

# Think Microgrid

A Discussion Guide for Policymakers,  
Regulators and End Users

---

*brought to you by*



## Introduction

North America is positioning for a new and significant round of microgrid development. But will we frame the rules of the game correctly to capture the full benefit of microgrids?

“Think Microgrid: A Guide for Policymakers, Regulators and End Users” outlines the major issues now before the microgrid industry as crucial, early policy discussion begins. Written by the experienced editorial staff at EnergyEfficiencyMarkets.com, the guide is the result of extensive information-gathering and interviews with key industry insiders and microgrid advocates.

We look at why microgrids are growing in popularity, their economics, the regulatory landscape, state activity, industry advocacy, resources and next steps to guide the industry. And finally we profile successful microgrid projects.

EnergyEfficiencyMarkets.com prepared this guide to assist those who are involved in today’s microgrid policy discussions: government decision-makers, grid operators, utilities, and microgrid developers, vendors, and advocates.

This guide also serves energy users, campuses and others who are contemplating microgrid installations — or already participate in a microgrid — and want to understand how policy can enhance microgrid capabilities. What might upcoming decisions mean to these colleges and universities, data centers, municipalities, pharmaceutical companies, research facilities, business parks, manufacturers, military installations, residential communities, and other large energy users?

Our guide focuses on the United States, but we also touch on Canada, where microgrid activity is on the rise.

We hope the information here will help foster deeper discussion about microgrids among all of the interested stakeholders. Please visit MicrogridKnowledge, an online channel of EnergyEfficiencyMarkets.com, and share your thoughts about the ideas we present here.

– Elisa Wood, Editor, EnergyEfficiencyMarkets.com

## Contents

<b>Introduction</b> .....	<b>2</b>
<b>Part 1: Why Microgrid Now</b> .....	<b>3</b>
Why now?.....	3
Benefits for End Users and Society .....	4
What Could Hinder Microgrids? .....	5
<b>Part 2: Defining Microgrid: The First Challenge</b> .....	<b>5</b>
<b>Part 3: Growth &amp; Economics of Microgrid</b> .....	<b>7</b>
Monetizing Microgrids.....	8
<b>Part 4: The Regulatory Landscape &amp; Risk</b> .....	<b>9</b>
Massachusetts and Microgrids: “Going Backwards Is Not an Option” .....	10
States in the Lead.....	12
California.....	12
Connecticut .....	13
Maryland .....	13
Massachusetts .....	13
New Jersey .....	14
New York .....	14
US Government .....	15
Canada .....	15
<b>Part 5: Next Steps: How Policy Leaders Can Help Microgrid Achieve its Full Value</b> .....	<b>16</b>
International District Energy Association .....	18
Notable District Energy/CHP/Microgrids .....	18
Microgrid Resources Coalition .....	18
<b>Part 6: Vision for Microgrid</b> .....	<b>19</b>
<b>Appendix 1</b> .....	<b>19</b>
Project Profiles .....	19
The University of Texas at Austin .....	19
Princeton University .....	20
<b>Appendix 2</b> .....	<b>21</b>
Why Microgrid is Economically Competitive.....	21

*This guide was made possible by:  
The International District Energy Association (IDEA),  
Schneider Electric and Microgrid Knowledge*

## Part 1: Why Microgrid Now

Microgrids have been around for decades; in fact, configurations that look much like microgrids go back to Thomas Edison's time. But for most of their history, microgrids operated as a niche technology, workable and financially feasible mostly on college campuses or in remote locations.

Now, the technology has radically 'changed its stars,' so to speak. Microgrids are poised to become an integral part of North America's energy transformation.

### Why now?

There is not one reason, alone, for the growing interest in these mini versions of the larger grid. It is a coming together of several societal, market and technological trends and changes.

First, cities and states see microgrids as a lever to spur economic growth. Today's economy — technology-intensive and information-centered — requires clean, efficient, economic, highly reliable and locally controlled power and thermal energy. Microgrids offer this kind of premium energy. So their presence attracts high tech businesses, data centers, research centers, and similar industries that create sought-after jobs — and for whom energy security and business continuity are critical success factors.

---

*"With microgrids we can develop reliability or resiliency zones that will be attractive for greenfield projects and eco parks."*

Philip Barton, Microgrid and Reliability  
Program Director, Schneider Electric

---

Second, certain energy market trends favor microgrids, Natural gas and solar prices — two common fuels for microgrids — have fallen dramatically in recent years. Lower fuel prices make microgrids increasingly cost-effective to operate. Prices also are declining for electric energy storage, allowing for more effective use of solar energy in microgrids.

Third, new smart grid technology allows microgrids to perform in an increasingly sophisticated manner. Real time data displays, grid interfaces, and various software

advances allow microgrids to maximize their use and timing of resources for greatest economy.

Fourth, industry and government officials are very worried about grid reliability and security. Microgrids can keep the power flowing when the central grid faces threats

Superstorm Sandy — and the expectation of similar storms ahead — intensely drives today's interest in microgrid development. State leaders, particularly in the Northeast, are seeking ways to make the electric grid more storm hardy. And mayors and other local officials want more control over electric supply in a crisis. They are often held accountable by the electorate when the grid is down. Yet, they have little influence in an age when utilities are no longer home-town operations, but are likely to be owned by large national or international energy companies.

---

*"People want local generation because of extreme weather — wind, flood, mudslides, fire, hurricane and storm surges — and they want a better approach to deal with the business disruption costs."*

Rob Thornton, CEO and President of the  
International District Energy Association

---

Storms are one threat to the grid; another is physical and cyber terrorism.

The *Wall Street Journal* recently published findings from a Federal Energy Regulatory Commission report that showed an assault on just nine key substations (out of 55,000) could cripple the US power system for weeks or possibly months. This occurred after unknown assailants shot out 17 transformers April 16, 2013 in Silicon Valley in a coordinated, night-time attack that included cutting telephone wires in the area, presumably to block 911 calls.

Perhaps more troubling, the US electric grid finds itself under almost constant cyber-attack, according to several recent state and federal reports. So far, we have warded off the danger, but the attackers are constantly changing their strategies. As Connecticut's Public Utilities Regulatory Commission said in its recent report, "Cybersecurity and Connecticut's Public Utilities:

*Hostile probes and penetrations of utilities occur frequently. Defenses in Connecticut so far have been adequate, but security challenges are constantly evolving and becoming more sophisticated and nefarious.*

So, microgrids have become an important part of the plan to create a more resilient, secure energy system, one that can withstand the attacks of wind and water or hackers and terrorists. Should the central grid go down, microgrids can quickly “island” — disconnect to provide a continuous energy supply and protect their customers from the damage occurring on the larger grid.

Microgrids also are an environmental play, in an era when society increasingly demands clean and efficient energy. When anchored by combined heat and power and district energy, microgrids ward off energy waste and cut regional greenhouse gas emissions. Because they produce generation close to load, they avert line losses and can provide very valuable capacity services to support local or even regional grids. In addition, with appropriate scale and integrative technologies like thermal storage, microgrids provide balancing capacity to support intermittent resources like solar and wind.

And finally, microgrids offer a way to build new resources without evoking today’s all-too-common protests, the not-in-my-backyard phenomenon. Energy providers find it increasingly difficult to site high voltage transmission or large power plants because of local opposition. Microgrids, on the other hand, are generally small, un-intrusive and embraced by communities as a form of clean, local energy.

## Benefits for End Users and Society

There are two ways to think about the advantages of microgrids. They benefit both their hosts, and society as a whole.

For end users, microgrids:

- ▶ Provide secure, reliable energy
- ▶ Earn revenue and reduce energy costs through buying and selling into sophisticated real-time wholesale energy markets
- ▶ Deliver high quality power and thermal energy, which is especially important to data centers, life sciences, e-commerce, pharmaceutical companies and similar tech-driven operations
- ▶ Customize energy operations to the distinct needs of the host
- ▶ Offer a way to produce and control energy supply locally
- ▶ Help businesses and institutions enhance their environmental reputation

Microgrids also can strengthen the central grid and reduce costs for everyone — even those not directly served by a microgrid. For society as a whole, microgrids can:

- ▶ Avoid the need for expensive upgrades and new infrastructure for the central grid
- ▶ Enhance efficiency and decrease costs by reducing line loss
- ▶ Enhance efficiency and cut emissions by using combined heat and power and district energy
- ▶ Provide services to the grid to balance load and stabilize frequency and voltage
- ▶ Reduce costly grid congestion
- ▶ Lessen strain on the central grid through load shedding when demand is high and wholesale power costs rise, such as a hot summer day
- ▶ Ease energy supply constraints, such as natural gas shortages in New England during cold snaps
- ▶ Serve as a source of power capacity to the central grid
- ▶ Increase the value proposition of solar and wind energy through use of energy storage
- ▶ Spur greater use of alternative energy technologies, such as fuel cells,
- ▶ Offer a new source of demand for America’s vast natural gas supply

## What Could Hinder Microgrids?

Given their many benefits, microgrids are poised for expansion in the US, particularly in the Northeast and California. But how quickly the expansion occurs depends on the disposition of policy and regulation.

Policymakers, regulators and grid operators are just beginning to consider the rules that will govern the next phase of microgrid development and operation. Many states have yet to even define the term ‘microgrid.’

Therefore, the microgrid industry finds itself in a nascent and crucial stage. The outcome will determine how easy — or difficult — it will be for microgrids to position themselves in the marketplace. Ease of siting, franchise access, interconnection, regulatory approvals and financing depend on the outcome of proceedings just beginning in many states.

Crucial questions have yet to be answered, such as:

- ▶ How will microgrids be compensated for their services?

- ▶ Will they threaten the established utility business model, or serve as an operational ally and perhaps even a utility asset?
- ▶ Who will develop, own and operate microgrids in restructured states?
- ▶ How will regulators measure and monetize the environmental benefits of microgrids?

All of these issues are under debate within a highly competitive energy policy arena. The way forward could be difficult if established players perceive microgrids only as a competitive threat and work against them in regulatory forums.

So, while microgrids are in demand — and in fact announcements of new projects are more and more frequent — much work lies ahead to ensure fair policy.

---

## Part 2: Defining Microgrid: The First Challenge

So what is a microgrid, exactly? The term has been used for years, yet those who attend microgrid conferences joke that much of the event is spent in debate over the definition. As is often the case with a popular technology, many would like to package their products as microgrids. Hence, we see the term’s meaning broadening in the marketplace.

Let’s start with what a microgrid is not. Rob Thornton, President and CEO of the 105-year old International District Energy Association, often says that microgrids are “more than diesel generators with an extension cord.” In other words, a microgrid is not just back-up generation but should be a robust, 24/7/365 asset that provides primary energy services to a market. A microgrid can provide back-up generation, but it offers additional, more intricate services as well.

For the purposes of this paper, we will focus on advanced, grid-connected microgrids with the following characteristics.

- ✓ Produce onsite generation and optimally thermal energy to be economically competitive
- ✓ Serve a distinct, interconnected load, usually with multiple buildings or meters, within a defined geographical boundary or business district

- ✓ Can act as a single, controllable entity within the central grid
- ✓ Can operate in parallel to the grid, as a grid collaborator not competitor
- ✓ Can connect or disconnect (island) from the central grid during interruption events with black-start capability
- ✓ May participate in demand response, and buy power from the grid or sell energy, capacity and ancillary services to the grid, depending on economics/pricing
- ✓ Provide energy 24/7, 365 days a year
- ✓ Often incorporate advanced controls and communications and automation software for transparent and intelligent energy management and demand response
- ✓ Include distribution wires
- ✓ May use any form of fuel, but are likely to run on CHP/natural gas, fuel cells or solar energy, and sometimes wind power
- ✓ May include thermal and electric storage



No set size exists for these microgrids; some generate power in the kilowatt range, while others produce more than 100 MW. Most existing microgrids in North America are customer-owned, although models are emerging for third-party ownership. A handful of utilities also are actively developing or operating microgrids. Some have rate-based microgrids, such as San Diego Gas & Electric, a model that is increasingly under discussion.

Several college campuses have operated microgrids in the United States for years. These are large and complex facilities that serve as models for the emerging era of the microgrid. The University of Texas at Austin, for example, operates a microgrid that provides 100 percent of the power, heating and cooling to 150 campus buildings encompassing 20 million square feet. It has done so for more than 40 years with 99.9998 percent reliability. (See [Appendix 1, page 19.](#))

These campuses use combined heat and power and district energy, two tried-and-true technologies characterized by their high efficiency. CHP puts to good use the heat that is typically wasted in conventional power production. Rather than dumping waste heat to a nearby river, lake or ocean or simply letting the heat dissipate into the sky, a CHP plant reuses it for heating, cooling and steam production. District energy systems pipe water or steam from a central plant to heat or cool multiple buildings. This creates efficiency and cost savings because the buildings can forego installing individual boilers, chillers and air conditioners in each building. (See more details [here](#) on other ways CHP and district energy increase energy efficiency.)

We do not focus in this guide on remote or mobile microgrids, although they, too, are increasingly being adopted worldwide. Remote microgrids can be found on islands and isolated locations that are not connected to a grid. The US military uses mobile microgrids in places like Afghanistan where fuel transport is inherently dan-

*“Having a microgrid allows you to marry the thermal side along with electrical and manage the whole thing together as a unit for your greatest benefit. That is really the power of microgrid.”*

James Adams, Director of Utilities at Cornell University

gerous and difficult. Some remote microgrids operate on fossil fuels, but increasingly they are incorporating wind power, solar energy, or other forms of renewable energy. By using energy storage, remote microgrids are able to accommodate the intermittency of renewable energy, a task that may be difficult for an energy facility that is not part of a larger, central grid.

But it is the grid-connected microgrid that is provoking the most discussion among US decision-makers. This type of energy facility could profoundly influence generation, distribution and transmission planning in the US. The microgrid also could become an increasingly important player in wholesale power markets, as we'll discuss in *Part 3* of this guide.



## Part 3: Growth & Economics of Microgrid

The North American microgrid is growing, but how big and how soon? And what economic factors will drive or hamper the industry?

North America, especially the United States, is the center of a microgrid market that Navigant Research expects to reach \$40 billion annually by 2020, up from \$10 billion in 2013. Capacity will grow from 866 MW in 2014 to 4.1 GW in 2020 under a base case scenario described in Navigant's report, "[Market Data: Microgrids](#)."

The research firm characterizes the industry as moving into its next phase of project development — commercialization. Two types of microgrids will attract the most attention: Grid-tied and direct-current, according to Navigant.

Exactly what the industry will look like, and how much it will grow over the next several years, depends upon decisions being made now by government and industry. "The key to future growth in microgrid now rests with greater creativity in both the public policy and business model arenas," Navigant says.

Frost & Sullivan also sees the US as the clear leader in microgrids, largely because of its military, which has created

a springboard for private sector development. Its [analysis](#) predicts rapid microgrid growth from 2015 to 2020. The research firm says it is likely that utilities will be among the players that will deploy microgrids. (We see other likely microgrid developers to be municipal governments, public power and municipal utilities, institutions and health-care, energy management and operation companies, independent power producers, independent transmission companies, solar and energy storage developers, and technology and engineering firms.)

Suba Arunkumar, Frost & Sullivan energy and environment industry manager, describes expansion potential as "immense" for players across the microgrid value chain. "First-mover advantage will be prominent for participants venturing into the market within the short term," Arunkumar said.

Frost & Sullivan warns that microgrid development can be expensive, especially for those facilities that integrate into a central grid. Costs are high, in part, because of a proliferation of custom interfaces and a lack of their standardization. To overcome this problem, Europe is building microgrid networks for field tests and analysis, says Frost & Sullivan.

**Average Market Growth Projection<sup>1</sup> of Campus Microgrids<sup>2</sup>, by Capacity and Revenue**

North America	Capacity (MW)			Revenue (\$)		
	2011	2017	CAGR %	2011	2017	CAGR %
<b>Total</b>	<b>603</b>	<b>1572</b>	<b>17.3</b>	<b>59.73</b>	<b>735.65</b>	<b>52.0</b>
<b>By Segment:</b>						
<b>Commercial</b>	71	179	16.6	8.95	80.91	44.3
<b>Education</b>	488	1281	17.5	45.48	603.71	53.9
<b>Government</b>	34	73	13.8	4.28	28.56	37.2
<b>Healthcare</b>	10	31	20.4	0.85	16.73	64.3
<b>Industrial</b>		4		–	3.06	N/A
<b>Research</b>	0	4	64.5	0.18	2.68	56.6

<sup>1</sup> Data from Navigant (Pike Research) Q1 2012

<sup>2</sup> Does not include Military and Remote Microgrids

Credit: Schneider Electric

Similar problems about technology are raised in a Sandia National Laboratories [report](#), "The Advanced Microgrid Integration and Interoperability," by Ward Bower, Dan Ton, Ross Guttromson, Steve Glover, Jason Stamp, Dhruv Bhatnagar and Jim Reilly.

"...much basic technology does exist today, but some products are often not well matched and much of existing technology deserves improvements in reliability, two-way communications, and standardization...Today's developments toward an advanced microgrid are already moving forward but sometimes in a disparate manner."

Many college and universities have valuable experience operating and optimizing microgrids, developed over many years of integration and focus on delivering highly reliable energy services to mission critical end-users, such as laboratories; research centers, surgeries and data centers. US institutions often host invaluable research projects that demand constant, precise temperature and humidity settings, and accordingly have not relied solely on the commercial electricity grid. These microgrids are essential infrastructure and are designed to deliver highly resilient energy services.

How large the market grows for advanced microgrids remains to be seen and depends on regulatory and policy movement, as well as continued success honing the technology and reducing interface costs. Even with these advances, some see microgrids as always being niche. Others describe a future grid comprised of mostly microgrids with the central grid acting as the coordinator.

selling of power into wholesale markets relies on rules set by different grid operators. Ten independent system operators (ISO) and regional transmission operators (RTO) serve two-thirds of US electricity consumers in what is known as the organized markets.

Given the balkanization of the US grid and its markets, rules could vary dramatically by location. Microgrids are likely to thrive in markets where electricity prices are high, large condensed load exists (such as college campuses or denser urban business districts) and rules allow microgrids to take advantage of their efficiencies to offer a cost-effective product. *(For more details on when microgrids become economically competitive see: Appendix 2, page 21.)*

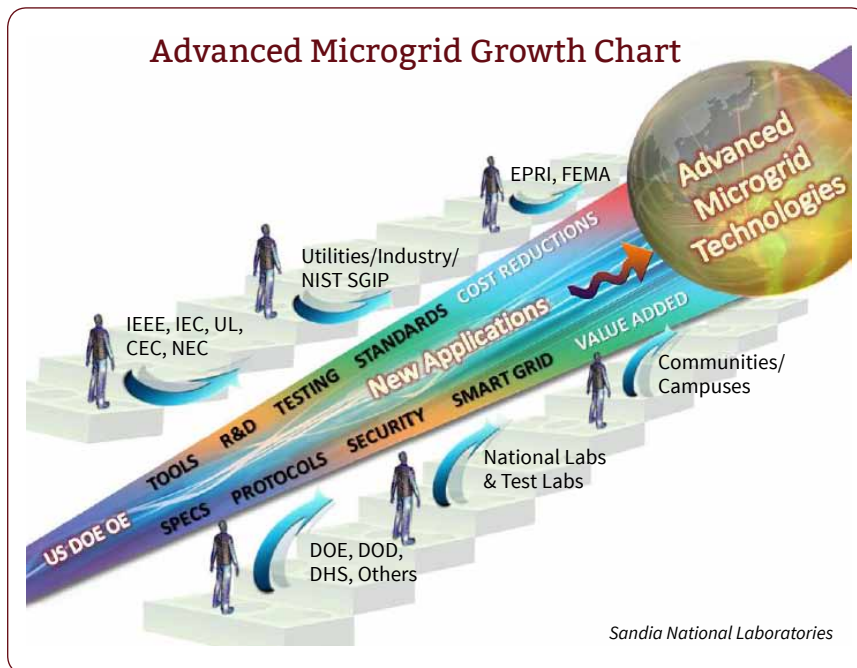
So simple geography will affect a microgrid's return on investment. Several other factors also play into microgrid economics, as DNV KEMA points out in its August 2013 paper, "[Microgrids for Fun and Profit](#)". Local electricity

prices, fuel prices, financing costs, timing of construction, equipment costs, and government incentives, all influence a microgrid's value.

The most obvious revenue source for a microgrid is its host. Depending on how the microgrid ownership is structured, the microgrid may collect retail energy rates from the energy users it serves. Microgrids can further improve their economics through sophisticated wholesale transactions and by maximizing power and thermal outputs. A capital intensive asset like a microgrid will likely require high load factors and utilization to generate a competitive rate of return for its investors.

Operators describe engaging in various hedging strategies and market transactions to reduce their costs, manage operating risks or earn revenue. For example,

a microgrid is likely to manage use of its onsite energy and storage to avoid peak energy costs. Microgrids also can earn revenue by selling power back to the grid when it makes sense economically. In addition, they can reduce costs and earn revenue by participating in demand response programs or wholesale capacity and ancillary services markets. They may sell into carbon credit markets or provide utilities with renewable energy or energy efficiency credits to meet state portfolio standards.



## Monetizing Microgrids

Market growth will depend on the economics of microgrids; and microgrid economics will depend largely on how effectively regulators, policymakers and grid operators allow microgrids to monetize. Utility regulation and power plant siting rules are set at the state level in the US. So microgrid developers could find themselves navigating 50 different sets of rules governing their major permits and relationships with utilities. Moreover, the buying and



Microgrid operators express confidence that they can successfully compete in these various markets — if they are offered fair compensation for services.

“If we can improve the regulatory environment to properly value many of the benefits for these assets, that will create pull in the marketplace for more investment. The perceived risk will be diminished if revenue streams are clarified and market access rules are more consistent,” says Rob Thornton, President and CEO, International District Energy Association.

But there is an even bigger economic hurdle for microgrid operators. Microgrids offer economic benefits that go unrecognized. How do microgrid advocates convince policymakers to assign value to these benefits? For example, power outages cost the US economy \$18 to \$33 billion annually between 2003 and 2012, according to the [US Department of Energy](#). Microgrids help reduce these costs by keeping the power flowing to their host customers.

Then there is the issue of avoided costs. A microgrid built by a private developer in a strategic location might avert the need for a utility to build or reinforce transmission and distribution infrastructure. Private investors pay for the microgrid, yet utility operators and ratepayers benefit.

How should the microgrid be compensated for reducing grid congestion or strengthening the grid overall? This is one area subject to much more discussion, especially since the current utility business model rewards investment in assets, but does not adequately incentivize efficiency, reliability, and optimization of system integration.

In short, the regulatory rules of the road must evolve quickly for emergent microgrid technologies to compete with traditional utility investment strategies. Regulatory guidance is critical.

There is another, larger risk faced by microgrids, one not so easily managed and likely to play a key role in determining the growth trajectory of the microgrid industry. That risk is the microgrid’s relationship with its local utility, and it is central to today’s policy discussions about microgrids. We discuss the utility/microgrid relationship in *Part 4, The Regulatory Landscape & Risk*.

---

## Part 4: The Regulatory Landscape & Risk

Microgrids face the same kind of development risk as other energy projects, such as permitting issues, market penetration, financing, and fuel supply management. But one of the greatest and most talked about risks for microgrids involves their relationship to the local utility.

The relationship is still largely undefined. The central question is: Will microgrids compete with local utilities or complement them? Many advanced microgrid advocates emphasize that the microgrid is a counterpart to the local grid, not a detractor.

Still, there are potential friction points between utilities and privately developed microgrids, the same issues that tend to arise between utilities and other forms of distributed energy, such as interconnection standards, standby rates or submetering rules.

Utilities have both financial and technical concerns about how microgrids will influence their business model and the functioning of the central grid.

On the technical side, utilities worry that microgrids may harm the reliability of the larger grid through faulty interconnection, tripping or failing to island or re-connect correctly. Meanwhile, private microgrid operators offer another perspective. Some say they find it difficult, from a technical perspective, to deal with the utility’s legacy system and to navigate interconnection procedures.

On the financial side, some utilities express concern about the cost to provide back-up power for microgrids, especially if they proliferate. (It also should be noted that some utilities have embraced microgrids and either have developed them or plan to.)

But much of the discussion centers around the ‘utility death spiral,’ the idea that customers will flee the system for distributed generation and microgrids in great numbers, leaving the utility with a rate base too limited to fund needed infrastructure without dramatic rate increases — which will in turn cause further customer flight.

## Massachusetts and Microgrids: “Going Backwards Is Not an Option”

*Ann Berwick makes clear that big change is afoot when asked about Massachusetts and microgrids.*

The chair of the Massachusetts Department of Public Utilities says that utilities better prepare as the new world of distributed energy emerges. Unless they find new ways to make money, “somebody is going to supplant them,” she said.

EnergyEfficiencyMarkets.com interviewed Berwick in early May as the DPU was preparing to issue a significant ‘grid modernization’ decision. The proceeding — and related DPU dockets — are likely to shape not only the state’s future utility, but also the developing microgrid and distributed energy industries.

“I think the utilities are going to have to figure out a different business model because it will be absolutely of no avail for them to push back against the addition of more and more distributed resources. That horse is out of the barn,” she said.

Climate change is demanding additional renewable energy. The grid is refashioning. Utilities must keep up and regulators must be on board, she said: “Going backwards is not an option.”

It’s little surprise that microgrids are important to Massachusetts. The state has been a leader — indeed some would argue *the leader* — in energy efficiency policy. For three years running it has ranked as the top state in a national scorecard produced by the American Council for an Energy-Efficient Economy. Microgrids could enhance the state’s energy efficiency in several ways. Among other things, they reduce electric line loss because of the close proximity of the customer to the generator in a microgrid. In addition, many existing microgrids incorporate highly efficient combined heat and power.

Efficiency is just one reason the state is looking to modernize its grid. Like its neighbors in the Northeast, it is seeking ways to harden its electric system to avoid a repeat of the power outages brought to the region by severe storms in recent years.

“This [grid modernization] docket has a number of global level objectives, including the integration of distributed resources and reducing the effects of outages. Microgrids are obviously relevant to both of those,” she said.

Microgrids also are an environmental play for Massachusetts. Governor Deval Patrick has enacted an aggressive greenhouse gas mandate that requires all sectors of the economy to reduce greenhouse gases 25 percent by 2020 and 80 percent by 2050.

What’s the best way to track Massachusetts’ on microgrids? Follow not one, but several proceedings before the DPU. These include the grid modernization docket (D.P.U. 12-76-A), along with related proceedings dealing with electric vehicle charging (D.P.U. 13-182), time varying rates (D.P.U. 14-04), and carbon dioxide pricing.

“All of these issues are closely related. In order to tap time varying rates, you’ve got to have advanced meter functionality. In order to have microgrids operate to their fullest potential, I think you also need advanced metering functionality and time-varying rates,” she said.

The state also is closely involved with the Massachusetts Clean Energy Center’s planned “Microgrid Challenge,” which will look at opportunities and barriers to microgrid.

“Grid modernization is really going to change the rules of the game,” Berwick said. “It is going to change what I heard somebody refer to as the game board that we are all on playing on: Utilities, regulators, customers. It’s going to break open our world to all kinds of new approaches to the distribution of electricity and how we pay for it.”

She couldn’t speculate on the outcome of the various proceedings, since they are still ongoing. But she expects Massachusetts to produce granular specifics — “not just it’s-a-good-idea” — on topics like time varying rates. “I’d say the Patrick administration is visionary. We’re looking at [the issues] at the 1,000 foot-level in terms of what do we need to do to change the playing field for utilities and regulators — and also at the more granular level in dealing with things like time-varying rates electric vehicles.”

*Stay tuned. Much more to come from Massachusetts in the coming months.*

One of the thorniest issues for microgrids involves utility franchise rules. In many locations, a microgrid cannot string wires across a public street to serve customers; doing so infringes on the local utility's franchise rights.

In March 2013 Public Utilities Fortnightly article, "[Peaceful Co-Existence](#)," Sara Brown and Paul McCary, point out that utility franchise laws vary widely throughout the United States. So ease of microgrid development varies widely too. The authors use South Carolina and Connecticut as examples of two extremes. In South Carolina, the state has jurisdiction over something as basic as the sale of power from rooftop solar panels to a host. In contrast, Connecticut allows certain microgrids to sell across power across public streets.

A simple microgrid, such as one serving a college campus with no intervening public streets, could likely operate even in South Carolina without concern about franchise rules, say the authors. However, for more complex microgrids — those with multiple end users on multiple pieces of property with public streets — the franchise issue arises. Microgrids aren't necessarily precluded in states with narrow franchise rules. But the developers depend on the goodwill of the regulators and local utility, or the utility's willingness to form a financial partnership or agreement with the microgrid, say the authors.

The competitive playing field also raises questions of risk — especially in restructured states. Who should be allowed to develop microgrids? Utilities typically cannot own or develop power plants in restructured states. Should they also be prohibited from microgrid development? Or might the state grant exceptions, as some have, in a limited fashion for utility development and ownership of renewable energy projects?



And if utilities do own microgrids, should they be allowed to charge a premium rate, given the high quality of the power? For example, if a utility builds a microgrid to supply quality power to a newly arrived data center, should there be a special tariff applied? Should utilities or grid operators create some form of locational pricing to attract microgrids to areas of the grid where they are needed, such as points of congestion?

And finally, how do we calculate and recognize the environmental value of a microgrid?

Environment Northeast points out in a filing before the Massachusetts Department of Public Utilities that the benefit/cost analysis for any grid modernization must consider the value of greenhouse gas emissions reductions. This issue is important to microgrids because many incorporate CHP, which ACEEE named as one of four key efficiency strategies to reduce greenhouse gases in its April 2014 study, "[Change Is in the Air: How States Can Harness Energy Efficiency to Strengthen the Economy and Reduce Pollution](#)." These strategies are particularly important in light of the Environmental Protection Agency's rule making on carbon limits for existing power plants.

## States in the Lead

Several states have begun to address these and other issues important to microgrids. Below we offer an overview of key proceedings, incentive programs and reports.

### California

The California Public Utilities Commission Policy & Planning Division issued a paper in April 2014 that outlines major policy and regulatory issues the state needs to consider. “Microgrids are coming; how utilities and regulators respond will go a long way to determining how innovation and services will impact the electric grid,” says “*Microgrids: A Regulatory Perspective*”, by Christopher Villarreal, David Erickson and Marzia Zafar.

The CPUC staff paper recommends that the state avoid pigeon-holing microgrids as just a set of technologies capable of keeping the lights on and instead consider their full range of benefits. It describes a microgrid as a fundamental building block for a smart electric grid, a kind of “cell in a matrix” of interconnected distributed energy resources and customer loads, controlled through the interaction between the microgrid and the utility.

Microgrids are likely to disrupt the conventional utility model, says the paper. So regulators and policymakers should consider a new role for the utility. For example, the utility might act as a ‘distribution system operator,’ akin to the independent system operators that run the US transmission networks. In essence, the utility would oversee the distribution grid, including any connected microgrids, to ensure that the lights remain on for all.

The paper also discusses problems with interconnection and net metering that California microgrids face. They illustrate the difficulties created by microgrids when they are not defined in regulation but must fit into a slot created for other distributed resources. The report says:

*Distribution interconnection rules that have been established by the Commission only recognize three types of generation interconnection: net metering, self-generation (nonexport), and wholesale distribution access tariff (WDAT). Net metering is on the customer side of the meter and involves a bill credit for exported energy. It is not visible to the California ISO, and is connected at distribution-level voltage. There is a limit of 1 megawatt (MW) of nameplate capacity. Self-generation interconnect is effectively wheeled to the*

*customer via the distribution grid, but is not intended for net production. Wholesale distribution access interconnect is visible to the CAISO and is interconnected on the utility side at distribution level voltage. There is a limit of 3 MW at the 12 kV PCC and 5 MW at the 60 kV PCC.*

It is important to note that none of these interconnection techniques support a general advanced microgrid as defined above, but all require the approval of the utility.

The paper raises a number of other regulatory problems that need to be addressed to foster microgrids in the state. For example, should the interconnection tariff consider the ability of a microgrid to switch back and forth from consumer to producer of electricity in short bursts of time. Further, most California utilities do not support islanding — will this dampen microgrid development in the state? And finally, what does it mean to microgrids that California requires net metered resources to power down in the event of an outage or grid failure? This negates another one of a microgrid’s most important benefits — the ability to serve during a grid crisis.

The paper suggests a number of steps regulators should take. They include development of standards for microgrids to ensure that they interconnect and interact safely with the central grid. The authors also advise that California map the distribution grid to determine where to site microgrids and perhaps set up a locational pricing system to encourage siting in those areas.

---

*“Microgrids offer locational marginal resiliency or stable nodes of resiliency and reliability that decrease the end users costs, and in some cases the utility’s cost.”*

Philip Barton, Microgrid and Reliability Program  
Director at Schneider Electric

---



### Connecticut

Connecticut began exploring the microgrid concept after suffering extended power outages from severe weather, even before the October 2012 Superstorm Sandy. The state has been supporting development of microgrids both through incentives and policy changes.

To date Connecticut has issued two solicitations for microgrids.

The first solicitation resulted in nine projects announced in July 2013. The state granted the projects \$18 million in total. The projects included microgrids that use micro gas turbines, natural gas reciprocating engines, solar PV, CHP, diesel, fuel cells (a manufacturing industry being cultivated in Connecticut) and some battery storage. The hosts are critical facilities, such as police stations, hospitals, cell towers, fire departments, shelters, as well as a naval submarine base, college campuses and schools.

Connecticut issued its second microgrid solicitation March 3, 2014. It offers \$15 million in funding, and seeks projects that promote geographic diversity. The RFP also seeks a variety of project sizes, scale, and technical configurations. Bid winners must support critical facilities when the grid fails. Bids are due Aug. 6, 2014 and winners will be announced by Oct. 1, 2014. The state also plans a third microgrid solicitation.

The state established the incentives as part of a storm emergency preparedness bill (Public Act 12-148) that became law in June 2012.

In addition to offering financial incentives, Connecticut has fostered microgrid development through changes in utility franchise rules. Public Act No. 13-298, passed in July 2013, make it possible to site microgrids that cross public streets without franchise infringement.

“Utility franchise rights in Connecticut are now essentially erased for municipal microgrids. So if you have a microgrid in Connecticut that is serving what is considered a municipal critical facility, you can string wires wherever you want, and the utility is not allowed to sue you — although that could still be challenged in court,” said Genevieve Sherman, senior manager at the Clean Energy Finance and Investment Authority at the Northeast Sustainable Energy Association Building Energy 14 conference in Boston.

### Maryland

Maryland has created a task force to study microgrids. The effort is being led by Abigail Hopper, an energy advisor to Governor Martin O’Malley. The Resiliency Through the Microgrids Task Force is looking at statutory, regulatory, financial, and technical barriers to microgrids. The effort builds on recommendations from a September 2012 task force report

“Marylanders expect and deserve an electric grid they can count on, especially during unpredictable severe weather events. Developing microgrids is critical to a sustainable future,” said O’Malley, announcing the effort.

The Maryland Energy Administration is providing staffing for the task force. The effort will include identifying areas of high electric demand where pilot projects may be built.

### Massachusetts

Massachusetts has several regulatory proceedings underway that are likely to influence the state’s microgrid policy. They are the result of Governor Deval Patrick’s aggressive green energy agenda. (See insert, [page 10.](#))

The proceedings include:

- ▶ D.P.U. 12-76-A Order on grid modernization
- ▶ 13-182 Order electric vehicles and charging
- ▶ 14-04 Investigation into time-varying rates

It’s little surprise that microgrids are important to Massachusetts. The state has been a leader — indeed some would argue *the leader* — in energy efficiency policy. For three years running it has ranked as the top state in a national scorecard produced by the American Council for an Energy-Efficient Economy. Microgrids could enhance the state’s energy efficiency in several ways. Among other things, they reduce electric line loss because of the close proximity of the customer to the generator in a microgrid. In addition, many existing microgrids incorporate highly efficient combined heat and power.



### New Jersey

New Jersey Governor Chris Christie has allocated \$25 million to 146 government agencies to develop microgrids and other projects that improve the state's energy resiliency. The money can be used for retrofitting existing distributed generation, including fuel cells or combined heat and power, to increase capacity. It also is available for engineering studies; buying diesel, solar or natural gas-powered generators; and purchasing dynamic inverters and storage for existing solar panels.

The New Jersey program targets critical facilities, and is part of an ongoing energy partnership between the state, Department of Energy's National Renewable Energy Laboratory and the Federal Emergency Management Agency.

Separately, New Jersey also is studying a first-of-its kind transportation microgrid through a \$1 million federal grant. Called NJ Transit Grid, the project is as result of a memorandum of understanding between the U.S. Department of Energy, NJ TRANSIT and the New Jersey Board of Public Utilities, which will collaborate with Sandia National Laboratories on the project.

NJ TRANSIT, the nation's third largest transportation systems, is considering:

- ▶ The design, construction and operation of self-generation power facilities;
- ▶ The design, construction and operation of a new, dedicated power grid;
- ▶ The distribution of self-generated power to NJ TRANSIT's overhead catenary wire network;
- ▶ The distribution of self-generated power to key NJ TRANSIT facilities.

The microgrid would power the transportation system between Newark and Jersey City and Hoboken, along with critical stations and maintenance facilities.

Sandia National Laboratories has already designed advanced microgrids now operating at about 20 military bases. The project will use Sandia's quantitative risk-based assessment tool, the Energy Surety Design Methodology (ESDM), to evaluate energy needs, identify advanced solutions to improve reliability and resiliency, and isolate the cost-effective strategies for system upgrades.

### New York

The New York Public Service Commission opened a proceeding April 24, 2014 that could significantly influence microgrid development in the state. Called Reforming the Energy Vision, or REV, the plan was devised by the staff of the New York Department of Public Service.

The plan would create a grid operator that manages distributed energy much the way independent system operators now manage bulk power markets in the United States. The new manager is called a Distributed System Platform Provider, or DSPP (although PSC chairman Audrey Zibelman recommended they consider a more pronounceable acronym.)

The DSPP becomes a kind of market platform where regulated and competitive distributed energy players buy and sell. The distributed grid operator would create markets, tariffs, and systems to monetize energy efficiency, microgrids, combined heat and power, energy storage, demand response, distributed generation, building management systems, and other forms of distributed energy. It also would target distribution grid needs, measure programs, and handle payments and transactions.

The plan specifically calls out microgrids as an element of distributed energy in need of policy attention.

Here are some of the microgrid questions the New York PSC intends to take on.

- ▶ What changes in current rules (e.g., interconnection and standby rates) are needed to enable microgrids and community grids?
- ▶ What are the issues regarding the relationship between utilities and microgrids (e.g., ownership of distribution lines within the microgrid, and regulatory status of microgrid owners as sellers of power)?
- ▶ What role do microgrids play in the DSPP planning function, related to system needs as well as critical facility resilience?
- ▶ Where microgrids serve critical facilities should this be reflected in pricing of utility services?

Of course the big question becomes who gets to be the DSPP. The staff report recommends that utilities play the role.

New York Governor Andrew Cuomo, a strong proponent of distributed energy and microgrids, has blessed REV concept. The proposal now undergoes review, discussion and possible change. The commission hopes to start putting policies in place in 2015.

Separately, Cuomo has announced a \$40 million competition to jump-start at least 10 community-based microgrids. (New York distinguishes between regular microgrids and community microgrids, which are “a style of microgrid that supports many customers in an area, including critical customers as well as businesses and residents.”)

Separately, the New York Power Authority, the nation’s largest state owned electric utility, has laid out a new strategy to create a “reimagined” electric grid that focuses on microgrids and local generation.

NYPA outlined the idea in its “Strategic Vision 2014-2019.” NYPA envisions microgrids serving individual communities. The authority already is working with customers to encourage development of microgrids and distributed generation, which it calls the “hallmarks of the new power system.” Known for its large hydroelectric resource, NYPA sees itself as well positioned to lead a grid modernization. The non-profit energy corporation is one of New York’s leading power suppliers. It operates 16 power plants and more than 1,400 circuit-miles of transmission.

Meanwhile, Consolidated Edison, which is one of the nation’s oldest and largest utilities, agreed earlier this year to take a look at microgrids as a grid resiliency measure. This came about in a rate case settlement with a group of NGOs.

A collaborative of NGOs and utility representatives will look at, among other things, high-efficiency combined heat and power and microgrids that can reduce system load, isolate outages, and create entities that can island from the grid.

### US Government

The Department of Energy in January 2014 issued a solicitation offering grants for microgrid research, development, and system design. In particular, the solicitation sought testing of advanced commercial-grade microgrid controllers for microgrids sized between 1 and 10 MW. Grant winners must work with an entity or community to design microgrid systems that offers enough power for a small community and ideally serves critical infrastructure such as hospitals or water treatment facilities.

The Federal Energy Regulatory Commission does not currently have an open docket on microgrids. However, FERC guidance is likely to be instrumental as ISO/RTOs work out issues surrounding payment to microgrids for grid services. Another issue that may come into play is whether or not microgrids should be considered qualifying facilities (typically small renewable or CHP projects under 80 MW). This would allow microgrids to sell electricity to utilities at competitive rates. As QFs, microgrids may also be exempt from state or federal rules governing utilities. Also under discussion is the impact on microgrids of FERC’s November 2013 ruling that reduces the time and cost for small generators to interconnect with the grid. (Docket No. RM13-2-000).

And finally, several federal agencies are studying microgrids or have issued reports on the topic, among them: Microgrids Group at Berkeley Lab; The Department of Energy; EPRI; Sandia National Laboratories.

### Canada

Canada is researching smart grid through The NSERC Smart Microgrid Network (NSMG-Net), a partnership of Canadian universities, government and industry. The multi-disciplinary research program is developing, testing and verifying technologies and regulations. Remote microgrids are especially important in Canada, which has almost 300 remote communities, many of which rely on diesel generators for electricity. In its long-term energy plan, Ontario calls for working with the federal government to develop microgrids for remote First Nation communities.

Canadian Solar, one of the world’s largest solar power companies, has opened a microgrid test center in Ontario to share information and services with utilities, colleges, communities, and companies that want to develop microgrids. The program is partially funded by the Ontario Ministry of Energy, which hopes to gain a strong competitive advantage in microgrid development with the help of the testing center. Located in Guelph, the center will study both off-grid and grid-tied microgrid projects. It will focus in particular on testing, developing and integrating high penetration renewable energy into existing microgrids that are not grid connected. The province sees benefit in off-grid projects for First Nations, remote communities and mining projects in Northern Ontario.

## Part 5: Next Steps: How Policy Leaders Can Help Microgrid Achieve its Full Value

Clearly, microgrids offer many benefits; they also raise many questions about the most effective rules and policies for the emerging new grid.

As we've shown, some states are beginning to answer these questions; others are likely to follow. The Northeast is taking the lead, largely because of an in-depth grid examination forced upon it by Superstorm Sandy.

What states will be next? "Follow the carnage," says Alex Kragie, deputy chief of staff for the Connecticut Department of Energy and Environmental Protection.

Kragie means that as more states face severe weather from climate change, they will look to microgrid technology as a way to ward off power outages.

How should these states frame the discussion about microgrids?

First, the term needs definition, preferably one that is somewhat consistent from state-to-state. This will allow for easier regional and national policy discussion and perhaps somewhat consistent rules.

Energy companies — not just microgrid firms — often say that consistent state-to-state policy for energy resources would allow them to take advantage of economies of scale and drive down prices. While 50-state universality is prob-

---

*"If you have little pockets of scattered microgrids that are operating during a storm, first responders can go a much shorter distance to recharge cell phones and flashlights, warm-up and get a hot meal. So the idea of having even a handful of microgrids makes a wide, regional emergency into a much smaller crisis because you have pockets of reliability."*

Edward (Ted) Borer, Energy Plant Manager at Princeton University

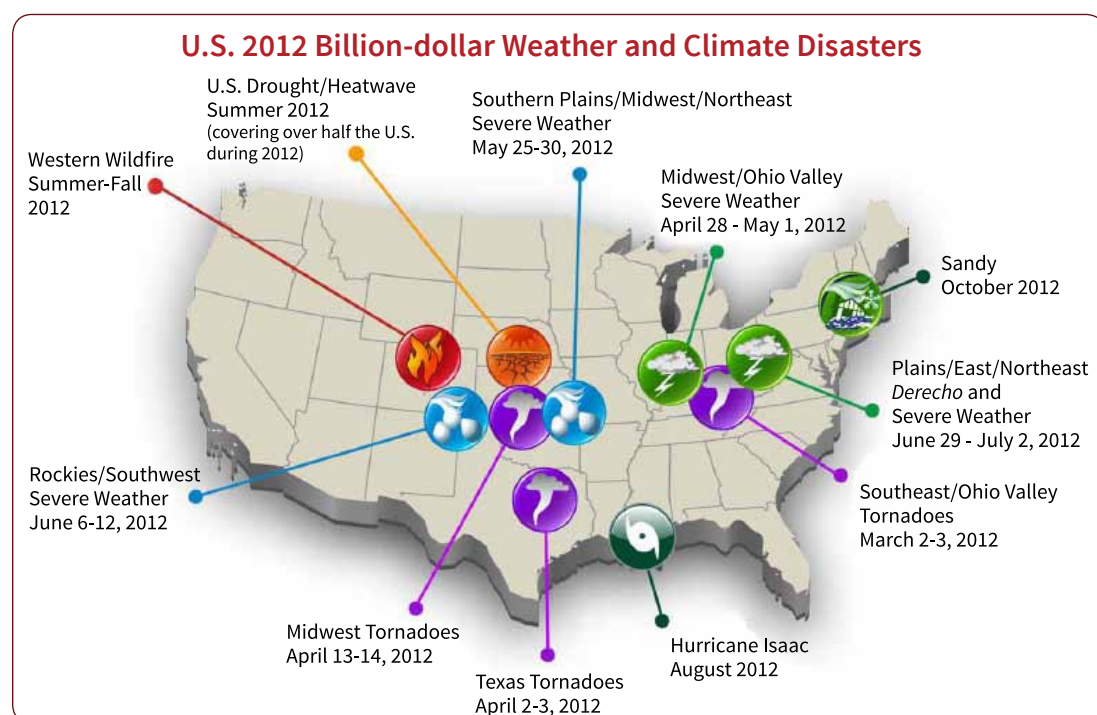
---

ably impossible, some effort in that direction helps. States are realizing this when it comes to other energy resources. For example, New England's governors are working on regional renewable energy solicitations and transmission development.

Second, microgrid advocates recommend that regulators and policymaker think of microgrids more as an asset class. Private capital is more likely to flow to microgrid development if these facilities are paid fully for any and all of

the services that they offer to the grid and hosts.

Third, it is important that states consider microgrids as a resource in utility planning. As such, microgrids would compete on a level playing field against generation, transmission and distribution and energy efficiency to fill a supply need.



And last, and perhaps most important, rules and policy need to balance the market effectiveness of competition against the need to preserve utilities as a distribution backbone of the US electric system. If microgrids become a threat, utilities are likely to fight their expansion in the marketplace. A better approach marries the economic health of utilities and microgrids with policies that allow the two industries to work jointly to strengthen the grid.

How can we honor the financial requirement created by a utility's obligation to serve, yet not place an onerous and unfair burden on microgrids? One approach would be to create a more performance-based rate structure for utilities.

Performance-based ratemaking sets goals for utilities and rewards them based on the results. It is a forward looking approach that contrasts to the more backward looking approach that dominates utility rate-making. Today, a utility spends money on, say, a capital asset, then goes to the regulator for cost recovery. The regulator looks backward to determine if the utility made a prudent investment.

The performance-based approach decouples a utility's profits from its costs and ties a utility's profits to performance. This creates more business flexibility for utilities — more options to pursue in the way they operate, as described in a March 2014 paper, "New Regulatory Models," by Sonia Aggarwal and Eddie Burgess. Elements of performance-based ratemaking are being used by utilities throughout the US — for example for achieving energy efficiency goals — but the approach is not being used universally.

Finally, it is important that states pursue policies that encourage a healthy, competitive microgrid industry. Over the last decade, electric competition has helped dampen energy costs and spur a wave of innovation. Solar and smart grid technologies offer two good examples of what microgrid can become if allowed to flourish in a competitive market.



To that end, ISOs/RTOs should look at microgrids as equal market participants, much as they have independent power and demand response. This would require:

- ▶ Reforming energy, capacity and ancillary markets
- ▶ Allowing microgrids to serve as their own balancing authority when in island mode
- ▶ Providing microgrids with compensation for congestion relief
- ▶ Recognizing the value of a microgrid's black start capabilities.

In addition, government entities need to re-examine exit fees, standby charges, net metering and interconnection rules in light of microgrids. Public utilities commissions must weigh what role, if any, microgrids should play in utility integrated resource planning. And they need to think about whether or not microgrids should qualify for renewable, energy efficiency or alternative energy credits in states with portfolio standards. Or perhaps a new kind of credit should be established for microgrids, possibly one that takes into account a microgrid's ability to reduce greenhouse gases?

Veteran microgrid operators and advocacy organizations stand ready to inform the debate about microgrids as it moves forward. They include the International District Energy Association, Microgrid Resources Coalition, and several college campuses.



## International District Energy Association

The International District Energy Association (IDEA) is a nonprofit trade association founded in 1909 to facilitate the exchange of information among district energy professionals. Today, IDEA has over 1,700 members in 25 nations and is governed by an all-volunteer Board of Directors.

IDEA fosters the success of its members as leaders in providing reliable, economical, efficient and environmentally sound district energy services. The organization promotes energy efficiency and environmental quality through the advancement of district heating, district cooling and CHP, and actively lobbies to secure favorable policies, legislation and regulations for district energy.

*“Microgrids are not something in the future; they are something from the recent past. They have been deployed, proven and they work.”*

Rob Thornton, President and CEO of the International District Energy Association

The association's members operate district energy systems owned by utilities, municipalities, hospitals, military bases and airports throughout North America and around the world. The largest district heating system in the United States, owned by **Consolidated Edison of New York**, is an IDEA member, as are the nation's largest district cooling systems, **Thermal Chicago** which provides chilled water service to over 100 buildings in Chicago's Downtown Loop and **Thermal Energy Corporation (TECO)** which operates a large CHP district energy system serving the largest healthcare campus in the world, the expansive **Texas Medical Center** in Houston, Texas.

College campuses that belong to IDEA operate some of the most sophisticated and robust microgrids in North America. As part of their educational mission, they are available to provide information about their systems, which incorporate combined heat and power and district energy. Below is a list of some of these facilities.

## Notable District Energy/CHP/Microgrids

Princeton University  
University of Texas Austin  
Cornell University  
University of North Carolina at Chapel Hill  
New York University  
University of Missouri Columbia  
University of California San Diego (UCSD)  
Fairfield University  
Texas A&M University  
University of California Los Angeles (UCLA)  
University of Rochester

Credit: IDEA

## Microgrid Resources Coalition

Formed in February 2014, MRC is a consortium of leading microgrid owners, operators, developers, suppliers and investors that promote microgrid as an energy resource. The MRC advocates for widespread implementation of microgrids through advocacy for laws, regulations and tariffs that support their access to market, compensate them for their services, and provide a level playfield for their deployment and operations.

### *The group describes its mission as follows:*

By providing power when the grid is down and energy savings when the grid is operating, microgrids meet their hosts' needs for enhanced reliability, energy savings and reduced emissions. By responding flexibly to the needs of the grid they deliver energy, capacity, and ancillary services that improve the reliability of the bulk power system and the efficiency of energy markets. The MRC advocates for policy and regulatory reforms that recognize and appropriately value these services, while assuring non-discriminatory access to the grid for a wide variety of microgrid configurations and business models.



## Part 6: Vision for Microgrid

Advanced microgrids are the product of better engineering — but they are more than that too. They are the outgrowth of increasingly sophisticated thinking about energy and its role in society.

During the power industry's first century, North America focused on stringing wire to every corner so that all could be served. Now the focus is on using today's technologies to improve the quality of that power and make it cleaner, more efficient, reliable and economic.

Consumers increasingly favor local energy, much as they do locally made products and locally grown food. Underscoring this trend is today's consumer enchantment with solar gardens and community energy efficiency. But microgrids offer local energy at an even more sophisticated and valuable level.

Microgrids encompass much of the best of today's energy innovation: smart, clean, reliable and efficient energy that can be managed via advanced software to leverage energy markets to achieve greatest economies. We built out North America's grid over the last century, next microgrids will strengthen this mammoth machine.

It's hard to forecast what the future grid will look like, given rapid changes in technology. But it seems quite possible that we are moving into an era where microgrids will be the norm not the exception. Electricity is becoming ever more important to our lifestyle and our economy. In the not-too-distant future, we may value location and real estate, not only based on the quality of nearby schools, roads, stores and services, but also on the proximity to premium, reliable energy. Having a microgrid in your neighborhood may soon be a very good thing.

---

## Appendix 1

### Project Profiles

#### *The University of Texas at Austin*

The University of Texas at Austin offers a model for saving energy and money with a large, integrated microgrid that relies little on the central grid.

Built in 1929 as a steam plant, the facility has evolved to provide 100 percent of the power, heat and cooling for a 20-million square-foot campus with 150 buildings.

The university is known for its premiere research facilities, which demand high quality, reliable power. And its microgrid has delivered with 99.9998 percent reliability over the last 40 years.

Often described as the largest and most integrated microgrid in the US, the facility features a combined heat and power plant that provides 135-MW (62-MW peak) and 1.2 million lb/hr of steam generation (300k peak).

The system also includes 45,000 tons of chilled water capacity in four plants (33k peak); a 4 million gallon/36,000 ton-hour thermal energy storage tank; and

six miles of distribution tunnels to distribute hot water and steam. The microgrid engages in real-time load balancing for steam and chilled water. Since 1936, natural gas has fueled the energy plant.

As the campus grew over the years, the plant operators had to find ways to increase its capacity in a cost-effective manner that maintained high reliability. UT Austin added over four million square feet in less than two decades and now has an additional two million square feet in design and construction.

"The objective was: How can we pay for this expansion and not increase costs to the campus," said Juan Ontiveros, Executive Director of Utilities and Energy Management.

Ontiveros achieved this goal by saving fuel. This meant redesigning the load control system and implementing new control strategies, always with an eye toward retaining high reliability not only for electricity, but also steam and cooling.

“We have a lot of contingencies built into our system that most people don’t have, but probably would like to have. We can island, wheel, and we handle all three energies simultaneously, 24 hours a day,” he said.

The plant’s CHP system allows it to recover heat energy that a conventional plant would waste — even a state-of-the-art super critical unit might discard 40 percent of the heat it produces, Ontiveros said. But a CHP system extracts the heat from a steam turbine generator and re-uses it to heat the campus. Leveraging the existing distribution system captures more efficiency in cooling technology.

“We use all the tricks. We can do turbine inlet-air cooling, thermal storage, load shifting, load shedding. It’s all built into our load control system. We produce our all electric cooling at probably 40 percent (of the cost) that the rest of the world does,” he said.

The campus has become so highly efficient that despite its expansion it now uses no more fuel — and emits no more carbon dioxide emissions — than it did in 1976.

“The overall plant efficiency in those days was 42 percent; we’re at 86 percent now,” Ontiveros said.

While some microgrids sell power or services to the grid, UT Austin does not. This is because its energy plant is sized to be net zero, to produce only what it needs.

The university holds a 25-MW standby contract with the local utility for back-up power if equipment fails, at a cost of about \$1 million annually, a small portion of the plant’s \$50 million annual operating budget. Other than that, UT Austin operates with autonomy from the central grid.

“I see ourselves as at high risk anytime we are on the grid because we are more reliable than them,” Ontiveros said.

Energy reliability is extremely important to the university. Eighty percent of the campus space is dedicated to research valued at about \$500 million.

“If a professor loses a transgenic mouse with 20 years of research built into it, that’s a nightmare. That’s what keeps me up at night,” Ontiveros said.

Ontiveros’ worry — about always keeping the lights on — is echoed by energy plant operators throughout the US as our power-dependent economy becomes increasingly research and technology oriented. This is why energy-sensitive institutions and industries are increasingly investigating development of microgrids. And with its impressive record of only three campus-wide outages in 40 years, UT Austin’s microgrid stands as a signature case study for how it’s done.

### *Princeton University*

Princeton University operates a microgrid that is now noted worldwide for its resilience and sophistication.

The facility more than proved its worth when Superstorm Sandy lashed the eastern United States in October 2012. More than eight million electric customers lost their power. But the university was able to continue to power its essential buildings and operations.

During the storm, the university was a beacon of light because of its microgrid — and the strategic vigilance of those who operate it.

Seeing trouble coming as the storm bore down on New Jersey, the energy facility islanded, or disconnected, from the local utility, Public Service Gas & Electric.

“We have four electrical feeders that come into the campus. We lost two and kept losing voltage for a fraction of a second. We knew the utility had problems. So we shed load and became an island,” said Tom Nyquist, executive director for engineering and campus energy at Princeton.

With its connection temporarily cut to the utility, Princeton was protected from the damage that was taking down the larger grid. The campus continued to receive power from its on-site 15-MW combined heat and power plant, part of a microgrid that includes district heating and cooling, chilled water, thermal storage, a 5.4 MW solar photovoltaic farm, and an advanced control system. The facility serves a campus community of 12,000 people across about 150 buildings.

Sandy made this microgrid newsworthy. But perhaps more impressive is how Princeton interacts with the grid on typical days.

The Princeton facility is a hybrid microgrid, meaning it can operate in island mode or connected with the central grid. The university only islands during emergencies. It prefers remaining connected because the relationship offers value to both the university and the grid.

For the university, the benefits are both operational and financial. Princeton can rely on the grid for back-up power should its own equipment fail. The university also can hedge its power purchases based on real-time prices in the PJM Interconnection's wholesale market. When wholesale prices are low, Princeton buys grid power; when power prices are high, it generates more power onsite.

In addition, the facility limits the amount of power it buys during the hours of the year when demand is highest in PJM. "So by reducing our load, we reduce our capacity payment to PJM, and we reduce the stress on the grid. So that's a win-win for both the grid and us," Nyquist said.

This mutually beneficial relationship exists because of the way PJM handles pricing. PJM "carves up the price you pay, recognizes the different aspects of power, and charges for it more or less proportionally to how you use it," said Edward "Ted" Borer, the university's energy plant manager. As a result, PJM is viewed as one of the more favorable markets for microgrids in the U.S.

Princeton also sells into PJM's ancillary markets, offering the independent system operator frequency regulation and synchronous reserve services.

"We don't look at the utilities or the ISO as the opposition. In a lot of ways we are shoulder to shoulder. A lot of our work is synergistic," said Borer.

So what story does Princeton's microgrid ultimately tell? A microgrid can tap into the best of many worlds. It has the flexibility to get out of the way and self-generate when the central grid is in trouble; the onsite resources to ease pressure on the grid when power is in high demand; and the sophistication to engage in real-time power purchase management to leverage best economics.

The bottom line is more reliability and lower energy costs for the microgrid and the central grid. It's a compelling argument for more microgrids.

---

## Appendix 2

### Why Microgrid is Economically Competitive *(Courtesy of Schneider Electric)*

OpenEI, sponsored jointly by the US DOE and the National Renewable Energy Laboratory, has compiled a historical cost-of-generation database covering a wide variety of generation sources. The Levelized Energy Cost is an economic assessment of the cost of the energy-generating system including all the costs over its lifetime: initial investment, operations and maintenance, cost of fuel, and the cost of capital. This method provides a simple comparison that is useful in comparing the costs of generation from different sources.

Microgrids begin to be economically competitive when the overall cost of generating power locally is at or

below grid parity. Recent microgrid designs have multiple energy resources, with generation using a low cost fuel, such as natural gas supplemented by generation using a renewable resource.

A microgrid project will have a positive payback when the average levelized costs of all energy resources, combined in proportion to their consumption, is below the cost of grid power at that location. Microgrids will become increasing popular as the cost of renewables decreases and/or the cost of utility power increases.

### OpenEI Transparent Cost Database

Plant Type	Levelized Cost of Energy (USD/MWh)			Overnight Capital Cost (1000xUSD/kW)			Fixed Operating Cost (USD/kW)			Variable Operating Cost (USD/MWh)			Capacity Factor (%)		
	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min
Hydropower	120	20	20	4.00	1.32	0.50	75	13.14	12.72	5.94	3.20	2.42	93.2	93.2	35
Coal, pulverized, unscrubbed	40	40	40							5.01	4.45	3.94		84.6	
Natural Gas Combined Cycle	70	50	10	1.68	0.88	0.51	45.60	13.71	5.50	8.09	2.86	1.29	93	84.6	40
Coal, pulverized, scrubbed	120	50	10	8.40	1.92	0.56	33.60	27.50	13.08	5.90	3.70	1.62	93	84.6	80
Wind, onshore	120	60	20	2.60	1.57	1.13	60.00	10.95	10.95	23	6.45	5.02	50.4	38	18.4
Geothermal Hydrothermal	140	60	40	5.94	2.82	1.63	229	155.41	68.33	0	0	0	95	85	75
Nuclear	120	60	40	8.20	3.10	2.28	127	85.66	12.80	6.00	.49	.42	90.24	90	85
Biopower	170	70	10	7.66	2.62	0.36	369.28	66.63	12.00	29.12	4.61	.01	85	84.04	75
Natural Gas Combustion Turbine	110	70	60	8.09	5.74	3.20	14.52	10.53	5.26	29.90	3.57	2.67	92	80	10
Coal, integrated gasification combined cycle	180	80	60		3.17	2.22	130.03	38.67	25.00	11.12	7.25	1.15	80.96	80.96	75
Wind, offshore	200	100	70	8.00	3.05	2.16	180	14.28	14.28	40	21.18	13	54	43	27
Blind Geothermal		100			6.85			222.98		0	0	0		95	
Enhanced Geothermal	130	130	60	7.25	7.00	1.78	199.69	199.69	134.05	40	30	5	95	84.6	80
Small Hydropower		140			4.50			130		0	0	0		50	
Distributed Generation	480	140	50	9.80	1.80	1.31	80	16.58	16.03	51	7.37	7.12		75	
Fuel Cell	150	150	140	7.00	4.64	3.80	850	5.65	5.50	47.92	47.92	5.78		95	
Solar CSP	300	200	60	8.09	5.74	3.20	142	55.72	7.80	25.50	.10	.10	65	31.16	21.84
Ocean	210	220	230		6.00	4.50		100		0	0	0		25.5	
Solar PV	590	280	150	9.50	5.10	2.50	110	32.03	6.44	0	0	0	28	21	15.48