project P2030.7, Standard for the Specification for Microgrid Controllers, at http://standards.ieee.org/develop/project/2030.7.html

[26] 16 U.S.C. § 824a-3(a) (2), (m); 18 C.F.R. § 292.303, 309.

[27] M.G.L. c. 164, § 139(e); See also 220 CMR 18.06(1).

[28] See, e.g., California Public Utilities Commission, CHP Feed-in Tariff, California Public Utilities Commission, available at http://www.cpuc.ca.gov/PUC/energy/CHP/feed-in+tariff.htm (last modified Aug. 21, 2013).

[29] See, e.g., Nat'l Renewable Energy Lab., Value of Solar Tariff, National Renewable Energy Laboratory, available at http://www.nrel.gov/tech_deployment/state_local_governments/basics_value-of-solar_tariffs.html (Factors that affect [value of solar] rate may include: Utility variable costs (fuel and purchased power); Utility fixed costs (generation capacity, transmission, and distribution; Distribution system and transmission line losses; Ancillary services (to maintain grid reliability); Environmental impacts (carbon and criteria pollutant emissions).").

[30] See "Microgrids for Critical Facility Resiliency in New York," NYSERDA, at 37.

[31] See M.G.L. c. 164, § 1G(g).

[32] See N.Y. State Dep't Pub. Serv., Developing the REV Market in New York: DPS Straw Proposal on Track One Issues Case 14-M-0101, 1, 62 (Aug. 22, 2014), available at http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BCA26764A-09C8-46BF-9CF6-F5215F63EF62%7D

[33] See California Environmental Protection Agency, Cap-and-Trade Program, State of California, http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm

[34] Id.