The Energy Efficient Microgrid
What Combined Heat & Power and District Energy Bring to the Microgrid Revolution

Courtesy Solar Turbines
Introduction

The Local Energy Revolution

A kind of collective ‘ah ha’ is driving North America toward a more distributed grid, what some call local energy. Businesses, industrial facilities, institutions and cities are realizing the value of taking control over their energy supply.

Local energy promises lower costs, more reliable electric supply, storm resiliency, reduced pollution, greater efficiency, community economic development and jobs, and less forfeiture of open space, habitat and aesthetics to big power plants and transmission lines. Local energy gives communities and businesses the ability to determine their energy future, rather than rely on large, distant corporations, sometimes operated by companies in other states or even countries.

Microgrids are central to this move toward local energy in the United States and Canada. Although they’ve been around for a century, microgrids are particularly attractive in their contemporary form because they bring updated technology and extraordinary intelligence to energy management.

These mini versions of the larger grid also are highly energy efficient, particularly when they employ a form of distributed energy known as combined heat and power (CHP).

This guide, our second in the Think Microgrid series, paints a picture of the emerging microgrid-driven world, with CHP at its core.

What exactly is CHP? If you’re not familiar with it—or only vaguely aware—you’re not alone. Its reputation remains under the radar screen, especially compared with solar and wind energy. Yet CHP is a far more proven form of distributed energy that goes back to Thomas Edison’s day and can be found in cities and at hospitals, colleges, hotels, petrochemical facilities, manufacturing companies and many other sites where large amounts of energy are consumed. For a long time CHP seemed like the best-kept-secret of energy insiders. That’s begun to change as government leaders push for more CHP—from mayors to the highest offices. In fact, President Barack Obama has set a goal for the U.S. to add 40 GW of CHP by 2020.
Also called cogeneration, it is often extolled for its two-for-one advantage. CHP derives twice as much energy from the same amount of fuel as does a conventional power plant. Think of it this way. Spend one dollar on fuel to operate a conventional power plant and you derive a certain amount of electricity. Spend one dollar of fuel to operate a CHP plant and you derive the same amount of electricity, plus heat energy that you can use to heat or cool buildings, manufacture products, or use in some other heat-intensive process.

In addition to CHP, this guide focuses on a closely allied technology, district energy (DE). These systems, too, are big part of the emerging microgrid story. District energy offers tremendous energy and environmental advantage. In brief, a district energy system supplies steam or hot water for space heating and chilled water for air conditioning through an underground piping network, enabling connected customer buildings to avoid installation of boilers, chillers and cooling towers. The thermal grid creates an economy of scale that facilitates deployment of CHP and other highly efficient or renewable technologies.

District energy often incorporates CHP. And when microgrid capabilities are added to CHP/district energy systems, they operate with a new level of sophistication, one that offers cost savings and revenue potential.

Microgrids, CHP and district energy share a common slice of the energy market—one that creates a new value proposition for the energy consumer. Their slice of the energy world is very much about energy efficiency and enhanced reliability—and it’s a slice that’s getting bigger and more important.

What You Will Learn from this Guide

MicrogridKnowledge.com prepared this guide to:

1) Show large energy users the benefits that CHP and district energy microgrids offer
2) Inform policymakers and regulators about how CHP/DE microgrids can help them achieve important energy, economic and environmental goals
3) Offer insight into polices needed to foster these energy systems
4) Heighten awareness within the CHP and district energy industries about the new opportunity created for them by the rapid adoption of microgrids

For those considering installing a microgrid, we offer recommendations on what you need to consider. We profile successful microgrids, CHP and district energy systems. And last, we offer a comprehensive list of CHP incentives and policies, which was provided courtesy of the US Environmental Protection Agency’s CHP Partnership.
Please note: This guide explores grid-connected CHP/DE microgrids. We do not focus on remote microgrids or those that use solar or wind as their primary fuels. However, MicrogridKnowledge.com plans to publish future Think Microgrid guides that cover these systems and the distinct advantages they offer. (See page 19 for a listing of planned guides and how you can participate.)

Who Should Read this Guide

Large energy users likely to benefit from installing an energy efficient microgrid, including:

▶ Colleges/research facilities/institutions
▶ Cities, towns and communities
▶ Hospitals
▶ Businesses
▶ Industry/manufacturing/petrochemical
▶ Data centers/information communication technologies
▶ Military bases/research campuses
▶ Hotels/fitness centers

U.S. and Canadian government leaders

▶ Energy & environmental regulators, policymakers and lawmakers
▶ Sustainability directors and urban planners
▶ Economic development commissions
▶ Emergency response agencies

Those in the microgrid, CHP and district energy industries

▶ Project developers
▶ Component manufacturers & distributors
▶ Smart grid software & controller makers
▶ Utilities
▶ Natural gas companies
▶ Regional transmission organizations and independent system operators
▶ Energy analysts & consultants

If you are new to microgrids, we suggest you begin by reading Microgrids 101: A Non-Geek Definition of Microgrid, which can be found on MicrogridKnowledge.com.

Key Definitions

A microgrid includes one or more buildings that are served by one or more dedicated sources of power and possibly heat, all within the same geographic footprint. A microgrid is a form of distributed energy that acts as a single controllable entity with respect to the grid. It can operate connected to the grid (in parallel) or in stand-alone fashion (islanding mode). Advanced microgrids include sophisticated controllers and software for smart energy management. Microgrids also increasingly include storage and in some cases electric vehicles.

Combined heat & power (CHP), also known as cogeneration, is the simultaneous production of electricity and heat from a single fuel source, such as: natural gas, biomass, biogas, coal, waste heat, or oil, as defined by the US EPA CHP Partnership. CHP is known in industry parlance for having a low ‘heat rate’—which denotes the amount of fuel needed to create electricity.

District energy, as defined by the International District Energy Association, produces steam, hot water and/or chilled water at a central plant or plants. The steam, hot water or chilled water is then piped underground to individual buildings for space heating, domestic hot water heating and air conditioning. As a result, individual buildings served by a district energy system don’t need their own boilers or furnaces, chillers or air conditioners.

Special thanks to the International District Energy Association and Solar Turbines for making this guide possible.
Part I: Market Landscape

Simple microgrids have existed for more than 100 years, going back to Thomas Edison. Until recently, North American energy planners viewed microgrids as largely niche energy projects, most likely to be found on college campuses, islands or remote Alaskan and Canadian outposts. However, North America now views microgrids more broadly, as the answer to very pressing energy needs.

Technological advances, falling fuel costs—and some very bad weather—brought about this change in thinking.

The 2012 Superstorm Sandy will go down in history as the wake-up call that accelerated America's move toward a distributed energy grid: a system that increasingly replaces large central energy facilities with on-site, local energy.

Governments and energy leaders began a serious quest to develop a more storm-resilient electric system after Sandy knocked out power to over eight million homes—in some cases for weeks—leaving large swaths of key cities darkened in New England, New Jersey, New York, Ontario and Quebec.

But in the darkness there were pinpoints of light. These were the microgrids that were able to continue operating. As wires and poles toppled, the microgrids escaped the cascading power failure by taking advantage of one of their key features—the ability to 'island' or separate electrically from the main grid. The buildings within the microgrid instead received power and heat from on-site generators. (See Princeton University's Microgrid: How to Partner, Not Part from the Grid.)

Microgrids not only kept the lights on for the buildings they serve, but also acted as a power oasis. For example, New York University's main campus served as a place of refuge for New Yorkers forced to evacuate from their homes. New York City officials were able to use the campus as a command post. The campus islanded from the main grid and never lost its heating, cooling or electricity thanks to its 10 MW Solar Turbines combined cycle CHP system.

Sikorsky Aircraft, a unit of United Technologies Corporation (UTC) in Connecticut, also stayed up and running because of its 10.7 MW Solar Turbines natural gas-fired CHP system. Sikorsky helped the relief effort by ferrying rescue workers free of charge via helicopter, and also by delivering necessities to a hospital on Staten Island.

Solar Turbines checked in with hospitals, universities, manufacturers and others that use the company's CHP gas turbines to see how they fared. Here's what customers told them.

New York University (NYU) – NYU operates a 10-MW CHP plant in New York City with two 5-MW Taurus 60 gas turbine generator sets. The plant system serves power and steam to a major portion of the campus, including the larger buildings, as well as most of the Washington Square campus in Manhattan. The units operated well during the storm. “Our cogen is up and running,” said John J. Bradley, the university’s assistant vice president for sustainability, energy and technical services.

Danbury Hospital – Danbury Hospital in southwestern Connecticut is a 371 bed comprehensive regional medical center with Solar Turbines’ 4.5 MW Mercury 50 gas turbine and three megawatts of standby generators. During the storm, the facility operated without any loss of power and despite most of the businesses in the surrounding area being without power for several days, Danbury Hospital still had lights and heat, according to Kevin Naurus, plant manager. The CHP facility enabled the hospital to be fully functional during the storm and continued conducting business and providing the critical and necessary health care necessary for patients.

Hunterdon Developmental Center – The Hunterdon Cogeneration facility, located in Clinton, New Jersey, is powered by a 4.5 MW Centaur 50 gas turbine generator set from Solar Turbines. Operated by Noresco, the turbines provide power and heat to both a health services complex with living facilities and a correctional facility. During the storm, power was out in the area for several days, but the CHP plant was able to operate in island mode, continuing to power the complex.

Pepco Midtown Thermal Energy Plant – Pepco’s Atlantic City, New Jersey’s 5.7 MW CHP plant is powered by a Taurus 60 gas turbine generator set and is located only a few blocks from the Atlantic Ocean—directly in the center of Hurricane Sandy. John Howell, Pepco’s maintenance manager, who was at the facility during the storm, said that the plant operated extremely well and was able to continue providing needed power to the local area, including chilling and heating. The Pepco plant provides power to high profile, mission critical facilities, such as Caesars, Bally’s Park Place, Bally’s Wild West, Claridges, Trump Plaza, Trump Taj Mahal, and the Atlantic City Convention Center. Many of these hotels helped house their own employees, local residents, and travelers during and after the storm.

2 Ibid

Copyright © 2014, Energy Efficiency Markets, LLC
Of course, wide-scale power outages are not new to North America. The decade preceding Sandy saw its share of major disruptions, among them the Northeast Blackout of 2003, the Hurricanes Katrina and Rita in 2005 and Hurricane Irene and the Northeast’s freak Halloween snowstorm in 2011.

After each event, the power industry vowed to harden the grid against repeat catastrophes, only to find its attention and resources soon redirected elsewhere. But with the devastation of the Superstorm Sandy, “this cycle of forgetfulness was finally broken,” says the Clean Energy Group in its September 2014 report, “Resilient Power: Evolution of a New Clean Energy Strategy to Meet Severe Weather Threat.”

The CEG report goes on to say:

For the first time, the conversation about resilient power did not die down after the storm passed. The public was angry; utilities, hit hard by the storm and struggling to restore power to their service areas, acknowledged that the electric grid was not built to withstand extreme weather events. Sandy was connected in the public dialogue with climate change and its associated risks to cause increasingly severe weather patterns — people began to talk about being better prepared for future storms.

Right Time for Microgrids

It wasn’t just the severity of Sandy that led to the new emphasis on grid resiliency and microgrids; it was also the timing. A convergence of other events — economic, technological and market — made North America ripe for microgrids and distributed energy.

First, the prices of natural gas — the fuel most often used in CHP microgrids — fell dramatically in 2008. More efficient drilling and growing abundance of supply contributed to the price drop. This created low-cost and ample fuel for CHP microgrids.

The forecast for natural gas continues to be bullish, with the US Information Administration predicting a 56 percent increase in total natural gas production from 2012 to 2040. The American Gas Association says a 100 to 150-year gas supply exists in North America. Such fuel availability bodes well for future development of CHP/DE microgrids.
Second, software and technology developers have bought new, affordable programs, communication networks and controls to microgrids. As a result, today’s microgrids can interact in a smarter, more flexible way with the outside grid. They also can manage with greater sophistication their own resources—load, generation dispatch, fuels, and storage. Scalable and efficient gas turbines are now economically competitive and deployable in multiple settings in size ranges ideal for city districts, campuses and connected communities.

Third, several market changes are under way that encourage microgrid adoption.

Wholesale energy markets increasingly allow participation of distributed energy resources. This gives grid-connected microgrids an opportunity to earn revenue in return for services they provide that strengthen the larger grid. These include demand response, or balancing, frequency and regulation services.

Other factors that may lead to more microgrids include:

▶ A market is developing for distributed energy resources as ‘non-transmission alternatives’ (NTAs). In this case, a microgrid might avert grid congestion and reduce locational marginal prices. Or an NTA may fill a new supply need, and do so in a less expensive, less intrusive way than a large transmission line.

▶ Microgrids, CHP and district energy can help North America reach various emissions reductions goals and requirements. These environmental efforts—along with the low cost of natural gas—are encouraging retirement of coal-fired plants at a surprising rate. North America needs to replace the retiring plants. CHP and district energy offer a cleaner, more efficient alternative.3

▶ And finally, as we’ll discuss in Part IV, some jurisdictions are beginning to create rules to foster distributed energy markets that are akin to existing wholesale power markets. This creates an opportunity for owners of microgrids to monetize their asset in energy trading and realize its full value.

“|There is a lot of new investment that will be required in our electric distribution infrastructure. Most transformers are 30 years old. There needs to be transmission upgrades for renewables. Having distribution generation circumvents those needs. Yet, we’re still in that old mentality of let’s build large central plants and run wires."

Chris Lyons, Manager of Power Generation, Solar Turbines

Growth Ahead for Microgrids, CHP and DE

For all of these reasons, forecasts call for dramatic growth in the microgrid market, particularly in North America. Navigant Research projects that the market will expand from just under $10 billion in 2013 to more than $40 billion in annual revenue by 2020.

The research firm has identified 4,393 MW of microgrid capacity worldwide, with 66 percent of the market potential in North America. North America also is site of the largest amount of microgrid development underway or proposed — about 67 percent of world share. The research firm finds that community/utility microgrids represent the largest kind of microgrid, about 1,111 MW of capacity.

“At this point in time, microgrids can provide a quality and diversity of services that incumbent utilities have been unable to match.”

Peter Asmus, Principal Research Analyst, Navigant Research

“While utilities have shown institutional biases against the entire concept of microgrids for decades,4 extreme weather events and the growing recognition of microgrids as potential sources of demand response resources are building engineering and cultural support for these systems in a variety of settings,” says Peter Asmus, principal research analyst for Navigant Research.

3 A September 15, 2014 report by the Government Accountability Office found that coal plants are retiring at a greater rate than previously expected. Coal has dropped from providing about 50 percent to 37 percent of U.S. electricity in 2012. The GAO expects another 13 percent of coal-fired plants, 42,192 MW, to retire over the next decade. Meanwhile, Ontario reached its goal to shut down all coal-fired generation in April 2014, nine months earlier than its target.

4 This institutional bias may be shifting, as indicated by a recent utility survey. See Industry Insiders _Not_ Surprised that Utilities Like Microgrids.
Meanwhile, CHP systems also appear to be on a growth trajectory. CHP already provides about 8 percent of electricity in the U.S. through 83 GW of CHP capacity at 4,300 facilities, according to ICF International’s “From Threat to Asset—How CHP Can Benefit Utilities.” Significant CHP capacity appears poised to begin operating in 2014 to 2016 time frame, as the figure above shows. ICF International attributes the rise to favorable natural gas pricing and the growing attention and value North America is placing on distributed energy because of storms and grid disruptions, some of the same forces encouraging microgrid development.

In all, ICF pegs CHP potential in the U.S. to be about 130 GW. It is not clear how many of these CHP projects will immediately incorporate microgrid technology, especially since microgrids are often not built all at once, but developed over time. For example, a large energy user might install CHP and later add microgrid capabilities, and still later add solar generation and storage, or undertake some other gradual configuring of the microgrid.

What is clear is that many of the same industries that benefit from CHP also would benefit from microgrids, creating a natural path for one technology to foster adoption of the other. A company looking at CHP might consider the added capability of a microgrid; and conversely a company looking into microgrids is likely to study CHP as possible generation and heat source for the system. The ‘buzz’ surrounding one spurs the other. The graphic below gives a sense of the kind of facilities that have incorporated CHP in recent years.

The International District Energy Association (IDEA) has identified 601 district energy systems in the US; 289 of those systems are currently district heating-only (DH only) systems with 16.6 GW of installed heating capacity. They currently do not have CHP and represent a good market opportunity for installation of CHP. CHP installed as part of DHC systems has grown in recent years—there is currently 6.6 GW of CHP generating capacity at DHC systems, spread across 55 downtown systems and 153 university campus district energy systems. This growth is expected to continue as cities, universities, and other DHC installations realize the economic and environmental benefits of CHP.

State governments also have an important role in new CHP—35 states, including the District of Columbia, have some type of state-level incentives and/or regulations encouraging the deployment of CHP and DHC. On the other hand, aside from eligibility for tax exempt financing and federal loan guarantees, there are few federal, state or local policy incentives intended solely for deployment of district heating and cooling systems in the U.S.

5 1 Btu/h = 3.412 W
6 Database of State Incentives for Renewables and Efficiency. Maintained by North Carolina State University. November 2013
How it All Works

CHP is a proven technology that has been widely used for decades at hospitals, colleges, petrochemical facilities, manufacturing, hotels and other facilities that use power and a large amount of heat. As we mentioned earlier, most CHP is fueled by natural gas; however, CHP also can use renewable energy in the form of biomass. These plants are typically developed in areas where there is ample feedstock, such as wood waste, and where renewable portfolio standards exist to drive the biomass market.

In recent years, CHP has received heightened attention because it solves several contemporary energy problems; CHP has even captured the attention of President Barack Obama, who has set a goal for the nation to add 40 GW of CHP by 2020.

**Here we will focus on three main benefits of CHP:**

1) Efficiency
2) Cost savings
3) Emissions reduction

CHP significantly bests conventional power plants when it comes to efficiency. This is because it does not waste the heat that is created during the production of electricity. Conventional power plants let the heat dissipate into the air and water. But CHP harnesses the heat to reuse in buildings or industrial processes—to heat, cool, steam or humidify.

As a result, CHP systems reduce fuel requirements and achieve efficiencies of 60 to 80 percent, according to the EPA. By comparison the efficiency level of a conventional coal-fired plant averages only about 33 percent. Coal-fired power plants still make up over 40 percent of the electric generation in the US.

CHP systems also achieve efficiencies because of their close proximity to those they serve. Usually, CHP systems are located near the buildings they serve or even inside the building in certain applications. This means the electricity and thermal energy need not travel far to reach the user. By placing the power generation plant close to the user, CHP averts much what’s known as line loss, the natural tendency for electricity to dissipate as it travels over power lines.

Not surprisingly, district energy also is seeing strong growth, as demand for air conditioning grows, especially in cities, and building owners seek a clean, efficient, reliable and cost-effective way to meet this demand. In a survey of its members, IDEA found that 114 buildings began using district energy last year in North America. This represents 30,666,772 square feet that contribute to a total 615,428,328 square feet committed to North American district energy systems since 1990.

District energy systems exist at many college campuses and cities. But the largest customer additions last year occurred in cities in commercial-office buildings, followed by hotels, schools/hospitals/institutions, and government. District energy growth is likely to foster microgrid and CHP markets, since both can add capabilities and efficiencies to a system.

---

```
"CHP is far more efficient than today’s best combined-cycle plant and eliminates T&D losses that average six percent of the electricity transmitted and even more during peak use times."

Lyons, Solar Turbines
```
This efficiency offers many benefits to the energy user. Burning less fuel, and losing less electricity, means lower overall energy costs. In addition, CHP users need to buy less utility electricity, since they generate power onsite and no longer use electricity to heat and cool. As a result, they typically see their utility bills decline, particularly if the utility calculates demand charges based on the building’s peak electricity over a designated timeframe.

In a comparison of CHP systems against a variety of conventional generators, CHP systems almost always display the lowest levelized energy costs, according to “How Electric Utilities Can Find Value in CHP,” a July 2013 white paper by Anna Chittum of the American Council for an Energy Efficient Economy. The comparison looked at conventional gas, coal, nuclear and biomass plants.

There is another way, too, that CHP can save money for facility owners. Once CHP is installed, owners may be able to forego replacing boilers and chillers—or do so less often. Also, less maintenance and repair is required for this equipment, since it is used less.

CHP will gain an even greater economic edge if electricity prices rise as expected in the coming years. The US Energy Information Administration projects that retail electricity rates could rise from an average 9.8 cents/kWh to as much as 12.5 cents/kWh by 2040. The price pressure will come as older power plants retire and the nation replaces them with new infrastructure. EIA laid out four possible future scenarios in its most recent long-term forecast. Under all, prices rise. (See left.)

CHP not only saves money, but also reduces air pollution because it recovers and uses heat that would otherwise be wasted. The recovered heat displaces combustion of fossil fuels. For large corporations and institutions, this is an increasingly important benefit. They want to be good corporate citizens; most are striving to meet sustainability goals that they have set. CHP can help them do so, since it results in lower carbon dioxide, nitrogen oxides and sulfur dioxide emissions in the regional economy. Compared with the average mix of electric generation in the US, CHP offers significant reductions in greenhouse gas emissions, as noted in the chart below from the EPA CHP Partnership.

Society as a whole benefits as well; lowering these emission minimizes respiratory illnesses associated with poor air quality and reduces the impact of our energy use on climate change. For this reason, North American governments have several emissions reductions policies in effect or under development that favor adding more CHP to the energy mix.
Combined heat and power (CHP) is an efficient and clean approach to generating electric power and useful thermal energy from a single fuel source. CHP is used either to replace or supplement conventional separate heat and power (SHP). Instead of purchasing electricity from the local utility and burning fuel in an on-site furnace or boiler to produce thermal energy, an industrial or commercial facility can use CHP to provide both energy services in one energy-efficient step.

Every CHP application involves the recovery of otherwise-wasted thermal energy to produce useful thermal energy or electricity. CHP can be configured either as a topping or bottoming cycle. In a typical topping cycle system, fuel is combusted in a prime mover such as a gas turbine or reciprocating engine to generate electricity. Energy normally lost in the prime mover’s hot exhaust and cooling systems is instead recovered to provide heat for industrial processes (such as petroleum refining or food processing), hot water (e.g., for laundry or dishwashing), or for space heating, cooling, and dehumidification. In a bottoming cycle system, also referred to as “waste heat recovery,” fuel is combusted to provide thermal input to a furnace or other industrial process and heat rejected from the process is then used for electricity production.

District Energy often employs CHP and offers many of the same benefits. Also highly proven, district energy has been used for over a century in most major cities across North America and is widely deployed across northern Europe and Asia. Most major cities have district energy including New York, Paris, Moscow, London, Beijing, Chicago, Copenhagen, Hong Kong, Stockholm, and hundreds of others. It has been used in the U.S. since the mid-1800s when a system was installed by the U.S. Naval Academy in Annapolis. Today, most major college and university campuses use district energy for the efficiency, reliability and environmental advantages.

There are now more than 700 district energy systems located in all 50 US states. Consolidated Edison operates the nation’s largest district energy system, with 105 miles of mains and service pipes and 3,000 steam manholes. The system serves many of New York City’s most important buildings—the United Nations complex, the Empire State Building, and the Metropolitan Museum of Art—along with about 1,800 other Manhattan customers. On average, over 50 percent of the steam supplied annually by Con Edison to its customers is heat recovered from CHP generation in Manhattan. Likewise, the downtown Philadelphia steam system owned by Veolia Energy NA supplies heat from a large CHP facility and is critical to the urban sustainability goals set by Philadelphia Mayor Nutter.

However, IDEA has identified nearly 300 existing district energy systems in the US that do not currently have CHP installed, representing a near term market potential of between 5000 and 11,000 MW of CHP electricity generation, depending on market factors. Since the district energy networks have already done the difficult work of aggregating the customer thermal loads, CHP can be optimized for very high efficiency.

In Canada, Vancouver has made district energy a part of its goal to become the world’s greenest city. Nine district energy systems are now operating in the city with two more planned. Vancouver calls these “neighborhood energy systems,” and expects them to reduce CO2 annually by 120,000 tons per by 2020.
A district energy system brings value to the buildings it serves that they cannot achieve on their own. There are several reasons why.

When it uses CHP, DE can significantly improve efficiency by reusing heat from power generation to produce its hot water and steam. The district energy system must meet regulations not required of individual boilers and chillers installed in buildings, so is likely to be more environmentally friendly. And because of its size and scale, the central plant can deploy industrial grade equipment that is inherently more reliable and efficient than commercial grade systems in buildings.

Building owners also reap several benefits from being part of a district energy system, among them increased climate comfort, absence of noise and vibration from onsite boilers and chillers, and freedom from the expense and hassle of replacement, repair, operation and maintenance of heating and cooling equipment—all of that is done centrally by professionals. District cooling systems, which provide chilled water for air conditioning, can utilize thermal storage or heat-driven chillers to reduce demand on the electricity grid. District cooling customers avoid operating on site chillers and cooling towers which can cut peak power usage by 50 percent or more, dramatically flattening demand on the grid.

The graph below is the electricity demand profile of a commercial office building in Cleveland, OH before and after connecting to a downtown district cooling system.
The Benefits of Bringing Together CHP & DE with Microgrids

CHP/DE microgrids take the advantages of these proven technologies — reliability, resiliency, back-up power, clean energy — and add a new element: intelligence. This intelligence comes in the form of software, sensors and controllers that allows the parts of the microgrid — power generation, heat, storage and energy consumer — to interact in a highly economic and efficient way. For example, a microgrid might switch back and forth between natural gas generators, solar and storage, depending on which is available and lowest cost at any given time. Newer microgrids also are incorporating electric vehicles, which when not in use, can act as battery storage.

But there are three key activities that the CHP/DE microgrid undertakes that make it a unique class grid resource.

1. It operates in parallel — not separate — from the electric grid
2. It adds heat to the value proposition
3. Both the electric generation and thermal output have load flexibility capability, making these plants more dispatchable and flexible when integrating renewable generation and other variable resources.

The Grid and the Microgrid

We tend to think that electric production and distribution is a fairly straightforward process. A power plant generates electricity and sends it over wires to buildings and homes. In fact, keeping the lights on is an intricate act of constant monitoring and correction. In North America, much of this work is done by 10 grid operators, also known as regional transmission organizations.

The grid operators oversee wholesale energy markets that serve about two thirds of North America.

In addition to dispatch of power, the grid operators undertake several other activities to keep the lights on. These include maintaining grid frequency and voltage, and balancing between supply and demand. Given the dynamism of our electric system — lights on and off, air conditioning up and down, computers and other electronic devices plugging in and out — grid management must be minute-by-minute to ensure electricity is constantly available.

In addition, the grid operator must look years ahead to make sure utilities, power plant developers, energy efficiency companies, and others plan to build or add enough capacity to keep up with future demand.

To make all of this work, the grid operator buys services from various entities, among them grid-connected microgrids.

Perhaps the most well-known of these services is demand response — where the grid operator or utility pays energy users to use less energy when the grid is under strain. Another is the capacity market, which pays for the guarantee that power will be available when needed. Others are ancillary services and may include regulation, synchronized reserve, black start capabilities, voltage support and similar assistance.

Microgrids provide some of these services and are able to earn revenue from the grid operator for doing so. In this way, a grid-connected microgrid strengthens the grid, and the grid in turn contributes to the microgrid’s financial wherewithal.

The microgrid may also act as a customer of the grid, buying power from the grid when its own generators are down for repair or when grid prices are more favorable than self-supply.

So by operating in parallel with the grid, CHP/DE microgrids offer a best-of-both worlds. Microgrids are good for the buildings and businesses they serve — and for everybody else as well.

The Importance of Heat

It can be difficult for microgrids to compete on cost alone if they provide only electricity. However, when heat is added to the equation microgrids become more competitive based on economics alone. Most power generation technologies involve production of heat. CHP recaptures this heat for productive uses.

As discussed earlier, CHP reuses waste heat to:

1. Provide heating and domestic hot water services and eliminate the need for boilers and associated equipment within a building
2. Produce chilled water for air conditioning and eliminate the need for customers to install, maintain and repair chillers, cooling towers and associated equipment
3. Reduce fuel costs and consumption, since the same fuel that produces the electricity produces the heat

Energy costs, however, are only one issue to consider. Some microgrids are built to avert financial loss to businesses by keeping the power flowing during an outage. Others keep health and safety services up and running. And still others provide high quality power to protect temperature-sensitive research or keep cell phone and data centers up and running.
A CHP district energy microgrid can optimize the production of electricity, power and cooling as needed to meet the heating, cooling and power loads of the connected buildings. With advanced controls and forecasting technologies, the system can operate more efficiently as loads vary seasonally and daily. Very cold and very hot days put strain on the grid as consumers increase use of air conditioners or electric heating systems. Electricity prices skyrocket. Further, grid operators often must turn on their last-choice, highest polluting generators when demand runs high. CHP/DE microgrids can help mitigate the strain by shifting their heating and cooling loads off the grid and instead using their on-site resources. This reduces cost and reduces emissions.

“By harvesting and using the heat produced when making electricity, you are establishing a much more bankable, financeable and economically attractive asset.”

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

Sometimes during severely cold periods, fuel supplies deplete. The US Northeast has run short on natural gas because of pipeline constraints during recent winters. At times the electric system has teetered close to outages because of the shortages. With demand great and supply low in winter 2013/14, fuel prices spiked, which translated into hikes as high as 38 percent in consumer generation costs in 2014. (Hartford Courant, December 17, 2013).

Other areas in North America have experienced shortages in coal during recent winters because trains lacked room to take deliveries, as oil and other commodities competed for space. Propane for home heating also was in short supply in winter 2013/14 for a variety of reasons, including competition for the fuels used for other purposes.

CHP district energy systems often operate on multiple fuels and can switch primary fuel supply depending on cost and availability. These fuel shortages underscore why it is important to have more CHP/DE microgrids, with their highly efficient use of fuel, integrated into the North American grid.

“When you locate the generating source closer to the load, you can reduce congestion, enhance reliability and lower the total cost of delivering that electricity. When the asset also provides integrated heating and cooling services, you can change the demand and load shape on the grid. As a result, you have a more resilient, reliable grid because you have reduced strain and taken some of the load off the wires.”

Thornton, IDEA
Part III: The Policy Landscape

Present

The Obama administration created one of the most significant milestones in the US CHP industry’s history when it announced a presidential goal to increase the resource 50 percent by 2020. The Department of Energy’s CHP Technical Assistance Partnerships (CHP TAPs) is focused on achieving the 40 GW goal, which is expected to:

▶ Cut energy bills by $10 billion a year compared to current energy use
▶ Save the equivalent of 1 percent of all energy use in the U.S.
▶ Reduce CO2 emissions by 150 million tons annually, the equivalent of taking more than 25 million cars off the road
▶ Infuse $40-$80 billion in new capital investment in manufacturing

Emissions regulations also are likely to encourage more CHP in North America. ICF International estimates that 3.5 GW of CHP could be added to meet certain emissions targets. A study by the ACEEE found that potential for CHP to save 68 million MWh of energy by 2030. This 18 GW of avoided capacity could significantly reduce CO2 emissions by averting the need for about 36 power plants, ACEEE said.

Some environmental policies that could heighten demand for CHP/DE microgrids include:

▶ The Clean Power Plan: Issued in June 2014 by the Environmental Protection Agency, it represents the nation’s first carbon dioxide restriction for existing power plants. States will determine their specific paths to reach the goal of a 30 percent reduction in CO2 emissions by 2030. But the EPA offered four building blocks to reach the goal, including increasing end use energy efficiency; improving EGU heat rate; shifting from coal to natural gas; and expanding zero or low emitting generation. CHP district energy can fit bill in all four categories.

▶ Regional cap and trade programs. The U.S. now has two state mandatory cap and trade programs that set limits on carbon dioxide emissions: the California Cap and Trade Program, the Regional Greenhouse Gas Initiative (RGGI) which encompasses nine states in the Mid-Atlantic and Northeast. RGGI, the older of the two programs, channels auction proceeds into energy efficiency projects, including CHP, such as the expansion of the CHP plant at the University of Massachusetts Medical School in Worcester, Massachusetts.

Learn about the energy efficiency and reliability achieved by the University of Massachusetts Medical Center in this case study.

Although RGGI in current form does not properly account for avoided allowances for the emissions reduction from heat recovery.

▶ Other jurisdictions have set voluntary targets for greenhouse gas reduction or reporting requirements. Ontario, for example, requires that facilities that emit more than 25,000 tons per year from certain sources report their emissions to the provincial government. The government says that the emissions reporting helps it in planning clean energy programs to reduce greenhouse gasses. Ontario is launching a special program for CHP district energy in 4Q 2014.

▶ Other emissions regulations also may stimulate development of CHP/DE microgrids, such as EPA’s Boiler Maximum Achievable Control Technology regulations. ICF International says that the rule could increase CHP by 1.26 GW, as industrial and commercial facilities replace their older oil and coal-fired boilers.

Additional policies promote CHP, such as state renewable or alternative portfolio standards that set energy efficiency goals or in some cases even CHP goals. The 2008 Green Communities Act in Massachusetts established an Alternative Energy Portfolio Standard to specifically support CHP. (See Appendix 3 for a complete list of CHP Policies and Incentives from the US EPA CHP Partnership.) The Ontario Power Authority is planning to support a series of CHP and district energy projects through its request for proposals process. Connecticut has conducted two solicitations for community-based microgrids, the California Energy is offering $26.5 million in microgrid grants; and New Jersey established a $200 million funding for an Energy Resilience Bank to support deployment of assets like microgrids.
Several states on the West Coast, Northeast and Mid-Atlantic are in various stages of creating policies to modernize their grids. These policies are likely to have a profound influence on the expansion of microgrids, since their intent is to create a more distributed grid. These include:

- **California:** Microgrids: A Regulatory Perspective
- **Connecticut Microgrid Pilot Program** (Public Act 12-148)
- **Maryland Resiliency Through Microgrids**
- **Massachusetts Grid Modernization** (Docket 12-76)
- **Massachusetts Electric Vehicles and Electric Vehicle Charging** (Docket 13-182)
- **Massachusetts Time-Varying Rates** (Docket 14-04)
- **New Hampshire’s 10-year energy strategy** (SB191)
- **New Jersey Transit Microgrid**
- **New Jersey Energy Resilience Bank**
- **New York Reforming the Energy Vision** (REV) 14-M-0101

### What is Needed

Recognition of the benefits and advantages of microgrids is growing among governors, mayors, CEO’s, university presidents, but there are still many obstructions and issues to be resolved to provide microgrids reasonable access to the electricity market. Now that public officials want to deploy microgrids in their communities, regulators must lead the review and adaptation of rule-making to more fully consider their full range of services. Traditional utility rate making generally incents IOU’s to add to rate base, when a better option for the local economy, for all the reasons stated earlier, might be shifting to a microgrid. Regulations should not constrain competition, discourage innovation and efficiency and prevent microgrids from full participation in regional power markets. Microgrids are a unique class of assets, much more robust than demand response, alone, since they can provide balancing capacity, voltage support and a host of other benefits to the grid.

“In many restructured states, investor-owned utilities are not allowed to own generating assets and therefore perceive microgrids as a threat and source of revenue displacement. At the same time, utilities are recognizing the paradigm shift from central generation to distributed assets and are seeking a regulatory path to potentially own and operate microgrids. It will be critical that the pendulum not swing entirely to a utility ownership model that crowds out private or public investment in microgrids.”

Thornton, IDEA
Microgrid advocates point to four areas where they hope to see more policy attention:

- Ensure that microgrids have equitable access to central grid resources and the full spectrum of revenue streams reflecting the full range of services provided
- Develop a new grid paradigm with emphasis on distributed energy
- Allow reasonable costs for grid access while also enabling compensation for services such as congestion relief, voltage support and balancing capacity, especially for intermittent renewables
- Establish durable and predictable polices to reduce investment risk and attract capital

“It is a challenge for public utility commissions to understand how to handle this new animal. Microgrids are a unique class of grid resource, more robust than demand response and more valuable to the grid overall. Frankly, we need to have them better understood so that they are adequately compensated for the full range of benefits they produce.”

Thornton, IDEA

Many of the regulatory barriers faced by microgrids are not new, but have dogged CHP development for years. They include high standby rates, difficult interconnection standards and unfavorable net metering rules. Utilities also sometimes put up roadblocks to CHP because it erodes their electricity sales, especially when large customers choose to leave utility service for onsite generation.

ACEEE ranks states annually based on their energy efficiency policies, including those that apply to CHP. In 2014, the organization evaluated states for CHP primarily based on interconnection rules, portfolio standards,\(^8\) net metering, incentives, out-put based emissions considerations\(^9\) and financing.

Connecticut and Massachusetts tied as the top states in 2014, followed by California, Oregon, Maine, Maryland, Rhode Island, Vermont, North Carolina and Washington.

The bottom CHP states/territories were Mississippi, Missouri, Montana, Nebraska, Puerto Rico, South Carolina, Tennessee, US Virgin Islands, Virginia, Wyoming.

Poor CHP policy creates several obstructions to CHP/DE microgrid development. For one, they can block incentive to size microgrids so that they not only serve their own load, but also can provide grid services. For example, a CHP/DE microgrid might be sized so that it has excess spinning reserve capacity that can be used for grid stability. This is especially important as more renewable energy is added to the grid. When wind suddenly stops blowing or a cloud covers the sun, renewable energy output suddenly drops. CHP/DE microgrids can offer spinning reserve to make up for the loss.

The Microgrid Resources Coalition is advocating to correct several barriers to widespread implementation of microgrids, among them:

- Conflicting regulation at the federal, state and local level
- Lack of federal rules for entities that offer both load curtailment, as microgrids do
- Lack of federal incentives to build microgrids to relieve grid congestion — such incentives do exist to build transmission
- Utility franchise rules that restrict microgrids from stringing wire across public rights-of-way

---

\(^8\) Many states have set targets for adding more energy efficiency, renewables or alternative energy. Some include CHP in the targets, while others do not.

\(^9\) Emissions regulations fail to consider the full value of CHP if they account only for emissions from the fuel used by the system, and not what the fuel produces (output). In other words, emissions regulations need to value the fact that CHP derives more energy from less fuel.
Part IV: Is a CHP/DE Microgrid Right for You?

It’s clear that microgrids can help the grid and many kinds of facilities, but what about your operation in particular?

First and foremost, developing and operating a CHP/DE microgrid requires a sophisticated understanding of power generation, heat and grid operations. This is not a core competency for many businesses. Unless you have onsite energy expertise, it may be best to seek a third-party provider to install and operate the facility.

Another prime consideration is the cost of electricity in your state. (See Appendix 2 for state-by-state retail electricity prices) CHP/DE microgrids generally earn a better return on investment in states with high electricity rates.

However, another key consideration is the prevailing cost of natural gas for CHP that uses the fuel. In particular, it’s important to consider what’s known as the ‘spark spread’ — the difference between the delivered electricity price and the total cost to generate power with CHP. Natural gas prices heavily influence spark spread. Today’s low natural gas prices have helped foster more CHP development.

As coal plants retire in greater numbers, utility electricity prices are expected to rise. This could create an even greater divergence between natural gas and electricity prices, meaning a more favorable spark spread for CHP. This price indicator is one reason more and more large energy users are expected to adopt CHP in the coming years. The EPA offers a calculator to help determine spark spread here.

The EPA says a facility may be a good candidate for CHP if it meets at least three of these criteria.

- Do you pay more than $.07/ kilowatt-hours on average for electricity (including generation, transmission, and distribution)?
- Are you concerned about the impact of current or future energy costs on your business?
- Is your facility located in a deregulated electricity market?
- Are you concerned about power reliability? Is there a substantial financial impact to your business if the power goes out for 1 hour? For 5 minutes?
- Does your facility operate for more than 5,000 hours/year?
- Do you have thermal loads throughout the year (including steam, hot water, chilled water, hot air, etc.)?
- Does your facility have an existing central plant?
- Do you expect to replace, upgrade, or retrofit central plant equipment within the next 3-5 years?
- Do you anticipate a facility expansion or new construction project within the next 3-5 years?
- Have you already implemented energy efficiency measures and still have high energy costs?
- Are you interested in reducing your facility’s impact on the environment?

We also encourage you to read the CHP case studies associated with this study, which can be found here.

Because of its CHP system, Montefiore Medical Center was able to accept patients from a hospital that lost power during Superstorm Sandy. See case study here.

Copyright © 2014, Energy Efficiency Markets, LLC
Part V: Conclusion

If Another Superstorm Sandy Hit Today?

CHP/DE Microgrids are clearly coming to North America. They will benefit those who install and use them, and they will benefit the larger North American electric grid. Government agencies have begun considering policies and regulations to foster microgrids, albeit somewhat slowly in light of their interest in creating grid resiliency and reliability. It has been two years since Superstorm Sandy. Should another mega storm hit a heavily populated city any time soon, there will not be enough microgrids to ward off massive power outages. We cannot control the weather, so speed is essential in bringing more microgrids to North America. And weather aside, as long as microgrids are delayed, the grid is missing out on important economic and efficiency advantages.

Special thanks to the International District Energy Association and Solar Turbines for making this guide possible.

Appendix

I. CHP & Microgrid Real World Examples:
   - Cornell University
   - Montefiore Medical Center
   - University of Massachusetts Medical Center

II. Electricity Prices by State

III. CHP Incentives by State from EPA

IV. Microgrid Knowledge Special Report Series:
   - Think Microgrids – Policy Guide
   - Microgrid Controllers
   - Microgrid & Energy Storage
   - Microgrids for Advanced Economy Industries
   - Military and Remote Microgrids
   - Community Microgrids
   - Oil and Gas Microgrids
   - Microgrids & Solar Energy

About the International District Energy Association

Established in 1909, the International District Energy Association (IDEA) serves as a vital communications and information hub for the district energy industry, connecting industry professionals and advancing the technology around the world. With headquarters just outside of Boston, Mass., IDEA comprises over 1,800 district heating and cooling system executives, managers, engineers, consultants and equipment suppliers from 25 countries. IDEA supports the growth and utilization of district energy as a means to conserve fuel, increase energy efficiency and reduce emissions to improve the global environment.

About Solar Turbines

Headquartered in San Diego, California, USA, Solar Turbines Incorporated, a subsidiary of Caterpillar Inc., is one of the world’s leading manufacturers of industrial gas turbines, with more than 14,500 units and over 2 billion operating hours in 100 countries.

Products from Solar Turbines play an important role in the development of oil, natural gas and power generation projects around the world. Solar Turbines’ products include gas turbine engines (rated from 1590 to 30,000 horsepower), gas compressors, and gas turbine-powered compressor sets, mechanical-drive packages and generator sets (ranging from 1.1 to 22 megawatts).

Solar’s customers put the company’s products to work in many areas including production, processing and pipeline transmission of natural gas and crude oil and generation of electricity and thermal energy for processing applications, such as manufacturing chemicals, pharmaceuticals, and food products.

Solar’s foundation is people and Solar’s culture is one where individual contributions are valued, diversity in the workplace is encouraged, and safety is emphasized in all aspects of the business. Solar Turbines is comprised of a dedicated and multi-talented workforce of more than 7,000 employees with decades of experience working as a global team.

See real world examples of Solar Turbine’s successes in this video library.