White Paper

CHP for Microgrids: Resiliency Opportunities Through Locational Analysis

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Shareables

- Great enthusiasm surrounds microgrids because of their energy resiliency benefits. Some states are beginning to incentivize their development and deployment.
- Natural gas combined heat and power (CHP) systems are an ideal microgrid anchor. Current CHP installations are expected to create the foundations of future microgrids.
- Community microgrids should be planned around existing CHP systems through a locational analysis, with potential configurations evaluated for economics and local resiliency benefits.

Abstract

In the wake of recent superstorms, governments, utilities, and end users are pushing for microgrid investments to increase power reliability, resiliency, and energy security. Although microgrids have been most commonly deployed in institutional campus settings such as universities and military bases, interest is surging for resilient community microgrid networks that connect critical loads like hospitals, fire and police stations, emergency shelters, and gas stations. Connecticut, New York, and other states are implementing incentive programs to encourage the development and deployment of community microgrids.

All microgrids require an anchor—a reliable, stable source of power. Natural gas CHP systems are well-suited for this role. Evaluating potential locations for community microgrids should start with a detailed analysis of current CHP installations. From these foundations, other energy resources, critical facility loads, and utility interconnection points can be modeled to evaluate potential microgrid locations and configurations. The ideal microgrid project would optimize design based not only on economic considerations but also on local resources, load characteristics, and resiliency benefits.

Benefits of Microgrids

Microgrids can be thought of as interconnected networks of distributed energy resources (DERs) with the ability to operate in isolation as a single controllable entity, independent from the larger electric utility grid. End users that are integrated with a microgrid receive reliable and efficient power year-round, even during extended utility outages. Utilities also benefit from microgrids through deferred transmission and distribution investments, demand response capabilities, ancillary service support, and minimized outage impacts. As a result of recent superstorms, changing climate conditions, energy security concerns, and aging utility grid infrastructures, many governments, end users and utilities are pushing for microgrids. Some states now offer incentives for microgrid development.

Existing combined heat and power (CHP) systems currently in service can become the foundations of future microgrids. Additional DERs, including renewable energy resources and storage devices, can be integrated with these CHP installations to provide resilient power for nearby facilities with critical loads. Although this type of microgrid configuration could be mutually beneficial for all involved parties, regulatory and market barriers that can make it difficult for separate business owners to work together on these projects.To date, microgrids have been most commonly deployed in institutional campus settings where disparate ownership is not an issue.

In 2012, CHP installations and campus microgrids at hospitals and universities in New York and New Jersey were able to continue generating electricity through the aftermath of Hurricane Sandy, providing relief for nearby communities. After Sandy, for many facilities with traditional backup power, diesel generators failed to produce electricity because of improper maintenance, inoperable fuel pumps, or limited fuel supply. In contrast, buildings and campuses with gas-fired CHP systems and microgrids were able to continue operation during the entire multiday blackout.[1] Following the 2012 superstorm, interest has increased in CHP, energy resiliency, and community microgrids that can serve multiple critical loads. Projected changes in future conditions, including sea level rise and intensification of coastal storms, could make energy resiliency even more urgent.

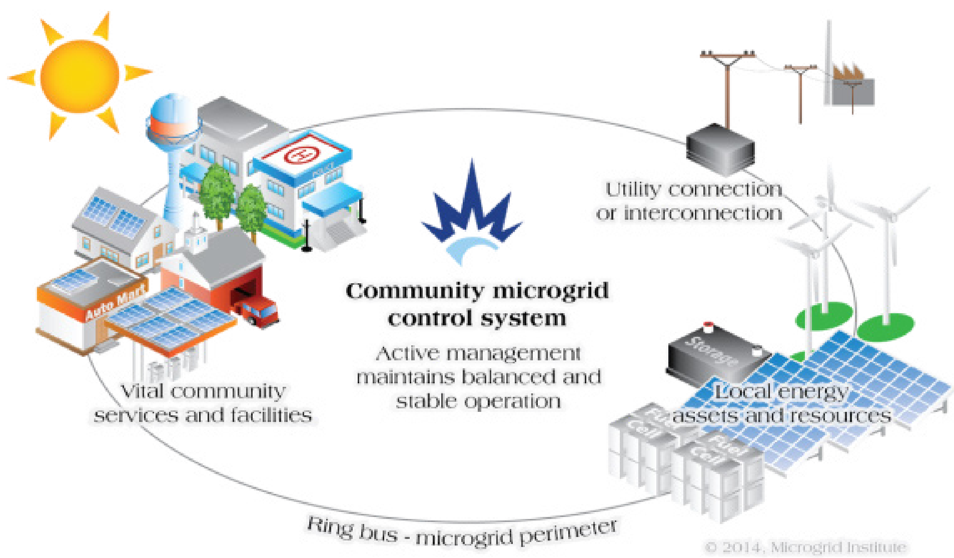
[1] Combined Heat and Power: Enabling Resilient Energy Infrastructure for Critical Facilities, ICF International, prepared for Oak Ridge National Laboratory, March 2013, available at http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_critical_facilities.pdf.

Community Microgrids

With community microgrids, critical facilities—including police departments, emergency responders, hospitals, supermarkets, and gas stations—can be tied together with local, resilient distributed energy resources. District energy (DE) networks that supply steam, hot water, and chilled water to multiple facilities could be ideal locations for community microgrids. Several of these systems already incorporate CHP. However, many owners of DE networks would be hesitant to install more generation capacity and sell electricity to multiple customers, because they do not want to become regulated like a utility. This issue is common in community microgrid development: Who would own the different sources of electricity. How would it be sold, distributed, and interconnected with the utility grid?

Community microgrids like the one shown in Exhibit 1 require cooperation and planning among business owners, project developers, utilities, and regulators. While this level of cooperation can be difficult to achieve, state governments are finding ways to incentivize microgrid development and deployment.

EXHIBIT 1. COMMUNITY MICROGRID DIAGRAM



Source: Microgrid Institute

In New York, the NY Prize microgrid competition from the New York State Energy Research and Development Authority (NYSERDA), will award a total of $40 million in funding for microgrid development and deployment. More than 130 communities applied for NYSERDA funding. In July 2015, 83 of the proposed community microgrids were awarded $100,000 each to conduct feasibility studies. "I feel like we poked a sleeping giant," said Micah Kotch, director of NY Prize and strategic adviser for innovation at NYSERDA. "In the 21st century, energy is a community issue. This is really big signal that communities want to have a say in their energy future."[2]

The next stage of NY Prize is to thoroughly evaluate the requirements of the 83 proposed projects and to select the most promising for engineering studies and business plans (up to $1 million per project will be awarded in this second stage). Finally, five to seven winners will receive up to a total of $25 million to build community microgrids that will increase resiliency for New York's most critical facilities.[3]

Connecticut's microgrid program through its Department of Energy and Environmental Protection (DEEP) is further along, having provided $23 million in funding to 11 pilot microgrid projects in 2013 and 2014, with an additional $30 million in new grants available as of November 2015. To be eligible for DEEP funding, planned microgrids must serve critical facilities like hospitals, police departments, and wastewater treatment facilities; and they must act as a single controllable entity with islanding (grid isolation) abilities.[4] Several community microgrids are starting to come online in Connecticut as a result of this funding.

In addition to New York and Connecticut, incentives for microgrid development are emerging in California, Maryland, Massachusetts, and New Jersey. If these programs are successful, more states are expected to follow suit.

Building Microgrid Foundations with CHP

A microgrid involves multiple hardware assets and sophisticated controls. In most cases, microgrids are designed to integrate existing assets and then augment these assets as needed to create a fully functional network. As an example, a microgrid could start with a natural gas CHP system providing baseload electricity for a single facility. In a community microgrid scenario, another nearby facility may have its own gas-fired generator, while another has backup diesel generators, and another is planning to install solar panels with energy storage. But all of the facilities are disconnected from each other, and some may not be able to withstand prolonged grid outages. Bringing these facilities and resources together and jumping over the regulatory hurdles can be the most difficult aspect of microgrid planning. Although regulatory requirements and contractual agreements require a great amount of coordination, the most important aspect of microgrids from a resiliency perspective is a reliable source of baseload power that can withstand extended power outages such as natural gas-fueled CHP.

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[2] Nehls, Chris, 83 New York Communities Receive Microgrid Grants, FierceCities, July 13, 2015, available at http://www.fiercecities.com/story/83-new-york-communities-receive-microgrid-grants/2015-07-13.

[3] Wood, Elisa, NY Awards Funds to 83 Community Microgrids in First Stage of NY Prize, EnergyEfficientMarkets.com, July 8, 2015, available at http://energyefficiencymarkets.com/ny-awards-funds-to-83-community-microgrids-in-first-stage-of-ny-prize/

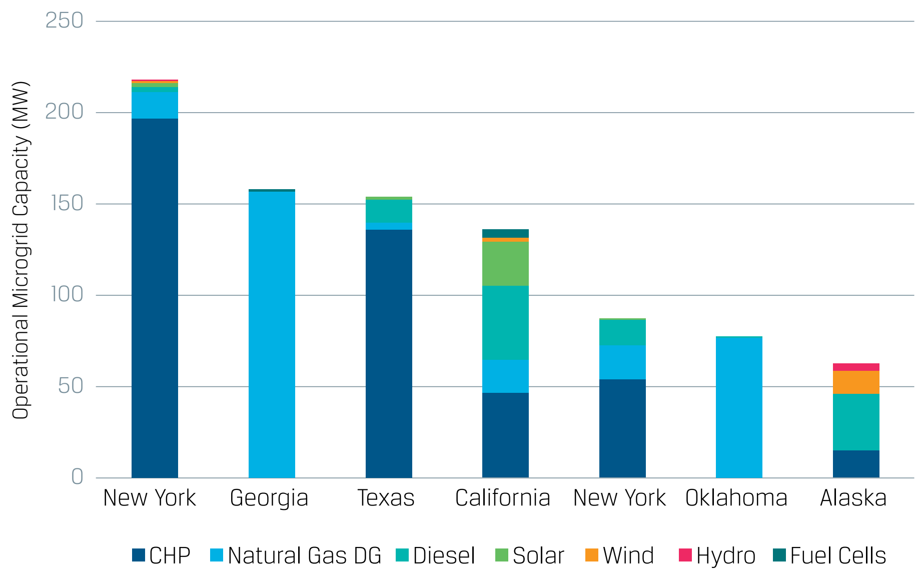
[4] Wood, Elisa, Connecticut Offers $30M in New Microgrid Funding, MicrogridKnowledge.com, November 6, 2015, available at http://microgridknowledge.com/connecticut-offers-30m-in-new-microgrid-funding/

States with Active or Developing Community Microgrid Incentives:

- California
- Connecticut
- Maryland
- Massachusetts
- New Jersey
- New York

CHP systems lead all technologies in U.S. microgrid deployments. The vast majority of existing microgrid capacity comes from CHP and other natural gas-fueled DG units that provide baseload power for microgrid networks. In GTM Research's compilation of data on microgrid deployments, the top seven states (in terms of current microgrid capacity) had more than 80 percent of the installed capacity from CHP and other distributed generators fueled by natural gas.[5] Exhibit 2 shows the total capacity by technology and the number of operational microgrids in these states as of 2015.

EXHIBIT 2. 2015 OPERATIONAL MICROGRID CAPACITY FOR THE TOP SEVEN STATES



Source: GTM Research

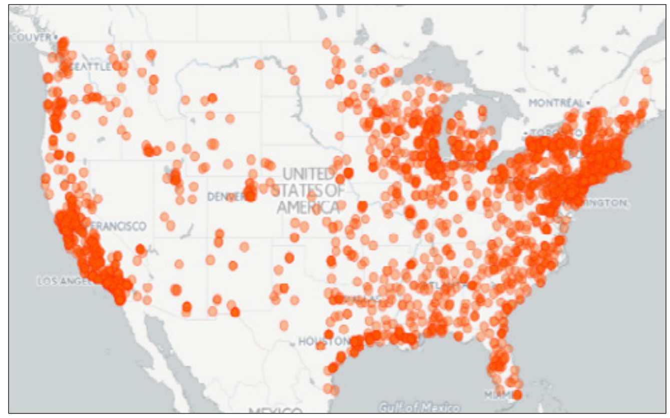
Unlike overhead electricity lines and solar and wind resources, natural gas transmission and distribution lines are rarely impacted by weather events. CHP units offer high energy availability and reliability. When waste heat from gas-fired generators is captured and used for on-site thermal requirements in a CHP configuration, the efficient operation improves economics and reduces greenhouse gas emissions. With all of these factors considered, natural gas CHP systems can be viewed as the ideal anchors for microgrids, capable of producing a reliable, efficient, and steady stream of baseload power.

Other microgrid components can be added to the CHP anchors to provide flexibility, reach more buildings, and enhance overall power generation capabilities. These components include renewable energy resources like solar and wind, storage devices, other gas or diesel generators, energy efficiency measures, and an active control system to manage all of the power resources and loads. Microgrid networks with all of these components can be modeled for specific locations to serve facility load requirements, provide utility benefits, and improve energy resiliency.

[5] Saadeh, Omar, North American Microgrids 2015: Advancing Beyond Local Energy Optimization, GTM Research, 2015.

Microgrid Modeling

EXHIBIT 3. LOCATIONS OF CURRENT CHP SYSTEMS



Source: ICF CHP Installation Database

Operational CHP units from ICF's CHP Installation Database (see Exhibit 3) can provide a starting point for future microgrid development. These CHP systems are generating baseload electricity and thermal energy to meet important needs at commercial or industrial facilities. If additional DERs and loads are connected to these existing CHP units, then the facilities and their surrounding communities could potentially benefit from the reliability and resiliency that microgrids can provide. More than 82 GW of CHP capacity exists in some 4,400 sites in the United States.[6] This large number of existing installations could serve as foundations for future microgrid networks, with minimal capital investment required.

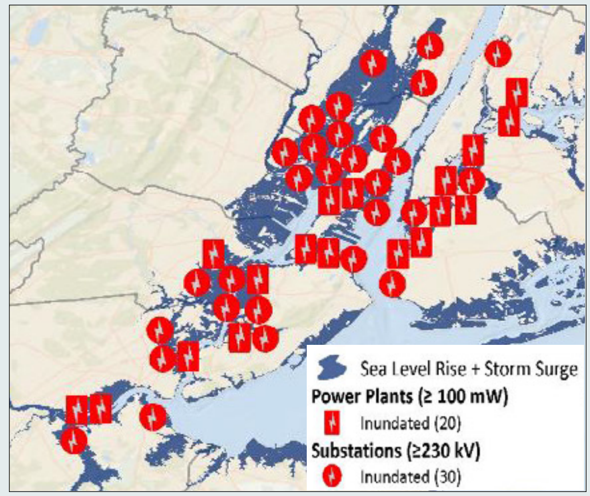
A locational analysis of existing CHP installations can be used to evaluate potential locations for future microgrids. With known physical addresses from ICF's CHP Installation Database, CHP anchors can be tested in different microgrid configurations. Nearby critical loads, facilities with DERs, and potential utility interconnection points can be identified. Additional resources like rooftop solar, energy storage, and energy efficiency measures can be considered in competing microgrid designs. The combinations of critical loads, existing distributed resources, and potential microgrid additions can be tested with programmable control logic, covering both normal operation and disconnected islanding mode for utility outage events.

[6] U.S. DOE Combined Heat and Power Installation Database, U.S. Department of Energy, maintained by ICF, available at https://doe.icfwebservices.com/chpdb/

Making Microgrids Resilient to Past and Future Conditions

Past extreme events such as Hurricane Sandy can be used to identify locations that need to be resilient to current climate conditions. Incorporating information about future climate and extreme weather such as sea level rise, changes in rainfall, and heat extremes helps communities to understand the changing risk they face and to ensure long-term resilience benefits of microgrid investments.

ICF is helping communities and asset owners evaluate the potential impacts of climate change related hazards to energy services. For example, we are using maps of potential flooding from sea level rise in combination with storm surge from coastal storms to identify electricity assets that may be vulnerable. This type of analysis can be used to prioritize communities whose electricity service may be most at risk to future climate and extreme weather.



Major electrical assets flooded by a combined 1 foot of sea level rise and storm surge from a Category 1 hurricane in the New York City area (adapted from Effect of Sea Level Rise on Energy Infrastructure in the New York Metropolitan Statistical Area, DOE 2015).

Together with the ICF CHP Installation Database, consideration of potential future risks can be incorporated into the selection and design of CHP-anchored microgrids.

Community microgrid planning should include the determination of optimal locations, sizes, and configurations to economically and reliably serve critical loads. The inputs, processes, and outputs for this type of locational microgrid analysis are depicted in Exhibit 4.

EXHIBIT 4. INPUTS AND OUTPUTS FOR LOCATIONAL MICROGRID ANALYSIS

INPUTS

- Known CHP installations (ICF CHP Installation Database)
- Critical facilities located close to CHP installations
- Additional DERs (both existing units and potential new installations)
- Energy efficiency measures that could reduce facility loads
- Control system logic—how loads and resources are distributed
- Utility interconnection points (must allow microgrid islanding)

PROCESS

- Potential microgrid locations and configurations
- Load shapes to be served—both individual facilities and the collective microgrid
- Combinations of DERs and energy efficiency measures that can serve the loads
- Estimated installation and maintenance costs for microgrid components
- Potential impacts on utility electric grid

OUTPUTS

- Top locations for microgrids based on existing CHP units and nearby critical loads
- Ideal microgrid size and configuration for specific locations, based on:
  - » Critical loads to be served by microgrid
  - » Resiliency—reliability of DERs during extreme weather and extended outages
  - » Economics—providing the most value to end users through avoided utility costs
  - » Potential utility benefits—what services can the microgrid provide?

Conclusion

If community microgrids are successfully deployed in states with active and developing incentive programs, governments, regulators, utilities, and communities will have an increased desire to strategically evaluate potential microgrid locations. Existing facilities with CHP systems can provide a logical foundation for future microgrids without the need for large capital expenditures. Additional DERs, including renewables and energy storage, can increase resiliency and allow multiple critical facilities to be connected to the microgrid network. As stakeholder interest in microgrids increases, a locational analysis tool for community microgrids such as the one described in this paper will be useful for identifying and evaluating specific locations and strategies for microgrid development.

About ICF

ICF (NASDAQ:ICFI) is a leading provider of professional services and technology-based solutions to government and commercial clients. ICF is fluent in the language of change, whether driven by markets, technology, or policy. Since 1969, we have combined a passion for our work with deep industry expertise to tackle our clients' most important challenges. We partner with clients around the globe—advising, executing, innovating—to help them define and achieve success. Our more than 5,000 employees serve government and commercial clients from more than 65 offices worldwide. ICF's website is **icf.com**.

About the Authors

David Jones has over 12 years of experience modeling the performance of distributed generation (DG) applications and analyzing potential markets for clients in the energy industry. He has modeled the hourly operation of several on-site power technologies including PV, storage, fuel cells, and combined heat and power (CHP) systems.

Prior to joining ICF, Mr. Jones served as Senior Engineer at Resource Dynamics Corporation and Engineering Aide for the Defense Information Systems Agency. He also obtained a Mechanical Engineering degree at the University of Virginia.

At ICF, Mr. Jones continues to utilize his modeling and analysis skills to evaluate potential distributed generation applications, communicate findings to clients, and manage project teams.

Rick Tidball has more than 25 years of experience related to research, development, and commercialization of advanced energy technologies. He has analyzed conventional and emerging technologies throughout the energy chain, with an emphasis on distributed generation (DG) technologies, including combined heat and power (CHP).

Prior to joining ICF, Mr. Tidball held engineering and management positions with Energy and Environmental Analysis, Energy International, and Alzeta.

Mr. Tidball has a master's degree in Chemical Engineering from the University of Colorado and a bachelor's degree in Chemical Engineering from Stanford University.

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