Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

Voices of Experience
MICROGRIDS FOR RESILIENCY

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Smart Electric Power Alliance

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Back To Our Roots

Microgrids are hardly new in the United States—although they haven't always been called microgrids. Thomas Edison introduced the first microgrid in 1882 at his Pearl Street Station. It produced electricity and thermal energy initially serving 82 customers with 400 lamps. While humble by today's standards, Edison's microgrid evolved into our modern electric grid.

Modern attitudes around microgrids have evolved too, from the idea that microgrids represent "grid defection" to perceiving them as a tool that utilities can use to solve challenges. One such challenge is improving resiliency. Faced with unpredictable, yet intensifying and dynamic weather and cyber risks, the value of resiliency is only growing for utility customers, regulators, and policymakers. Moreover, policymakers and regulators are increasingly asking utilities to accommodate the expansion and enhancement of such resiliency.

> ***"Resiliency is how robustly and flexibly a utility can respond to and recover from an event. Reliability is the consistency of electrical service and the ability for customers to avoid an outage."***
>
> Christina Alston | Georgia Transmission Corporation

Voices of Experience is an initiative sponsored by the U.S. Department of Energy (DOE) Office of Electricity's Advanced Grid Research group designed to bring utilities together to share their knowledge, insights, and lessons learned through implementing the emerging technology that is reshaping the electric power industry. You are encouraged to download the *Voices of Experience* series from **SmartGrid.gov/voices** and tap into a growing industry knowledge base built on utility experience. Each guide is intended to stand alone, but together they build a more complete understanding of some of the challenges of transforming this industry. Previous topics in the *Voices of Experience* series include:

- Smart Grid Customer Engagement
- Advanced Distribution Management Systems
- Integrating Intermittent Resources
- Leveraging AMI Data and Networks
- Artificial Intelligence

The purpose of *Voices of Experience | Microgrids for Resiliency* is to guide discussions around this topic—everything from defining the many types of microgrids, to siting, ownership, control, and value streams. Utilities who participated in this project were generous with their time, insights, and examples of how they are using microgrids to solve one of their most urgent challenges: resiliency.

> ***"Start to understand the technology and how it works now, so that when your PUC or customer asks for it, you have some experience and knowledge to draw upon."***
>
> Andre Gouin | Xcel Energy

About This Guide

The information in this guide came directly from the people who are working through the rapidly evolving challenges of developing, siting, and integrating microgrids into their distribution systems. This effort started with two regional workshops in January and February 2020, hosted by the Smart Energy Power Alliance (SEPA). SEPA held the first workshop in Boston, Massachusetts followed by another in Denver, Colorado. Then, due to the COVID-19 outbreak, the project pivoted to an online format, with SEPA hosting seven virtual events that included utility led discussions, each focused on a specific microgrid challenge. In total, approximately 290 people representing 105 utilities participated in this initiative through the in-person workshops, online events, and interviews.

This guide preserves the voices of the participants from the peer-to-peer discussions wherever possible. However, the themes and common ideas that emerged have been summarized and edited into a single narrative with insights and advice, and without attribution to any one person or organization. *Voices of Experience | Microgrids for Resiliency* includes links to the "voices" that led some of the utility discussions too. These recorded interviews and the links to DOE's Grid Talk podcasts provide additional depth for the readers of this guide. To listen, scan the QR codes in this document with your smart phone, click on the Grid Talk links, or go to SmartGrid.gov.

Utilities engaged in developing and interconnecting microgrids have learned lessons and gained insights that other utilities and industry stakeholders can apply and tailor to their own unique circumstances. The goal of this guide is to provide information that might not be accessible elsewhere—the kind you might get from talking to a colleague from a neighboring utility or city. A few things to note:

All utilities are different and have unique strategies, advantages, limitations, and requirements. This document is not a road map. Instead, it is a compilation of advice and insights that other utilities have learned through their own experience.

Much of the information in this document is summarized from group discussions, and therefore cannot be attributed to a single source. Examples attributed to specific utilities are included with permission from the source of the information.

Along the way, the working group identified helpful resources, including documents produced by industry stakeholder groups and the national labs. These are intended to point readers to additional information on the topic.

And finally, this guide is not a how-to manual or set of technical specifications that must be followed. It is meant to help guide important discussions regarding microgrids and resiliency in which stakeholders are already engaged across the United States.

Contents At A Glance

Key Takeaways

THE CONCEPT IS AS OLD AS ELECTRICITY, BUT MICROGRIDS ARE A NASCENT TECHNOLOGY.

The concept of a microgrid has been around since the beginning of the industry. However, integrating and optimizing microgrids for customer and system benefits requires further investigation from research labs and the support of industry partnerships to demonstrate emerging technology and innovative business models.

> *"We do want to see the role that microgrids can play on the bigger grid, supporting the bigger grid. I would say that what we're learning is just that—how we can integrate microgrids into the larger grid and do that seamlessly."*
>
> Ben Fowke | Chairman and CEO | Xcel Energy

Listen on Grid Talk ►

MICROGRIDS ARE ONE OF MULTIPLE POTENTIAL RESILIENCY SOLUTIONS.

Utilities view microgrids as one of many tools they can use to solve challenges around resiliency. However, ensuring a microgrid is the best solution for a given circumstance requires consideration of many factors that impact the costs and benefits over the longer term.

> *"Let's not make a microgrid a solution looking for a problem, which stresses the importance of first defining your problem."*
>
> Rob Stewart | Pepco

INTEREST IN MICROGRIDS IS SURGING, BUT KNOWLEDGE IS LAGGING.

The term microgrid means different things to different people. Frequently customers ask for a microgrid without understanding exactly what a microgrid encompasses and entails. When a customer or community asks for a microgrid, they may actually want something else; often they want to be more sustainable, lower their energy bills, and/or increase the reliability and resiliency of their energy supply.

> *"Our members are also asking for microgrids but they may not understand what they really want. They say they want a microgrid, but when you dig deeper, they really just want to be net-zero energy. And then, when you dig in further, they really just want to be net-metered."*
>
> Chris Bilby | Holy Cross Energy

THE ABILITY TO ISLAND AND PROVIDE RESILIENCY IS WHAT DEFINES A MICROGRID.

What differentiates a microgrid from a single system of distributed resources (e.g., solar and controllable loads) is its ability to island from the grid to continue powering the local loads within the electrical boundary. Hence, the primary value proposition of microgrids is their ability to island and provide resiliency to communities as well as to the grid. One of the challenges is justifying the additional cost required to island. Unless the benefits of resiliency can be monetized and included into a benefit-cost, least-cost, or least-risk analysis, microgrids at current equipment cost structures are difficult to justify economically.

> *"It is critical to look to your finance and accounting teams to run financial analysis and determine the NPW [Net Present Worth] and NPV [Net Present Value] of potential projects. It's important to work with cross-functional areas of the utility to engage planning, operations, and financing/accounting to determine when a microgrid can become less expensive or equal to other non-wires solutions."*
>
> Christina Alston | Georgia Transmission Corporation
>
> Listen on Grid Talk ►

VALUE STACKING IS A KEY—AND A CHALLENGE—TO THE ECONOMICS OF MICROGRIDS.

The economic case for microgrid projects is often based on the benefits beyond resiliency it delivers in normal (grid connected) mode. This is particularly true for microgrids that are significantly reliant on distributed renewable generation and storage resources. When the multiple value streams associated with energy savings for customers and grid services, such as peak demand charge reduction and capacity value, are captured, the microgrid is more likely to make economic sense. However, the ability for certain locations to access such markets may potentially require significant grid upgrades, and such costs can be hard to justify or finance.

> *"Resiliency planning is not about creating a benefit for a single microgrid recipient, it is more about creating benefit to customers as a whole."*
>
> Darren Murtaugh | Portland General Electric
>
> Listen on Grid Talk ►

WHEN IT COMES TO DELIVERING LONG-TERM RESILIENCY FOR CRITICAL INFRASTRUCTURE, RECIPROCATING ENGINES AND FOSSIL FUELS ARE IN THE MIX FOR NOW.

Meeting the demand for long-term resiliency currently requires that reciprocating engines with either fossil or renewable fuels be in the mix. Utilities mentioned black start capabilities, short-circuit fault duties, load following, maintenance, current battery energy storage limits, and geographic or space limitations to accommodating photovoltaic (PV) panels as some of challenges that preclude sole reliance on PV plus storage to power microgrids for longer durations (i.e., more than a day).

> *"Renewable technology needs to continue to mature and become more cost effective when compared to diesel generators or small-scale natural gas turbines to be a first choice for powering critical loads over long periods of time. Clean resiliency will be a key especially in states with significant clean energy and carbon reduction goals."*
>
> Steven J. Casey | Eversource Energy

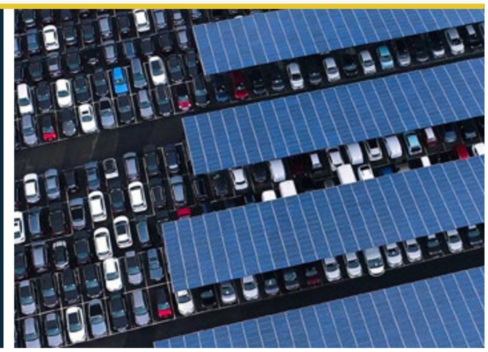
THE LACK OF STANDARDIZATION AND REGULATORY CERTAINTY IMPEDES MICROGRID ADOPTION.

A lack of technology standardization, proper valuation of resiliency and grid benefits, and jurisdictional variations in rules regarding who can own various assets make it difficult for utilities to respond to customer requests for microgrids. The uncertainties in many jurisdictions around asset ownership also complicate project economics and creates obstacles to financing.

> *"It's important for utilities to put resources towards interconnection processes and studies and, to take a methodological approach for updated standards and processes for microgrids."*
>
> Mamadou Diong | Dominion Energy
>
> Listen on Grid Talk ►

Key Drivers of Microgrid Development

1. **Resiliency** sustaining critical services and operations during a widespread outage.
2. **Sustainability** integrating clean distributed energy resources.
3. **Battery Integration** mandates and incentives have encouraged technology adoption and research.
4. **Traditional Investment Deferral** a least cost solution where traditional reliability solutions are not practical or are cost prohibitive.



List of Acronyms

ACE: Area Control Error
ADMS: Advanced distribution management system
ARPA-E: Advanced Research Projects Agency - Energy
BTM: Behind-the-meter
CAIDI: Customer average interruption duration index
CDC: Centers for Disease Control and Prevention
CEMI: Customers experiencing multiple interruptions
CHP: Combined heat and power
CMI/CI: Customer minutes of interruption
CPUC: California Public Utilities Commission
CPUC: Colorado Public Utilities Commission
DER: Distributed energy resource
DERMS: Distributed energy resource management systems
DERSA: Distributed energy resources service agreement
DF: Demand flexibility
DG: Distributed generation
DOE: U.S. Department of Energy
DOGAMI: Department of Geology and Mineral Industries
DRP: Dynamic renewable pricing
EIM: Energy Imbalance Market
EPC: Engineering, procurement, and construction
EPRI: Electric Power Research Institute
EV: Electric vehicle
FEMA: Federal Emergency Management Agency
HVAC: Heating, ventilation, and air conditioning
IBR: Inverter-based resource
ICC: Illinois Commerce Commission
ICE: Interruption Cost Estimate
IIT: Illinois Institute of Technology
IOU: Investor-owned utility
IRP: Integrated resource plan
ISO: Independent system operator
LBNL: Lawrence Berkeley National Laboratory
NCDP: National Center for Disaster Preparedness
NERC: North American Electric Reliability Corporation
NODES: Network optimized distributed energy systems
NPV: Net present value
NPW: Net present worth
NREL: National Renewable Energy Laboratory
NWA: Non-wire alternative
OEM: Original equipment manufacturer
POET: Power Outage Economic Tool
PSPS: Public Safety Power Shutoff
PTR: Peak time rewards
PUC: Public utility commission
PuRE: Purchase Renewable Energy
PV: Photovoltaic
RA: Resource adequacy
RFP: Request for proposal
RTO: Regional transmission organization
SAIDI: System average interruption duration index
SAIFI: System average interruption frequency index
SEPA: Smart Electric Power Alliance
SFHA: Special Flood Hazard Area
T&D: Transmission and distribution
TOU: Time-of-use
TVA: Tennessee Valley Authority
VAR: Volt-amp reactive
WECC: Western Electricity Coordinating Council

What is a Microgrid?

IT IS A SOLUTION TO A PROBLEM.

Ask a room full of utility people what a microgrid is and you are likely to find that the word "microgrid" means different things to different people. Add customers, developers, the military, or other stakeholders to the conversations and the definition will widen to include distributed generation, storage, solar PV, autonomy from the grid, low-cost power, clean energy, etc. As a baseline though, what defines a microgrid is the capability to operate in conjunction with or independently from the traditional grid.

> *"A lot of people see microgrids as a bright, new shiny object…but it's not the solution to everything."*
>
> Tom Bialek | SDGE

What defines a microgrid?

Survey results from February 2020 Voices of Experience workshop in Boston, MA.

The DOE Microgrid Exchange Group defines microgrids as "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected and island-mode."[1]

Types of Microgrids

A microgrid is a custom solution. Each microgrid is unique in its configuration and assets designed to solve a specific challenge or meet specific goals. Microgrids also range in levels of sophistication and complexity, and generally include a mix of critical and controllable loads along with a mix of controllable and non-controllable generation assets, and a central microgrid controller. Utilities are beginning to explore ownership and operation of microgrids for community resiliency, though customer and third-party owned microgrids are more common right now. Corporations, universities, and communities are increasingly electing to develop—and finance—their own microgrids to ensure continued electric service during an outage event. Table 1 provides the defining characteristics of different types of microgrids.

TABLE 1: TYPES OF MICROGRIDS | TERMS AND EXAMPLES USED IN THIS GUIDE

TYPE	DEFINING CHARACTERISTICS	EXAMPLES
Behind the Meter Microgrid or Nanogrid	• Relationship to Power Grid: Grid-tied system with limited coordination and integrated operation with distribution system • Breadth of Grid: Single domain of power and physical layer of power distribution that is typically a single building or facility • Customer Type: Applications include residential, commercial and industrial, and governmental	• Los Angeles Department of Water & Power (LADWP) Municipal Facility Microgrids • Residential customer with solar and storage paired with a smart inverter • **Beaverton Public Safety Center** (Portland General Electric)
Campus Microgrid	• Relationship to Power Grid: Grid-tied system that involves integrated operational coordination with utility • Breadth of Grid: Typically leverages existing on-site generation and loads and is typically located behind the customer's meter • Customer Type: Applications include college campuses, business parks, and industrial complexes	• **Philadelphia Navy Yard** (PECO) • **Kings Plaza Shopping Mall** (ConEd) • Illinois Institute of Technology • Fort Carson Microgrid (Colorado Springs Utilities)
Community or Multi-User Microgrid[2]	• Relationship to Power Grid: Grid-tied system that involves a high level of integrated operational coordination with utility • Breadth of Grid: Small section of a utility distribution grid with contiguous loads and resources • Customer Type: Typically has single entity representing customers (e.g., HOA, property manager or independent microgrid operator)	• **Bronzeville Community Microgrid** (ComEd) • PG&E's **Community Enablement Program** • **Redwood Coast Airport Microgrid** (PG&E) • Xcel Energy's **Community Resiliency Initiative** • **Basalt Vista** (Holy Cross Energy) • Ocracoke Island, Butler Farms and Heron's Nest (NCEMC)
Mid Feeder Microgrid	• Relationship to Power Grid: Grid-tied system that involves a high level of integrated operational coordination with utility • Breadth of Grid: Segments of the utility distribution grid that typically ties customer and third-party resources together • Customer Type: All end use customers within the electrical boundary	PG&E's Distributed Generation-Enabled Microgrid services (DGEMS) Program for Mid-Feeder Microgrid and Resilience Zones
Remote Grid	• Relationship to Power Grid: Off grid system that requires no coordination with the utility (unless it is a utility-operated remote grid) • Breadth of Grid: Relies completely on local power generation and control capabilities • Customer Type: Typically applied to customers in remote, rural or island geographies	Cordova, Alaska
Temporary Microgrid	• Relationship to Power Grid: Grid-tied system that may be utilized for non-wires alternatives and emergency services • Breadth of Grid: Typically consists of permanent disconnect and controls capacity, but portable generation and storage assets, rapidly deployable upon necessity • Customer Type: May include any type of customers. Set up on an as-needed basis.	PG&E's Temporary Microgrids fo Wildfire Resiliency

PG&E's Temporary Microgrid Solution

Following the unprecedented devastation of the 2018 wildfires, the California Public Utilities Commission (CPUC) mandated that the state's IOUs develop microgrid and resilience strategies to mitigate customer impacts from Public Safety Power Shutoff (PSPS) events. In response, Pacific Gas & Electric (PG&E) is exploring the idea of creating a collection of temporary microgrids. They would configure substations across northern California to act as microgrid hubs with everything pre-installed except generation. To power the temporary microgrids, PG&E is procuring over 400 MW of "portable" generation fueled by renewable diesel derived from vegetable oil. Utilities will either stage these generators at substations or deploy these generators to remote sites by truck and plug into the substation-microgrid hubs when needed. This temporary generation strategy uses deployable capacity to keep communities energized during a PSPS and can be used for short-term outages such as line repair.

According to Quinn Nakayama, Director of Grid Innovation at PG&E, they chose this solution due to two main factors: 1) the availability of land and 2) cost-effectiveness. For their analysis, PG&E looked at a substation microgrid with a 13 MW peak load, capable of responding to a PSPS. Such a load would require 3 MW of solar coupled with 197 MWh of battery storage. That equates to approximately 101 football fields of available land at a cost close to $119 million just for the generation assets alone. While permanent microgrids can access other value streams, such as California's Resource Adequacy (RA) market, and the wholesale energy market, the cost of transmission upgrades for RA deliverability, as well as the cost of land acquisition, can make this an extremely expensive endeavor. While the temporary microgrid model lacks the ability to value stack, is can be potentially more cost effective than a microgrid with a permanent generation source, regardless if the generation is renewable or fossil fuel. It also means that PG&E can create optionality, in that portable microgrid generation sources can be potentially moved to a number of needed locations and provide resilience depending on the need, instead of either pre-selecting a given location to install a few microgrids or deploying microgrids everywhere.

Bottom line: Microgrids are one of multiple solutions that PG&E can employ to help achieve its PSPS resiliency goals.

"Temporary and portable generation assets can provide utilities the ability to re-energize customers in a variety of use cases that allows for flexible resilience in a wide range of locations for a wide range of events. Furthermore, such assets can also scale from small loads, such as a single customer facility, to large full substation loads, that could be needed in times of a loss of transmission source. While reciprocating engines currently make up the majority of generation assets that provide this service, PG&E is partnering with the industry to identify cleaner technology solutions that can operate in this fashion, and looks forward to seeing what type of innovations can be brought into this field."

Quinn Nakayama | PG&E

LADWP's Porter Ranch Fire Station 28 Nanogrid

The **Los Angeles Department of Water and Power (LADWP)** is the largest municipal utility in the United States with over 1.5 million residential electric customers and an annual power system budget in excess of $4.1 billion. LADWP is one of the most reliable electric utilities in the nation. To continue the high standard of reliability, LADWP is pursuing a utility microgrid strategy that starts small with a gradual ramp to accommodate future needs.

LADWP's first community-oriented microgrid facility was completed in 2018 at the Porter Ranch Fire Station 28. This serves a community that was severely impacted by the 2018 Aliso Canyon natural gas leak. The project consists of a rooftop solar system combined with a 12-kW, 40 kWh, Sunverge battery energy storage system. In the event of a grid outage, the facility can operate independently using the microgrid system.

Despite its small size, the system provides a community resource hub to charge electronics, provide cooling, and offer other critical services during emergency outages, while also reducing the firehouse's demand-based charges in non-emergency operations. The fire station's backup power capabilities were put to the test just 5 weeks after project completion when a grid outage occurred due to unusually heavy rainfall. The solar plus storage system successfully provided over 7 hours of backup power, although it was capable of operating significantly longer if necessary.

The Porter Ranch Fire Station 28 solar and storage project serves as a demonstration case for other community facilities located through the City of Los Angeles. LADWP and the City's Park and Recreation department identified some 12 near-term candidates for similar community microgrids that could add resiliency at the local level. These facilities were identified based not only on their location within LADWP's service territory, but also their ability to serve disadvantaged communities. These communities are a major part of the clean energy transition and those facing economic hardships during a power outage will eventually be able to access resilient shelters.

By providing local levels of resiliency at specific facilities, the utility can tie in other critical facilities nearby once it reaches critical mass.

Bottom line: The idea of placing microgrids throughout LADWP's service territory will help achieve their near-term resiliency goals and lesson their dependence on natural gas, while working towards the city's longer-term goal of 100% clean energy by 2045.

> *"LADWP has advertised a 30 MW DER RFP and is preparing to launch a 10 MW Feed-in Tariff+ pilot program (solar + storage), where we will be exploring opportunities to partner with industry and developers to achieve the local solar, storage, resiliency and energy efficiency goals in a new and exciting way."*
>
> Jason Rondou | LADWP

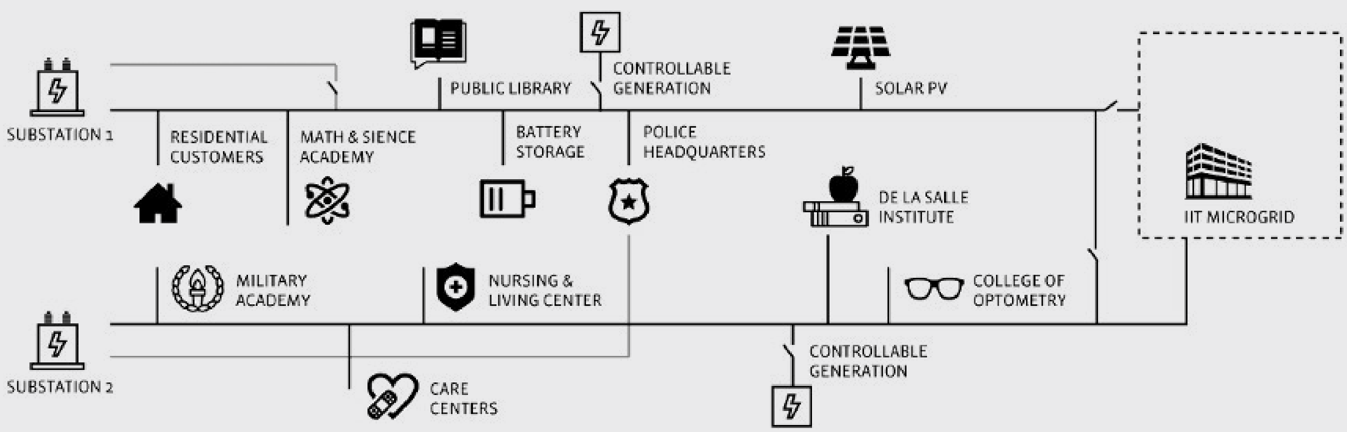
The Bronzeville Community Microgrid

Commonwealth Edison (ComEd) is building one of the first "utility-scale" microgrid clusters in the nation. The project is located in the historic Bronzeville neighborhood on Chicago's South Side. The community is known for its diversity of people and businesses. It's also home to critical public infrastructure, such as the City of Chicago Public Safety Headquarters for police and fire departments, in addition to high schools, a library, senior living facilities, and public housing – about 1,000 customers in total.

Bronzeville's proximity to Illinois Institute of Technology (IIT) is key to one of its unique features: connection to IIT's behind-the-meter microgrid. Connecting two microgrids and allowing them to "talk" to each other is a first-of-its-kind. The key to connecting the two microgrids is a microgrid master controller that has been developed and demonstrated with a $1.2 million grant from the DOE in partnership with a number of universities, national labs, and technologists who are developing the software. The controller senses when a disruption event occurs. It then evaluates the state of the system in the local area and utilizes grid infrastructure and distributed resources to keep the grid operating and picking up the load if there's an outage. The controller will serve as the microgrid's "brain". Its integrated algorithms will be developed into a cyber-secure platform. This newly created grid-edge intelligence has the ability to control different power generation and prioritize different "customer modes" in different types of emergencies.

Facts about the Bronzeville Community Microgrid:

- 7 MW aggregate load, serving approximately 1,000 residences, businesses, and public institutions
- One of the first utility-operated microgrid clusters powered by controllable generation, solar PV, and energy storage
- Demonstration of advanced technologies supported by six grants from DOE
- Developed in partnerships with universities, vendors, and national labs
- Estimated completion in 2021



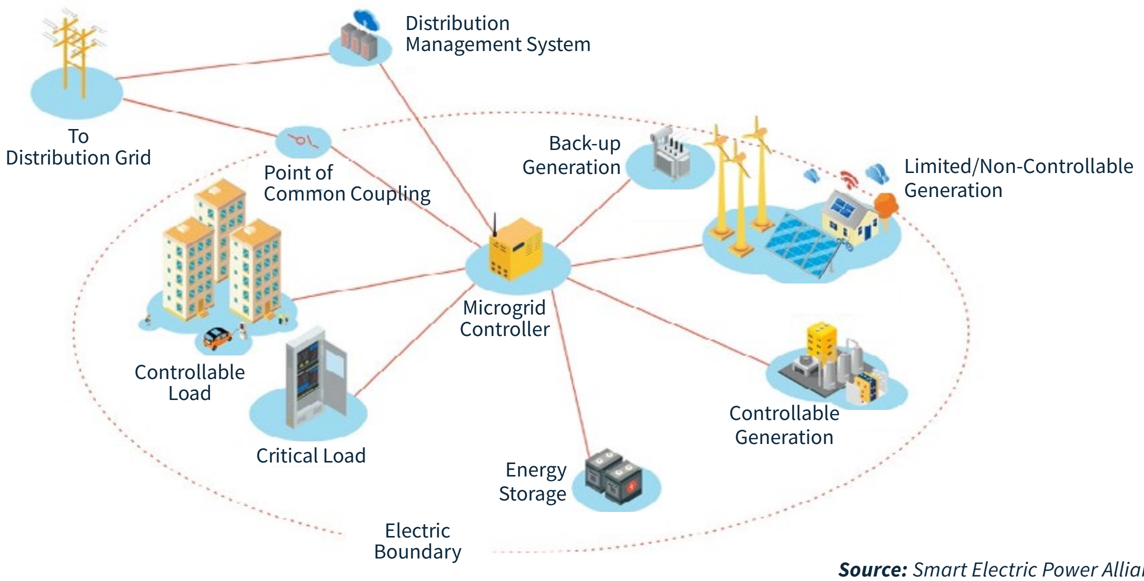
Bottom line: While the Bronzeville Community Microgrid project will provide increased resiliency for a community with critical infrastructure, it is also a model for developing green, resilient, and sustainable neighborhoods for consumers. Equally important, the demonstration project is providing the utility and its research partners many key insights about how the electric grid may operate in the future.

Listen to Shay Bahramirad, Vice President of Engineering and Smart Grid at ComEd, on Grid Talk

Basic Components of a Microgrid

Similar to the larger electric grid ("the grid"), microgrids are comprised of generation and load which must be locally defined within the electrical boundary, plus a controller. Depending on the scale or size of a microgrid, necessary distribution assets (i.e., conduits, wires, poles, isolation switches, inverters, transformers, and substations) are included within the electrical boundary to electrically tie the system together. The basic components of a microgrid as illustrated in Figure 1 are briefly described below.

FIGURE 1: BASIC COMPONENTS OF A MICROGRID



***Source:** Smart Electric Power Alliance, 2020*

LOAD

For many microgrids, the load—what consumes the electricity—is what defines the microgrid. The microgrid design process must consider individual and combined load shapes as an input to the generation selection process. Some loads may be less critical and therefore turned off during island operation. Others may support flexible operation to help maintain microgrid flexibility. It is important to identify and understand the differences between critical and total loads when designing and sizing controls.

A residential microgrid would typically include a home with electric appliances, controllable systems for heating and cooling air, a water heater, lights, and maybe (increasingly more common) an electric vehicle. A community microgrid may include multiple residences, plus buildings and critical load such as hospitals, fire and police stations, grocery stores, gas stations, and community centers or shelters. A campus microgrid may include housing, industrial processes, and offices that are co-located in a campus setting, and generally only have one unified customer, no matter how many buildings or meters are on the microgrid. Sometimes the microgrid includes a source of thermal load such as water boilers or chillers. These thermal assets are often used by combined heat and power (CHP), which can be harnessed to generate electricity. The sum total of all the electric loads on a microgrid will look different for a residential setting, a community microgrid, a campus microgrid, and any that includes thermal loads.

Are You Sitting on a Microgrid Foundation?

Lincoln Electric System (LES), the electric utility provider in Lincoln, Nebraska first investigated the concept of a community microgrid to support disaster recovery in the downtown area in 2016. Many of Lincoln's critical loads—city, county and state facilities, federal building, police headquarters, and even the basketball arena—are all served out of one substation with a tie to a 29 MW duel fuel (natural gas and diesel fuel) combustion turbine. This substation's distribution grid had all the makings of a microgrid that could provide resiliency to the city following a catastrophic event; including black start capabilities and the ability to run indefinitely, so long as it had either the natural gas supply or the ability to truck in diesel fuel.

LES initially rejected the plan following a detailed review that determined it would take too long to manually switch the distribution system to isolate and serve just the critical facilities within the area, and it would be cost prohibitive to automate the process.

In 2018, LES redesigned the project by making a simple, but crucial change to their islanding methodology. Instead of restricting service to just critical facilities, the microgrid would serve nearly all load within a finite downtown area. This simplification would allow LES to use a manual process to island that they can complete much more rapidly.

Bottom line: Don't just look at new technology. Look at pre-existing components of your system that you may be able to use to build your solution. You may already have several, or even most, of the assets required for a microgrid.

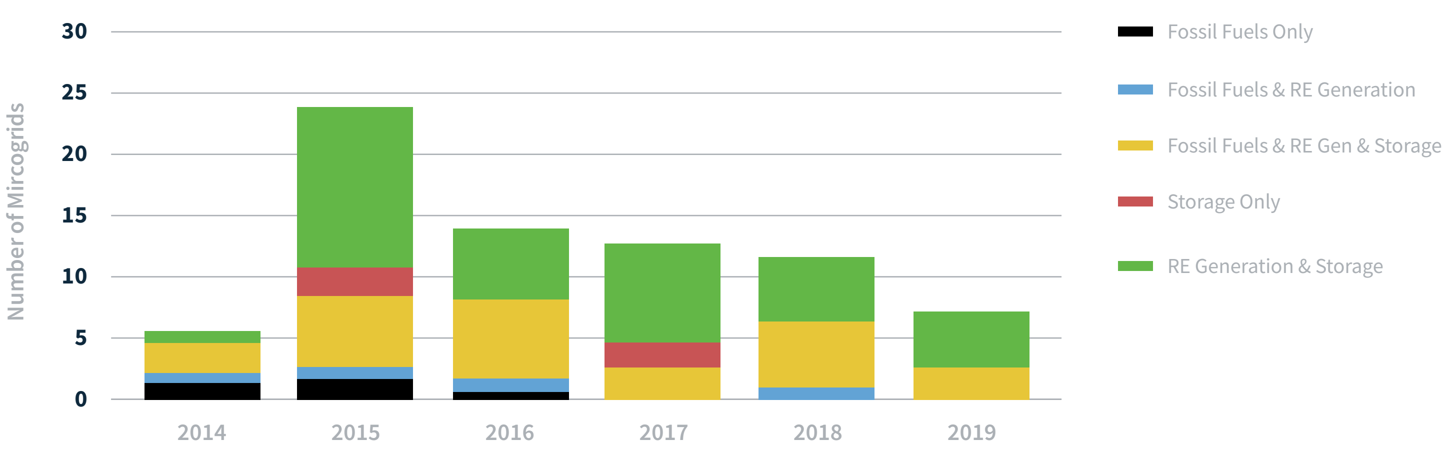
GENERATION AND ENERGY STORAGE

Long-duration microgrids (i.e., microgrids that power loads for more than a day) typically include three forms of local generation assets—controllable (e.g., fuel cell and reciprocating engine), limited or non-controllable (e.g., wind and solar PV) and back-up (e.g., diesel gensets)—plus energy storage. Short-duration microgrids (i.e., several hours) may or may not include controllable generation and back-up generation. Often, existing generation or infrastructure is the catalyst for developing the microgrid in a particular location. **Colorado Springs Utilities**, for example, discussed siting microgrids where existing natural gas supplies were available. Other utilities used the availability of solar generation assets and incentives for integrating battery storage to develop a microgrid. A number of utilities, including **Xcel Energy** are developing microgrids to explore the use of solar plus battery storage systems to keep a local grid energized during an extended power outage, as well as to provide other market and grid services. If the microgrid is located in a remote area, and therefore at the grid's edge or even off-grid, renewables such as wind and solar may provide more economic and environmentally sustainable generation for the grid operator.

The fuel source(s) or choices in a microgrid are driven by the purpose for the microgrid (again, the problem it will solve) and are often selected based on how long the microgrid must operate independent from the larger grid, the availability of the fuel, and the resources available to the microgrid operator.

Although achieving clean energy goals is often the impetus for developing microgrids, nearly half of the microgrids commissioned in the United States from 2014-2019 included at least some fossil fuel generation, according to data collected by Bloomberg News Energy Finance. The trend though, especially since 2016, has been towards including at least some renewables or storage, as shown in Figure 2. Utilities are tackling the challenge of understanding the operating complexities that come with increased amounts of intermittent energy sources in microgrids. Some participating utilities stated that when resiliency is the primary goal, the technology simply isn't yet sufficiently mature or cost effective when compared to diesel generators or small-scale natural gas turbines.

FIGURE 2: MICROGRIDS COMPLETED ANNUALLY BY GENERATION SOURCE



Source: *Bloomberg News Energy Finance*

CONTROLLER

The microgrid controller is a device that manages the microgrid's resources. It includes both hardware and software that work together to ideally deliver seamless performance. The controller may integrate various inputs, which may include price forecasting, natural gas fuel price, load forecasting, and solar forecasting. Microgrid controllers can be coded to operate and optimize for a mix of desired outcomes, such as energy savings, capacity savings, emission reductions, reliability, and resiliency.

Microgrid controllers are also responsible for maintaining and regulating frequency and voltage to ensure a microgrid can seamlessly connect and disconnect to the grid without interruption. The controller acts as a management system for the microgrid and typically communicates back to the centralized distribution management system (e.g., SCADA) at the utility. Distributed energy resource management systems (DERMS) are an emerging technology that typically sits near the distribution management system and acts as a conductor to all of the distributed energy resources, including microgrids, deployed on the system.

Microgrid controllers can perform other functions as well. They can function as distributed energy resource (DER) aggregators and manage the entire microgrid system by controlling the dispatch of available resources by serving as a field-DERMS. Finally, the controller can initiate the tasks of islanding and resynchronizing between operating states, which allows the microgrid to conduct voltage optimization, power flow control, and dispatch to economic signals. The controller also allows operators to maximize the value streams to the customer or the utility, depending on the settings.

Like microgrids as a whole, controllers are an emerging technology with many functional capabilities that utilities are just beginning to explore. Table 2 shows the currently identified functionality and use cases for microgrid controllers. While customization of controllers is prevalent in the industry, **Southern Company** is one utility that is looking for ways to standardize communications protocols to enable utilities to move away from demonstration and towards commercialization.

> ***"The [microgrid controller] market is being driven by what customers want. As customers get more sophisticated, the controllers will get more sophisticated and will start to have a lot more of these functions…especially once utilities get involved."***
>
> Jason Autrey | Southern Company

TABLE 2: MICROGRID CONTROLLER FUNCTIONALITIES AND USE CASES

Black start	The controller can black start the microgrid if the interconnection to the grid is open and there is no power coming in. This functionality enables the customer and/or resiliency value stream.
Unintentional or Intentional Islanding and Resynchronization	The controller can enable a microgrid to seamlessly transition back and forth from normal operating mode to islanded mode during an unplanned power outage. This functionality can ensure the customer does not experience any interruption of its power and can help a commercial customer maintain economic productivity and business continuity or a governmental customer maintain a public good or safety service within the community.
On-Grid Optimization and Economic Dispatch	The controller can automatically dispatch DERs based on weather forecasts, price forecasts, load forecasts and other inputs that can increase bill savings and reduce energy costs for the customer as well as optimize the DER assets within the microgrid to provide energy and grid services to the utility during normal operations.
PV Smoothing and Firming	Where systems include energy storage and solar PV, a microgrid controller can manage when to charge and discharge the energy storage asset to firm or shape solar PV production based on solar forecasts. These use cases can enable increased efficiency for the solar PV, reduce emissions and drive energy costs down for the customer.
Power Quality	The controller can provide a means to optimize the dispatch of DERs to produce desired power factors, voltage requirements, frequencies, etc. This use case can ensure economic productivity and business continuity for commercial and industrial customers with high power quality needs.

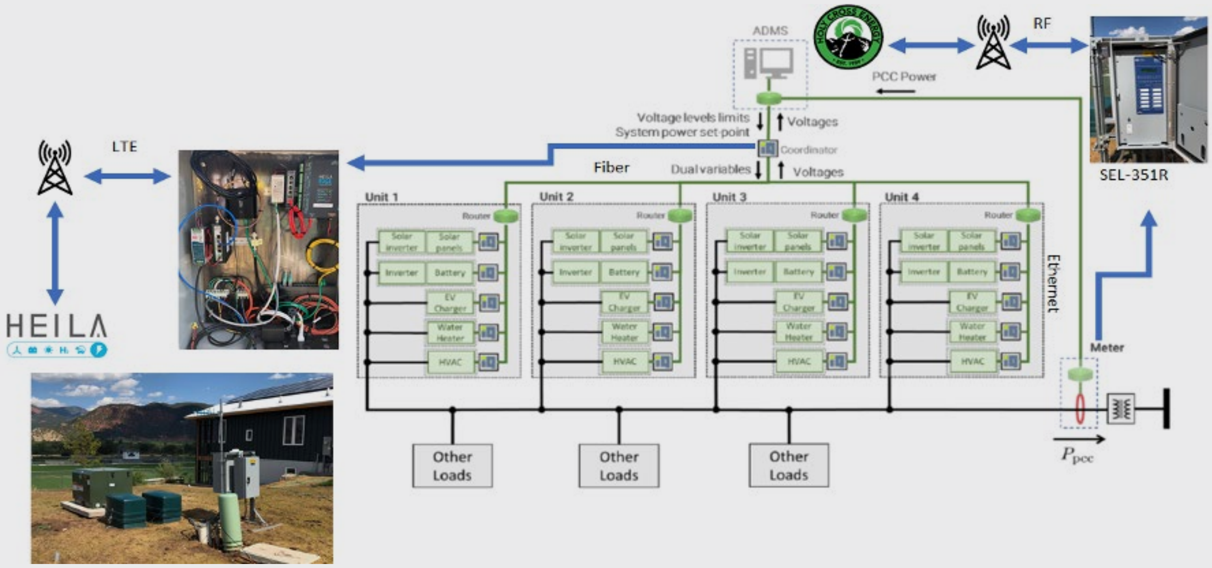
Source: *Southern Company. See the compendium for the Microgrid Controller Performance Specification Reference Document developed by Southern Company's Research and Development Group. Available for download on SmartGrid.gov.*

ENABLING TECHNOLOGY

Microgrids that incorporate DERs such as PV, batteries, and electric vehicles (EVs) and/or are designed to support multiple loads in multiple buildings may require a modern communication network and an advanced distribution management system (ADMS), distributed energy management system (DERMS), or a microgrid controller to enable the utility to control and coordinate the distributed assets to orchestrate grid services and achieve grid flexibility. One participating utility stressed the importance of open source communication to the success of integrating and controlling DER technology within the microgrid. In addition to the technology, utilities participating in the *Voices* discussions suggested it is to the utility's advantage to have agreements with their customers that will grant the utility control over any non-utility assets of the microgrid, including those that may be located behind the meter. Although, not all customers will be interested in this arrangement.

Optimizing and Orchestrating with an ADMS

Holy Cross Energy (HCE) is using an ADMS that uses algorithms developed under ARPA-E's Network Optimized Distributed Energy Systems (NODES) program. The ADMS reaches past the end-users' meters to integrate customer-owned DER assets that include water heaters, HVACs, EVs, battery storage systems, and distributed PV with smart inverters.



The ADMS is capable of handling extraordinary complexity in real time, as it needs to ensure that every load, generation source, and energy storage system can be manipulated in exactly the right way at exactly the right moment for optimal performance. Using algorithms that were developed in partnership with the National Renewable Energy Laboratory (NREL), the ADMS can individually control distributed generation and storage at any point to help flatten voltage or wattage demand profiles. Simultaneously the system can curtail discrete loads to sustain optimal grid balance, and it can manage both to maintain frequency stability.

HCE's system does face constraints. It works best for the utility if customers permit the utility control of the DERs behind the customers' meters. Moreover, it requires modern infrastructure throughout the system, presenting both hardware and economic challenges for such a model in communities with long-standing infrastructure.

> *"One of the really neat aspects of this project is that we can set the interface between the homes and the grid to whatever we need based on local grid conditions, a price signal, or in the case of a microgrid, we can actually set that interface to zero where the building is actually neither consuming from the grid nor contributing to the grid; the grid isn't there. We call this more of a 'functional microgrid', which is a different way of thinking about providing energy resilience."*
>
> Bryan Hannegan | President and CEO, Holy Cross Energy

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Is it a Microgrid or Not?

When customers or communities ask for a microgrid, they may actually want something else. Perhaps they want to be more sustainable, lower their energy bills, or increase the reliability and resiliency of their energy supply. A customer-sited system comprised of distributed generation and storage can help a customer achieve those goals, but it is not the same as a microgrid. What differentiates a microgrid from other system configurations or solutions is the ability to island from the grid and continue powering the local loads within the electrical boundary. Developing the islanding capabilities can provide benefits to both customers and the grid, but it is more complex to build and operate, and requires significantly more upfront investments in equipment, controls, and communications networks. Table 3 illustrates the key differences between distributed generation, distributed generation with storage, and a microgrid.

TABLE 3: MICROGRID OR DISTRIBUTED GENERATION RESOURCE?

	CUSTOMER SITED DISTRIBUTED GENERATION	CUSTOMER SITED DISTRIBUTED GENERATION + STORAGE	MICROGRID
Backup Power	No backup power, but could support a future microgrid	Could provide backup power	Backup power for multiple loads or an entire site
Upfront Cost	Lower cost	Higher cost than customer sited DG for storage and controls	Much higher cost for additional required equipment, controls, and communication
Cost Savings	Can lower energy charges and demand charges with smart inverter functionality	Can lower energy and demand charge with potential for additional savings and/or revenue streams (e.g., non wire alternative)	Can lower energy and demand charges with potential for additional savings and/ or revenue streams (e.g., resilience services)
Grid Benefits	Can provide energy and grid services (e.g., voltage support through smart inverters)	Can provide energy and grid services (e.g., bulk system services)	Can provide energy and grid services, as well as resilience services to nearby loads (e.g., microgrid forming services)
Complexity	Fairly straight forward installation and interconnection requirements	More complex due to required connect/disconnect interconnection requirements	Much more complex, requires isolation, communication, and detailed analysis of existing distribution system

Key Insights

- A microgrid is a custom solution to meet customer load using local generation. Different types of microgrids are used to address different challenges, but each is unique in both function and configuration.
- Microgrid controllers can provide key system functionalities and use cases that can benefit the grid and the utility, when designed to do so.
- ADMS or DERMs as well as a modern communications network will enable the utility to control, coordinate, and call upon grid services to achieve grid flexibility.
- Consider existing assets when evaluating your options. Utilizing existing assets and infrastructure may make a proposed microgrid more economically feasible.
- Almost half of microgrids built between 2014-2019 use some form of fossil fuel generation to support on-site fuel requirements and other resiliency goals.

ADDITIONAL RESOURCES:

- **How Microgrids Work**, U.S. Department of Energy
- **Choosing the Type of Microgrid that is Right for Your Operation**, microgridknowledge.com, January 16, 2018.
- **Microgrids: Expanding Applications, Implementations, and Business Models**, Smart Electric Power Alliance (SEPA) and Electric Power Research Institute (EPRI), 2016.
- **Microgrid-Ready Solar PV – Planning for Resiliency**, National Renewable Energy Laboratory (NREL), 2017.

[1] Office of Electricity Smart Grid R&D Program. (2011). DOE Microgrid Workshop Report (August 30-31, 2011). U.S. Department of Energy. https://www.energy.gov/sites/prod/files/Microgrid%20Workshop%20Report%20August%202011.pdf

[2] How to Design Multi-User Microgrid Tariffs, Smart Electric Power Alliance (SEPA) and Pacific Energy Institute, 2020. https://sepapower.org/resource/how-to-design-multi-user-microgrid-tariffs/

The Value of Resiliency

IT'S WORTH A LOT MORE IN AN EMERGENCY.

Defined by the DOE's Grid Modernization Laboratory Consortium, "resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."[3] For utilities, resiliency is the ability to anticipate, prepare for, and withstand major events or restore functionality to the parts of the electric grid that go down. While most industry stakeholders would agree that resiliency is important and has value, the question is how we systematically establish what that value is. The challenge is quantifying the monetary benefits of resiliency so that they can be incorporated into benefit-cost, least-cost, or least-risk analyses. Currently, no standard approach exists to monetize it; the value of resiliency depends on the perspective of the stakeholder.

> *"We had two applications get denied because we couldn't come up with a value for resiliency. And it's one of those – it seems to be worth more when you're up to 50 inches of water than it is when you're sitting there when the sun's shining. And people understand that, but it's hard to get to that."*
>
> Rob Stewart | Pepco

The Role of Utilities in Resiliency

Recent high-profile natural disasters such as the California wildfires, 2017 Hurricanes Harvey and Maria, and 2012 Superstorm Sandy put an increased emphasis on electric grid resiliency. The Smart Electric Power Alliance noted that large weather events—fires, floods, and hurricanes—in 2017-2018 thrust electric utilities into the role of first responder, and that after each event, electricity resilience discussions intensified. It is also important to recognize that resilience might be required to address a variety of different events including cyber-attacks.

Stakeholder discussions around improving resiliency are happening across the country within municipal governments, state and federal entities, and private businesses, but utilities are not always part of those discussions. Addressing resiliency as part of utility business planning will require utilities to understand their customers', regulators', and policymakers' main motivations for wanting more resilience.

> *"Utilities exist to empower and strengthen communities. When communities involve the utility in resiliency planning, we can work together to achieve a microgrid that delivers shared benefits and value for all stakeholders, making our community even stronger."*
>
> Darren Murtaugh | Portland General Electric

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Including Stakeholder Perspectives on Resiliency

The **Tennessee Valley Authority (TVA)** supplies businesses and local power companies serving 10 million people in parts of seven southeastern states. These customers, like those of so many other utilities, have increasingly inquired with TVA about microgrids. TVA is not subject to public service commission regulations as it relates to rate cases or grid investments, but it does need approval from its board of directors, which requires a process to gather input from stakeholders across the Tennessee Valley.

Stakeholder-informed decisions around planning DERs, integrated resource planning, and microgrid deployments rely on including and balancing a variety of stakeholders, and their often diverging agendas and biases. TVA has two Federal Advisory Committees that advise the board of directors; one on environmental policy and strategy, and the other on energy policy and strategy. TVA has convened several other ad hoc or single purpose stakeholder groups to help develop specific strategies, including one focused on integrated resource planning, which ties directly into improving resiliency.

Resiliency can sometimes be a sensitive topic. Municipal governments want to ensure continuity of emergency services in their communities without the high price tag associated with it. Forming an array of stakeholder groups is necessary. These groups include local power companies, different customer classes, and various advocacy organizations. They are tasked with developing strategies for ensuring continuity of electric service to critical municipal facilities, as well as universities or large commercial operations. Holding sensitive economic conversations, without shutting anyone out of the dialogue, is a key challenge.

Bottom line: This process of discussing tradeoffs and stakeholder priorities, can help cultivate decisions that are not only stakeholder-endorsed, but also developed in part by the stakeholders themselves. Here are some insights from TVA's stakeholder engagement process:

- To do this successfully, you must build a track record of convening people. Use stakeholder groups frequently as a normal part of the business; you do not want your first stakeholder group to form when you have crisis.
- Diversity of stakeholders is key. You must bring together differing opinions, especially those that you expect to be contrary to yours.
- Keep it stakeholder centric. The utility's role as the convener is to watch, listen, and learn.

> ***"Everyone has an agenda, but it's about being able to bring those to the table openly and having a good robust discussion. We make them [stakeholders and advocates] watch us make the sausage. In fact, we make them get in there and help us make the sausage."***
>
> Gary Brinkworth | TVA

Key Considerations for Resiliency

Discussions around improving resiliency often include a request for the utility to develop a microgrid. Here are some key considerations to help guide those discussions:

- What critical infrastructure or functionality is the customer trying to maintain?
- What are the current threats and vulnerabilities? Some threats and hazards are universal (e.g., cyber), while other (e.g., natural disasters) vary by geographic location.
- What is the frequency of the threat and vulnerability that may cause the need for resilience?
- What is the incremental benefit gained vs. the potential costs in being resilient, vs. in being reliable, even in high impact events?
- Are there any new and evolving threats (short term and long term) that need to be considered?
- What role will the utility play?
- What are the costs and benefits of inaction vs. action?
- Who will pay for the solution? Some customers or groups of customers will be willing to pay more for resiliency services because any downtime costs are significant right from the first minute (e.g., data centers, U.S. Department of Defense, public purpose facilities).
- How can resilience increase for all ratepayers equitably?
- Are there other stakeholders or partners that may support the project development?
- What are the options for financing the project?
- Is there an operations and maintenance plan in place for the project? If it is inadequate the microgrid may not deliver the promised resiliency.

Resiliency vs. Reliability

You may hear reliability and resiliency used interchangeably; however, the two terms do not mean the same thing. Reliability refers to frequent and less significant events. Reliability is constrained to routine uncertainty in operating conditions, which could include temporary disruptions within a confined area of the grid. SAIDI, SAIFI, and CAIDI are all reliability indicators. Reliability focuses on high-frequency, low-impact events. Resiliency deals with low-frequency, high-impact events.

Christina Alston, Transmission Development Manager at **Georgia Transmission Corporation (GTC)** pointed out the importance of understanding resiliency not only from the utility industry viewpoint, but also how other industries look at it. For GTC, reliability is the outcome, and resiliency is how you achieve that outcome.

> *"Although the two terms often are used interchangeably, they are not the same. Reliability is commonly defined as the ability of the electric power system to deliver electricity in the quantity and with the quality demanded by end-users. Resiliency is the ability for the electric power system to withstand and recover from extreme, damaging conditions. While the two are different, your resiliency solution directly impacts grid reliability."*
>
> Christina Alston | Georgia Transmission Corporation

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The Intersection of Microgrids, Renewables, and Resiliency

In 1998, **Georgia Transmission Corporation (GTC)** installed diesel generators to provide backup generation to a rural community in South Georgia that suffered from poor reliability, with excess outages due to the exposure of a 16-mile radial 46kV transmission line to harsh elements. With the generators approaching end of life, GTC wanted to know how a microgrid stacked up as a resiliency solution compared to other solutions. GTC is actively examining four microgrid projects, most of which have some type of renewables paired with battery energy storage. Christina Alston, Transmission Development Manager, shared GTC's methodologies for evaluating microgrid alternatives and their insights around balancing the use of emerging technologies with resilience.

Methodology

GTC evaluated four resiliency solutions, which included utilizing traditional wires, developing a solar and battery energy storage system, replacing the existing diesel generators with a similar power source, or installing two new micro turbines. Each solution was evaluated on its financial, technical and operational merits, and the final solution had to make sense for generation and transmission (Is it cost effective?), distribution (Does it provide additional grid services?), and customers (Does it provide energy savings?).

FINANCIAL	TECHNICAL	OPERATIONAL
– Initial cost of project including distribution upgrades – Depreciation – On-going maintenance costs – Cost of financing – Company overheads – Financial savings due to arbitrage and transmission savings	– 35-year project life (vs. transmission wires solution) – Does it provide the same level of reliability? – How many minutes of outage time are not covered under the solution? – Is the resiliency solution a full or partial solution over the project life?	– How much training will associates need to operate the equipment? – Do we need to put in a maintenance contract for the solution? – Does the solution provide additional operational benefits beyond reliability?

Insights

The net present worth of each of the four resiliency solutions was close, however:

- As a transmission company, GTC considers a 35-year project life. When you compare the upfront cost with the asset depreciation over time, the wires alternative looks better over 35 years.
- Because this is a reliability-based project, the microgrid costs would need to be more in line with the costs of a traditional long-term wires solution to offset the capital investment.
- A reduction in battery energy storage system costs to about $290/kWh and an extension in the depreciation schedule from 10 years to 15 years would have brought the evaluated costs of the microgrids more in line with the other solutions.
- Strategically, some locations are better suited to solar and battery storage based on the stacking of benefits or arbitrage.
- Engage your financial people in the analysis. You need to know how interest rates and depreciation schedules impact the solutions you are considering.

Bottom line: Although microgrids can be used as a resiliency solution, they are not without drawbacks. From a transmission perspective, extended outages become a reliability risk. GTC would have to accept that without a prime power alternative, full reliability of a non-wires alternative is difficult and costly to achieve.

Listen to Christina Alston, Transmission Development Manager at Georgia Transmission Corporation, on Grid Talk

A Holistic Approach to Resiliency

Using a holistic approach—considering resiliency from operational, customer and planning perspectives—emerged as a common theme from the utilities that participated in *Voices of Experience | Microgrids for Resiliency*. ComEd utilized a holistic data driven approach to evaluate its entire service territory to identify potential locations for microgrid pilot projects that would improve resiliency. The approach divided the service territory into one-mile by one-mile sections outside the city of Chicago and into half-mile by half-mile sections inside the city of Chicago, and considered three key drivers:

- Power delivery infrastructure
- Critical services infrastructure
- Input from external stakeholders (i.e., DOE, Department of Homeland Security, Illinois Emergency Management Agency, and City of Chicago Office of Emergency Management and Communications)

Bronzeville was one of the sites ComEd selected using this approach. When the Bronzeville Community Microgrid is fully built, it will be the largest interconnected microgrid in the world. ComEd plans to evaluate its impacts holistically (Table 4) and has started strategic partnerships to measure the impact of resilience on communities and the grid. In partnership with Lawrence Berkeley National Laboratory (LBNL), ComEd plans to build a Power Outage Economic Tool (POET) to estimate the direct and indirect economic impact of power disruptions of various durations and geographic extents. The National Center for Disaster Preparedness (NCDP) is supporting ComEd in preparing a tabletop exercise focused on the Bronzeville Community Microgrid area to bring together emergency responders and community partners to test the broad impacts of the microgrid on resilience during a simulated long duration outage. ComEd also plans to use the learnings about integration and control of this microgrid to enhance resiliency at other sites in their service territory. (See page 13 for more information on the Bronzeville Microgrid project.)

TABLE 4: METRICS TO EVALUATE IMPACTS OF THE BRONZEVILLE COMMUNITY MICROGRID

AREAS	INDICATORS	METRICS
Energy System Resilience	Power Delivery Resilience & Performance	
	Energy Efficiency Performance	
	Emissions Performance	
Critical Infrastructure Resilience	Reliable Communication & Mobility	
	Continuity of Critical Services	INTEGRATED METRICS
	Critical Infrastructure Security	
Community Resilience	Community Economic Resilience	
	Community Health	
	Community Livability & Safety	

Source: *ComEd*

> *“We've been talking with the communities we serve about their interest in microgrids for critical infrastructure such as town halls, police stations, gas stations, hospitals, and other medical services. I think that architecture has to be designed in a way that gives resilience to those critical resources, and allows you to think through the ‘what happens if…?’ questions. When that disturbance comes to pass preventing your grid from serving consumers the usual way, you need to be ready with a “plan B” for maintaining electric service. As a utility, you ought to use the “blue sky” days of today to plan on how you're going to execute during the “black sky” days of tomorrow."*
>
> Bryan Hannegan | Holy Cross Energy

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Chris Bilby, Research and Programs Engineer at **Holy Cross Energy**, calls their approach to resiliency "blue sky benefits for black sky resilience.” The idea being that the prospective microgrid will be connected to the larger grid 99 percent of the time, so it must deliver benefits to the utility such as grid flexibility, and customer benefits such as decreased power supply costs. He also believes that if you balance DERs correctly and add distributed storage, you will be resilient. Utilities such as **Portland General Electric (PGE)** and **Los Angeles Department of Water and Power (LADWP)** are also taking a holistic approach by considering the socioeconomic benefits, renewable energy goals, and potential grid services in their development of microgrids to support resiliency.

Microgrids and Black Starts

Black start is the process of restoring an electric power system without relying on an external electric power transmission network. **PJM**, as a regional transmission organization (RTO), occasionally faces the challenge of a regional black start when major grid segments go down. Microgrids are assumed to have excess generation by design (beyond their internal dedicated loads) for resource adequacy, so PJM views microgrids as potential black start “regional assets”. Because of their black start potential, PJM has reached past local utilities to engage directly with privately-owned microgrids regarding regional integration.

If a microgrid chooses to become a regional asset, it agrees to participate in an RTO or independent system operator’s system in a more meaningful way than just selling capacity. In such cases, the microgrid can serve as a distribution system operator that can isolate if needed, and “behave” as a traditional asset for black starts within a balancing authority footprint under standards of the North American Electric Reliability Corporation (NERC). This requires black start generation system certification from both NERC and their applicable RTO/ISO (each has their own set of specific certification criteria above and beyond NERC’s baseline requirements).

Although PJM does not, some RTOs/ISOs require a microgrid’s electricity to be generated by at least two separate fuels for black start certification (the most common is natural gas with dual-fuel capability to run on oil). PJM does require microgrids to be capable of nonstop generation for a minimum of 16 hours, the longest of any RTO/ISO. This is a major reason PJM has not certified any microgrids powered exclusively by inverter-based resources (IBRs); although 16 hours for storage is technically feasible, batteries at that scale aren't yet cost effective.

One significant challenge with grid restoration and black starts at all scales (not just for RTOs/ISOs), is the balancing act of ramping up both generation and load in parallel without disrupting the grid. If a microgrid is operational by the time it is being used to help restore the larger grid, by definition, the microgrid also has local loads online to help balance its power input, thereby making it a viable black start asset.

Bottom line: Microgrids have the potential to be a black start resource with the right configuration and assets.

> *“PJM would like to encourage more microgrids and their supporting generators to apply for and meet black start certification standards. This would help realize a vision for a more resilient system where the black start framework is an interconnected web of microgrids.”*
>
> Jonathan Monken (Formerly with PJM)

TABLE 5: EXAMPLES OF GRID RESILIENCY METRICS

DIRECT	
Electric Services	– Cumulative customer-hours of outages – Cumulative customer energy demand not served – Average number (or percentage) of customers experiencing an outage during a specified time period
Critical Electrical Service	– Cumulative critical customer-hours of outages – Critical customer energy demand not served – Average number (or percentage) of critical loads that experience an outage
Restoration	– Time to recovery – Cost of recovery
Monetary	– Loss of utility revenue – Cost of grid damages (e.g., repair or replace lines, transformers) – Cost recovery – Avoided outage cost
INDIRECT	
Community Functions	– Transit time for residents to obtain basic needs (food, medicine, etc.) – Maintenance of transportation (public and private) infrastructure for evacuation
Monetary	– Loss of assets and perishables – Business interruption costs – Impact on gross municipal product or gross regional product
Other Critical Assets	Key defense facilities without power

Source: *Department of Energy Solar Energy Technology Office*

Key Insights

- For utilities, resiliency is the ability to anticipate, prepare for, and withstand major events or restore functionality to the parts of the electric grid that lose it.
- Addressing resiliency as part of utility business planning will require utilities to understand their local customers', regulators', and policymakers' main motivations for wanting more resilience.
- While reliability and resiliency are often used interchangeably, they are not the same. Resiliency can help reduce the reliability impacts of high-frequency events.
- Resiliency is related to dynamic weather or cyber risks, which can evolve very quickly and dramatically, and often are the impetus for increased utility investments.
- Resiliency has a monetary value that must be considered. The challenge is quantifying that value.
- As a tool for grid restoration, microgrids have the potential to be a black start resource with the right configuration and appropriate assets.
- Microgrids based exclusively on intermittent resources, such as solar and wind with storage, can present cost-effectiveness and feasibility challenges for longer islanding requirements.

ADDITIONAL RESOURCES:
- **Electric Power System Resiliency: Challenges and Opportunities**, EPRI, February 2016.
- Resiliency: Theory and Applications, **Argonne National Laboratory**, 2012
- State Energy Resilience Framework, **Argonne National Laboratory**, 2016
- **Valuing the Resilience Provided by Solar and Battery Energy Storage Systems NREL**, 2018

[3] Presidential Policy Directive 21 [PPD-21, Obama 2013]
https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resiliency

The Utility Role in Microgrids

A KEY MICROGRID PARTNER.

All microgrids are partnerships between the utility and the customer. Even if the microgrid is entirely privately owned and operated, if it is interconnected to the utility's infrastructure, there must be a high level of integrated operation and control of the microgrid. Sometimes, multiple partners are involved, potentially including the local government, a developer, or an independent generator. Historically, the utility built and owned electric generation and distribution grid assets, but in this new era of partnerships and customer-owned assets, the utility's role is less clear, and may vary depending on state and local rules governing utilities specifically around the ownership of generating assets. In addition, few standards exist around interconnection and compensation.

What Utilities Are Doing

- Providing technical expertise to customers and third party developers;
- Initiating and participating in pilot projects and research projects to learn how to integrate emerging technology and maximize its value;
- Engaging and educating customers on the value of microgrids and opportunities to partner on microgrid projects;
- Partnering with communities to develop projects that enhance resiliency especially around critical infrastructure and services;
- Streamlining and standardizing interconnection processes to incorporate storage and microgrids;
- Developing tariffs and other mechanisms to compensate microgrids for grid services; and
- Supporting upfront microgrid investment, particularly when the grid benefits.

Taking the Lead

Today, utilities are increasingly taking a proactive role in developing microgrids, often in response to mandates or incentives designed to support the adoption of battery energy storage technology, or to defer or avoid a costly distribution system investment. Like many utilities, **Xcel Energy** is leveraging these opportunities to invest in battery energy storage to not only learn more about integrating batteries on their system, but also to improve community resiliency. **Alabama Power** and **Holy Cross Energy** both are developing residential microgrid programs with the support of the national labs and other partners to evaluate microgrid technology and optimize controls between the neighborhood and the electric grid.

Utilities that participated in this effort took on varying roles—everything from technical consulting to developing, owning, and operating the microgrid. Regardless of the ownership structure and location, getting the utility involved early in the process to provide their technical expertise will help ensure the microgrid is interconnected and operated safely.

Embracing Innovation in Colorado

In 2018, the State of Colorado enacted the Energy Storage Procurement Act (HB 18-12700) which allows investor-owned utilities to file applications for rate-based energy storage systems of up to 15 MW of capacity by May 2019.[4] The objective is to improve resiliency within Colorado communities, support the clean energy transition and storage integration, provide grid benefits, and create clean energy jobs within Colorado.

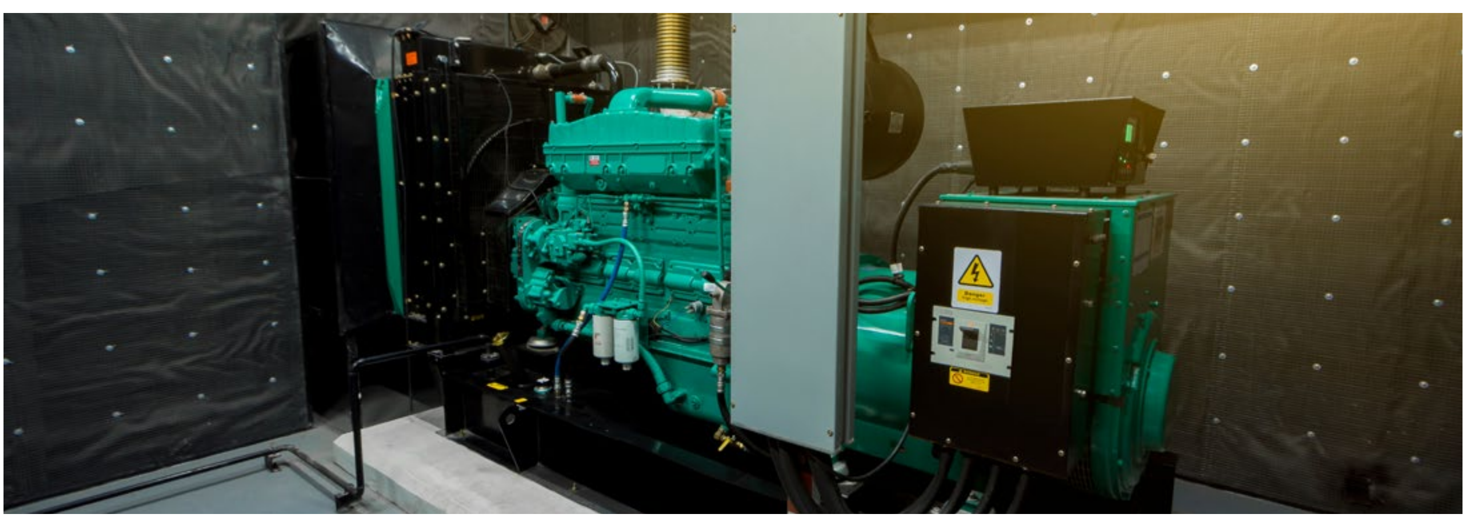
Rather than deploying one large-scale project, **Xcel Energy** is looking to deploy several small battery systems as part of their Community Resiliency Initiative. Xcel's community relations staff and key accounts managers collaborated with external stakeholders to identify potential customer sites. Xcel received applications for twenty sites in response to their solicitation. The selection process started by screening out the projects that did not serve emergency services. They ranked the remaining eleven projects based on three categories:

1. **Feasibility**. How difficult would it be to deliver the proposed system? (e.g., space requirements, safety considerations, availability of communications infrastructure and existing on-site generation)
2. **Societal Benefit and Partnership**. What is the societal value of each proposed project? (e.g., serving emergency evacuation areas, serving diverse customers, serving underserved populations)
3. **Grid Benefit**. What type of potential benefits could the battery storage asset provide to the grid? (e.g., capacity value, energy arbitrage, peak reductions, investment deferral, reducing impacts of outage to the community at large)

They ultimately selected seven sites to move forward, including: Denver International Airport's Automated Guideway Transit System, National Western Center, Denver Rescue Mission's Lawrence Street Community Center, City of Arvada Center for the Arts and Humanities, Town of Nederland Community Center, Summit County Middle School, and Alamosa Family Recreation Center. Siemens was chosen as the microgrid controller vendor and the cost to the utility for these pilot projects is $24 million. A decision on the proposal to the Colorado Public Utilities Commission (CPUC) is expected in late 2020.

Bottom line: Xcel used a cross-functional team to design the resiliency pilots and select the projects that will help the utility better understand the role microgrids may play in the future.

Listen to Ben Fowke, Chairman and CEO, Xcel Energy on Grid Talk



A Smart Neighborhood Demonstration Project

Alabama Power has partnered with a local real estate developer who is building a state-of-the-art community of 62 homes outside of Birmingham, Alabama. The builder is incorporating energy-efficient construction, advanced heat pumps, interconnected appliances, and LED lighting into each home. Additionally, the designer is weaving it all together into a microgrid that will include solar PV, battery storage, a natural gas generator, and a microgrid controller.

Three separate organizations have collaborated to drive this demonstration project forward: the Alabama Power End User Research Group, **Southern Company** (Alabama Power‘s parent company), and the marketing department at Alabama Power. The joint effort’s objectives include:

- Understanding how smart homes operate and benefit both customers and the utility;
- Evaluating microgrid technology and optimizing controls between the neighborhood and the electric grid;
- Identifying opportunities to leverage smart homes for balancing the grid; and
- Collecting feedback on how new home technology can support future utility businesses cases.

While still in its development phase, this project is a public-private partnership that includes the utilities, home builder, Electric Power Research Institute (EPRI), Oak Ridge National Laboratory, and several technology vendors.

Bottom line: Demonstration projects can teach us a lot about how emerging technology coupled with changing customer behavior will become the new “grid intelligence.”

Working with Developers and Customers

In general, if a third party or customer owns the microgrid, they conduct and lead the operations. However, when the project utilizes the utility’s infrastructure, there must be a high level of integrated operation and control of the microgrid, including when it disconnects from the grid. The operations and coordination of interconnection and disconnection are usually addressed in the interconnection agreement, the supplemental microgrid operation agreements, or service agreements between the microgrid operator and the utility. In the event that the microgrid is also a non-wires solution, the operator and utility must establish performance requirements and agreements that specify the rules around when the microgrid can disconnect and when the microgrid needs to provide grid services to the utility.

“

> ***By defining technical standards, not only are you giving clear guidance to whoever is trying to connect to your system, but you are making sure that the standards you’re referencing are following the best utility practices and industry standards."***
>
> Mamadou Diong | Dominion Energy

Consolidated Edison (ConEd) identified several potential issues and challenges associated with establishing community microgrids, as illustrated below in Table 6. The considerations range from questions around appropriate control and communications structures, tariff rates and business models, to how to handle franchise rights and DER ownership policies.

TABLE 6: POTENTIAL ISSUES AND CHALLENGES WITH ESTABLISHING COMMUNITY MICROGRIDS

ESTABLISHING COMMUNITY MICROGRIDS POTENTIAL ISSUES AND RECOMMENDATIONS
Franchise Rights & Ownership
– Recommend utility ownership of the microgrid backbone. – Encourage the use of existing infrastructure to support the microgrid. – Utility will install additional infrastructure to support the microgrid, similar to DG projects, at cost to the developer.
Control and Communication
– Con Edison would coordinate with the developer on the microgrid operations during emergency situations. – As per Con Edison's EO-2161 'Technical Requirements for Microgrid Systems Interconnected with the Con Edison Distribution System', Con Edison will exercise jurisdiction on the operations of the microgrid management system.
Tariff Rates & Business Model
– Con Edison believes only slight modifications (if any) to its existing tariff (specifically Standby Service and Buy-back Service) would be sufficient to cover microgrid projects.
Operation, Reliability & Safety
– Proposing a partnership with the microgrid developer who will own and operate the microgrid DERs at all time. – Con Edison owns and operates all other microgrid-enabling utility assets (feeders, breakers, controllers, protection, etc.). – Con Edison coordinates with the developer on the microgrid operations during emergency situations. – Microgrid operation would be in accordance with Con Edison's EO-2161 'Technical Requirements for Microgrid Systems Interconnected with the Con Edison Distribution System' and the Interconnection Agreement.

***Source**: ConEd*

> *"Newer-style microgrids that cover multiple locations may be crossing multiple rights-of-ways, multiple streets to connect different outside businesses, residents and critical customers at prisons and hospitals. As a result, there is a need for the utility to get involved as an advisor to support since all of the systems are currently supplied 100[%] by the utility."*
>
> Ahmed Mousa | Public Service Electric & Gas Company (PSE&G)

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PSE&G on the Multi-Stakeholder Process: What's the Role of the Utility?

Following Superstorm Sandy, the catastrophic 2012 hurricane that hit the east coast of the United States, utilities—not only those on the east coast—realized they must build their grids to a more robust and resilient standard. For **PSE&G**, that meant elevating some substations, transformers, and switchgear to withstand the widespread flooding that often follows severe storms. It also meant working with their customers and commission to understand how microgrids might make their system more resilient.

In 2018, the New Jersey Board of Public Utilities distributed $2 million to study the feasibility of installing microgrids in 13 town centers. The idea behind the town center microgrid program is to protect municipal services from natural disasters that may cause extended power outages. Proposals were evaluated on multiple criteria, including the use of renewable energy and storage, coordination with the local electric utility, and the town's commitment to cost sharing. Because the program takes the projects only through feasibility and design, the projects will ultimately need to seek private funding and possible government incentives to continue.

PSE&G supported the program by taking on a consulting role. Looking back at their involvement in this multi-stakeholder process, Ahmed Mousa, Manager of the Utility of the Future at PSE&G, offered these insights on the role of the utility in a multi-stakeholder process for microgrid development:

- There is no one definition of a microgrid and that can cause problems. Make sure all stakeholders understand the proposed project and all that it entails (and does not entail).
- It is more efficient to include the utility in discussions upfront. The utility can use their expertise to flag things that may not be feasible while they are still ideas and can be easily modified.
- Multi-stakeholder collaboration is important and necessary in the development of a microgrid; make sure you remove any barriers to communication.

New Jersey's town center microgrid program is ongoing. The program continues to generate more lessons and questions, including what role PSE&G will have in operating, controlling and maintaining the systems once they are online.

Bottom line: Involve the utility upfront. Utilities need to be part of the conversation at the beginning of a proposed project to offer technical assistance and solutions that may not otherwise be considered, and to ensure the safety of everyone involved in the final project.

Listen to the interview with Ahmed Mousa, Manager of the Utility of the Future at PSE&G, here on Grid Talk

Dominion Energy: 9 Rules for Successfully Interconnecting Microgrids

Dominion Energy has developed a set of internal operating rules to ensure the safe interconnection of microgrids to the distribution grid. These rules may provide a foundation for future microgrid interconnection standards, and were shared by Mamadou Diong, Engineer III at Dominion Energy:

1. Have clearly defined engineering and technical standards and requirements.
2. Build an internal team dedicated to studying DER integration and invest in their ongoing training to keep pace with emerging technology and evolving standards.
3. Engage all internal stakeholders in the interconnection process such as IT, engineering, operations, billing, customer service, etc.
4. Ensure any interconnection requirements follow industry standards (IEEE 1547, IEEE 519, IEEE 1453 Standards, etc.) and best utility practices.
5. Make microgrid interconnection practices and requirements a living document that keeps pace with changing technology.
6. Take a methodical approach to embracing changes (even if it takes more time).
7. Share what you are learning and learn from your peers.
8. Rely less on screening and more on detailed studies.
9. Trust engineering judgements when faced with unknowns and use a questioning attitude.

Bottom Line: Take the time you need to interconnect new resources safely and reliably.

> *“You may not know everything about the implication of connecting this new microgrid design that you've never seen before, but as engineers, we learn to appreciate and understand that, if you do x, you get the outcome y. If you have the feeling, your engineering judgment is telling you there may be something or we need further review, do it.”*
>
> Mamadou Diong | Dominion Energy

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Pilots to Programs: Developing Programs and Executing Contracts for Win-Win Microgrid Projects

North Carolina EMC (NCEMC) is the wholesale power provider for the 26 member-owned cooperatives that provide services in 93 of North Carolina's 100 counties. NCEMC has partnered with their cooperative members to execute win-win microgrid projects providing cost savings, sustainability and resiliency to their customers. In a *Voices of Experience* virtual discussion, John Lemire, Director of Grid Management at NCEMC called these partnerships a win-win for customers and utilities. So far, they have three existing microgrids, Okracoke Island, Butler Farms, and Herons Nest, and two more under development.

Even though the concept of microgrids was new to **NCEMC** and their members, NCEMC's board adopted the policies that allowed the cooperative to move forward and develop the microgrids. The first two microgrids started by partnering with the host distribution co-ops and looking for locations where customers wanted more resiliency or to expand their environmental commitment. NCEMC was then able to work with their member cooperatives and their customers to find other locations where microgrids could benefit the grid. These include the Heron's Nest Project, which is a sustainable neighborhood where the developer put in solar plus storage and the utility provides the controller; Rose Acre Farms, a huge agriculture facility with a sustainability goal; and a resilient neighborhood called Eagle Chase.

Insights from NCEMC
Breaking new ground always comes with challenges and unforeseen hurdles.

- Focus on communications. You cannot over communicate with your partners and stakeholders.
- Design your use cases and then make sure you implement on them.
- Discuss the ongoing support for the microgrid upfront. Who will control and maintain it once it is operational?
- Be flexible, learn as you go, and make the changes needed along the way.
- Listen to your partners so you understand what they want out of the microgrid project or what is important to them, and then tailor the contract to meet their needs in addition to your organization's needs.

Bottom line: Microgrids are an important component in **NCEMC**'s energy tool kit that allows them to work with their members to meet their customers' needs.

> *"This is new territory, so contract negotiations are going to take some time… the key is to talk to your partners first and hear what it is that they want out of doing a microgrid project or what's important to them and then tailor the contracts to meet their needs."*
>
> John Lemire | NCEMC

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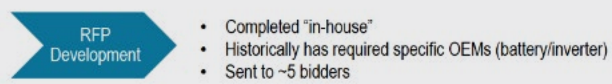
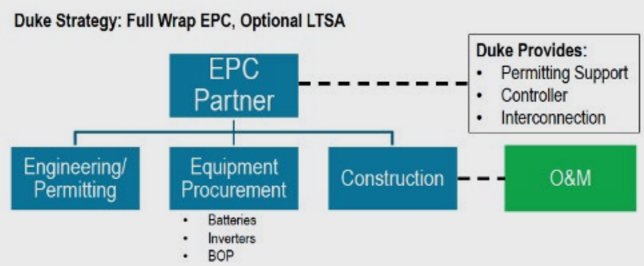
Making Microgrids Happen: Roles and Responsibilities of Utility Procurement, Contract Execution, and Project Development

Duke Energy, with its long history of building large baseload facilities, is now leveraging its expertise in engineering and project management to deploy microgrids, often in partnership with customers, communities, and third-party EPCs. In addition to providing increased reliability and resiliency to their customers, these projects are helping Duke's engineering team to build its knowledge of battery energy storage systems—understanding how batteries work, discharge rates, charge rates, degradations curves and how to work with their vendors.

Duke Energy's procurement strategy develops the request for proposal (RFP) in house. Before the RFP is developed, the engineering team spends time identifying the problem, analyzing the data and selecting a solution that fits the problem and the location. While the engineering, procurement, and construction vendor (EPC) will purchase the battery for the project, Duke's engineers determine the exact battery size and the use cases; e.g., improving reliability, peak shaving, frequency regulation, etc., that will be specified in the RFP. Duke Energy's RFPs typically take 2 to 3 months to develop, which differs from a strategy of identifying the problem and asking vendors to propose solutions.

Duke Energy's Procurement Strategy





Bottom line:

- Ensure appropriate time is provided for procurement
- Establish relationships with battery OEMs
- Evaluate EPC contract experience with battery OEMs

"Establishing relationships with battery vendors is key to ensuring the use cases identified can actually be executed. It is important to ensure there is appropriate time for procurement and contracting for these projects."

Adam Nygaard | Duke Energy

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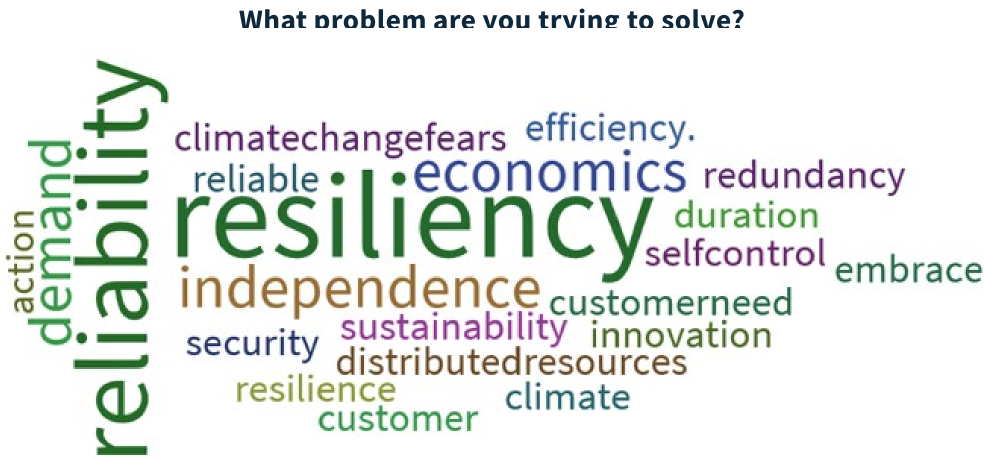
Key Insights

- Utilities have a key role in microgrid development and need to be involved in the discussions as early as possible to provide technical support and guidance toward the right solution to enhance resiliency and support customer goals.
- Make sure everyone involved in the project ideation and design understands what the microgrid project entails and what it does not include, technical issues around interconnection and disconnection, and tariffs, compensation, and upfront payments for grid services that may be available.
- Utilities are taking advantage of state and federal incentives to study how they can best utilize the combination of battery storage, solar generation, and other controllable DERs to better understand how to they can optimize grid and customer value.
- Interconnecting microgrids is complex. Make sure industry and utility engineering standards are clear and are followed, the right internal and external people are involved, the process is flexible to keep pace with and embrace changes, best practices are shared with and accepted by utility peers, and detailed engineering studies are developed and relied on.
- Identify ways utility staff can learn more about microgrids and their components; leverage your engineering expertise to learn first-hand how components and systems work.

[4] https://www.transmissionhub.com/articles/2019/05/public-service-company-of-colorado-seeks-approval-of-community-resiliency-initiative.html

Siting a Microgrid

WHERE THE PROBLEM LIES.



Survey results from February 2020 Voices of Experience workshop in Denver, CO.

A microgrid is a tool that solves a problem. If the problem belongs to a customer or is intended to meet a customer's goal such as greater resiliency or cleaner energy, the microgrid is likely to be located behind the meter and primarily used to address the needs of the specific customer. If the microgrid is solving a problem affecting more than a single customer, such as a city or community-level challenge or goal, the microgrid likely will be built in front of the meter to support critical infrastructure and sites that serve the needs of the entire community. In either situation, customers are likely the driver of microgrid development, and the assets they bring to the project will dictate the site. However, utilities are increasingly using a variety of data-driven processes, decision criteria, and stakeholder engagement methods to identify microgrids sites that will maximize their value to both the grid and their customers.

Here are some of the siting considerations that affect decisions around microgrid siting:

- Existing infrastructure
- Customer partnerships
- System constraints
- Geographic constraints
- Socioeconomic status

Existing Infrastructure

Siting microgrids around existing generation—both centralized and distributed—can provide cost- effective opportunities to provide local resilience. **PG&E** is currently doing this by utilizing the Humboldt Bay Generation Station to power multiple substations within a specified electrical boundary if and when transmission line losses occurs. **Colorado Springs Utilities (CSU)** is exploring siting several microgrids on the military bases in their service territory that will utilize their existing natural gas infrastructure. If sited on the installations, Colorado Springs Utilities also intends for the units to provide resilience to the local military bases via a microgrid in the event of a long-term widespread outage.

> *"If there is already a distribution connected biomass, solar farm, etc. that might make for a good location for a microgrid because you can utilize and augment existing generation already in the area and a lot of the work is already done."*
>
> Quinn Nakayama | PG&E

Customer Partnerships

Microgrids are usually built in partnership between the customers and the utility because the assets generally are built on the customer's property, even if the microgrid is owned by the utility. In Oregon, **Portland General Electric (PGE**) is partnering with the City of Beaverton on a microgrid that provides resiliency to the city's critical services. The system will also allow PGE to study how to use batteries to achieve a number of ancillary objectives. The new Beaverton Public Safety Center, as part of the microgrid, will incorporate a PV system owned by the city and PGE will provide a battery and controller that will allow the Center to island during an outage event.

To keep their critical infrastructure energized during natural disasters-caused outages, municipalities are developing their own resiliency plans. By including the local utility in the planning process, municipality partnerships can result in increased benefits to both the community and the utility.

System Constraints

American Electric Power (AEP) is developing a Reliability Mapping Tool that uses data science, visualization and analytics to identify "innovative grid solutions," including the optimal locations for microgrids and energy storage on their network. Features related to reliability data include:

- Viewing and quantifying outage and reliability hotspots through Customer Minutes of Interruption (CMI/CI);
- Viewing and quantifying reliability indexes including SAIDI, CAIDI, SAIFI, and CEMI; and
- Viewing fault causes such as vegetation, weather, and equipment failure in visual format.

One of the use cases for AEP's tool is a quantitative comparison between microgrids and traditional solutions for outages to determine the least cost solution. Using new analytical tools like the Reliability Mapping Tool, AEP can better assess where microgrids and DER could solve reliability problems at a lower cost than traditional wires only solutions. As the cost of technology decreases over time, more of these opportunities will become economical.

San Diego Gas & Electric's (SDG&E) Borrego Springs Microgrid and **North Carolina EMC's (NCEMC)** Okracoke Island Microgrid are other examples of microgrids that provide resiliency to communities otherwise supplied by a vulnerable transmission line.

> *"As a vertically-integrated, regulated utility, I think we're closest to the data to understand where the problems on our grid lie, and so I think it honestly makes sense for us to be the ones that analyze that data, determine what the issue is, and then analyze different alternative solutions to solving that problem."*
>
> Adam Nygaard | Duke Energy

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Geographic Constraints

Islands, mountains, and vast expanses of land are some of the geographic constraints that make building transmission lines impractical and very expensive. Remote communities are typically served by microgrids that are not connected to a larger grid. However, these systems must provide the same reliability and resiliency as connected microgrids. **Cordova, Alaska** is a remote community that recently added a battery energy storage system to their municipal microgrid. Cordova's objectives were three fold: 1) to increase the town's resiliency, 2) to decrease its dependence on diesel fuel, and 3) to provide voltage and frequency support. **Holy Cross Energy's (HCE)** service territory's vulnerability to wildfires, and the rough Rocky Mountain terrain make it expensive to build transmission. Thus, HCE overlays wildfire impact zones on their service territory to identify locations were DER assets could provide resiliency for communities at higher risk for an outage caused by wildfires.

Microgrid Site Selection Methodology for Wildfire Resiliency

Southern California Edison (SCE) has developed a site selection for its public safety power shutoff (PSPS) microgrid pilot program. The approach is intended to determine where community or multi-customer microgrids have the best potential to cost-effectively mitigate PSPS impacts on their grid and to their customers. The site selection methodology is comprised of four steps:

1. Begin with high frequency PSPS circuits. This step begins with looking at circuits that were preemptively shut off due to high risk of wildfire impacts.
2. Filter for locations that can safely remain energized during PSPS. This involves looking at areas that are not designated in Tier 3 – high risk to wildfire.
3. Screen out locations that already have other planned mitigations. Other planned mitigations include insulation of transmission and distribution lines, building transmission system redundancy, hardening substations and feeders, and managing vegetation.
4. Prioritize candidate locations based on key criteria and establish a shortlist.

Bottom line: Prioritize the safety of your customers and grid when selecting potential microgrid sites.

Listen to Microgrids as a Tool for Wildfire Resiliency featuring 3 California utilities here on SmartGrid.gov

Socioeconomic Status

Energy equity is gaining the attention of communities, utilities, and regulators, especially when resiliency is one of the goals. **LADWP** has partnered with the LA Department of Recreation and Parks to create microgrids at community centers in low-income communities. The goal of these collaborations is to provide cooling centers on dangerously hot days and phone charging stations if power is out. **ComEd's** Bronzeville Microgrid is located in an economically diverse community that includes the Chicago Police headquarters, a library, several high schools, senior citizens' homes, and public housing.

In Oregon, **Portland General Electric** initially planned to cast a wide net and request input from a dispersed array of potential stakeholders on if they wanted to be part of the microgrid. Following their realization that most stakeholders would have limited information about their options, Portland General Electric developed a set of criteria, which they called a Suitability Analysis, to define sites that "are most desirable for a resiliency solution," and gauge the interest of stakeholders in those locations. While Portland General Electric narrowed down the potential solution set prior to stakeholder engagement, they made engagement a central component of the final siting decision process. In addition to the initial Suitability Analysis, PGE has since included the CDC's Social Vulnerability Index as a key input into their thinking around microgrid siting, especially as it leverages work supporting diversity, equity, and inclusion.

> *"[We] have relationships with the [Oregon] Office of Emergency Management [(OEM)]and other resiliency planning entities around the state. We have relationships with local governments. And so we sat down with some of those individuals and talked through what we're intending to do, asked them if they had any sites that they thought would be interesting or viable for this project, and then we also showed them what early analysis we did, the suitability analysis to identify some sites that we thought were interesting."*
>
> Darren Murtaugh | Portland General Electric

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TABLE 7: GIS SUITABILITY ANALYSIS USED BY PGE TO IDENTIFY OPTIMAL MICROGRID LOCATIONS

LOCATION CRITERIA	DATA	METRIC
Near a critical facility	– Hospitals – Law Enforcement – Fire Stations – Emergency Operation Centers – Public Schools – Water Treatment	Location only suitable within 1,000 ft: – Hospitals - High – Law Enforcement - Medium – Fire Stations - Medium – Emergency Operation Centers - High – Public Schools - Low – Water Treatment - Medium
Near a distributed energy resource	Portland General Electric Generator Data	Location only suitable near a generator: > 50 kW within 1,000 ft - High > 1 MW within 3,000 ft - High > Everything else – Low
Not a flood zone	FEMA SFHA Flood Hazards	Location not in flood hazard area. Flood hazard areas were used as a mask in this analysis
Low landslide susceptibility	DOGAMI Landslide Susceptibility	Location in a low DOGAMI ranked landslide susceptibility area
High population density	Census Bureau American Community Survey Population Data	Location in top 50th percentile of population density by block group
An underserved community	Census Bureau American Community Survey Median Income Data	Location in bottom 25th percentile of median income by block group

***Source**: Portland General Electric*

Key Insights

- It is important for the utility to understand what problem the customer is trying to solve.
- Engage commission staff, community leaders, influencers, and interveners early in the process will help ensure that you address their concerns early in the process.
- Use data science and analytics to identify areas on your system where microgrids can optimize the benefits to the system, and then share this with your stakeholders.
- Cast a wide net when looking for project partners and potential microgrid sites, but make sure your stakeholders understand the full spectrum of benefits that microgrids offer.
- Leveraging existing infrastructure and assets may lower the cost of a microgrid helping to make it more economical to customers and the utility.
- Several utilities have found that microgrids can be least-cost assets in remote locations, instead of replacing aging infrastructure that experiences frequent outages, or where geographic constraints like mountains, water, and vast land plots, exist.
- Communities are increasingly focused on energy equity and considering how microgrid siting can bring underserved community benefits.

The Economics of Microgrids

HOW MUCH DOES IT COST?

The primary value proposition of microgrids is their ability to island and provide resiliency. (See The Value of Resiliency starting on page 20 for further discussion on this topic.) Since microgrids operate in normal, grid-connected mode 99% of the time, even when a value for resiliency is considered, microgrids are rarely economic when solely providing resiliency benefits. The economics of a microgrid project primarily come from operating in normal (grid connected) mode and delivering benefits beyond resiliency to the customer and/or the grid. When the microgrid captures multiple value streams associated with energy savings for customers and grid services such as lowering customer peak demand, capacity value, and voltage and frequency support, the microgrid is more likely to make economic sense. While there are ways to monetize the benefits when microgrids are grid connected, there are challenges associated with valuing resiliency, and there is the question of socializing the costs.

> *"There's a recognition that some of these projects might not be 100% cost effective right now. We don't know what we don't know. The whole point is not to use that as a barrier that keeps us from investing in storage and learning what storage can do for the system."*
>
> Darren Murtaugh | Portland General Electric
>
> Listen on Grid Talk ►

The Cost-Benefit Analysis

Calculating both the costs and the benefits of microgrids present challenges to understanding the economics of microgrids. The cost of developing a microgrid is difficult to pin down because project costs vary based on location-specific factors including the regulatory environment, customer type, assets associated with the proposed microgrid, land availability, and fuel source to name a few. For example, microgrid development in the northeast is thriving in the large commercial and industrial sectors because it has moderately priced electricity, a "microgrid friendly" ISO, and a demand price structure that considers reliability and energy cost savings. Community or public purpose microgrids are having a harder time making economic sense largely because the value of resiliency is not yet quantifiable. Unless the benefits of resiliency can be monetized and included into a benefit-cost, least-cost, or least-risk analysis, microgrids at current equipment cost structures are difficult to justify economically.

However, some commissions are starting to accept cost analyses that have used the **Interruption Cost Estimate (ICE)** calculator, an online tool developed by the Lawrence Berkeley National Laboratory (LBNL) to estimate the cost of outages. To better project the direct and indirect costs of long-term outages, LBNL is now working on building a prototype extension of the ICE calculator called the Power Outage Economic Tool (POET). Still, the lack of standards around monetizing the benefits of microgrids is a barrier to financing proposed projects.

> *"How do you value resiliency? This is a critical issue for the industry. I know there are several calculators out there but are any of them accurate in valuing resiliency over a period of time and accepted to be used? I believe when there is an agreement on the value of resiliency it will open all sorts of microgrid possibilities. Once this question is resolved we can solve the problem of how to value and pay for resilience."*
>
> Steven J. Casey | Eversource Energy

ICE Calculator

The Interruption Cost Estimate (ICE) Calculator is a tool designed for electric reliability planners at utilities, government organizations or other entities that are interested in estimating interruption costs and/or the benefits associated with reliability improvements.
https://www.icecalculator.com/home

How much does a microgrid cost?

Microgrids come in many sizes, configurations, applications, and purposes. Estimating the cost to develop one or even a cost range is not straightforward. According to one microgrid technology vendor, it is kind of like asking, “What does a house cost?” Similar to houses, many factors contribute to an overall cost of the microgrid, including—but not limited to:

BACKUP POWER DURATION:

The microgrid’s capability to provide power during a grid outage duration is a key factor in both the design and cost. In general, the longer the backup capability, the more expensive microgrid design.

> *“The first question we ask – and we call it ’the fours’ – is how long do you want to island? Do you want to island for four hours, four days, or forever? I think that's an important first step—to really understand what they are trying to get out of their microgrid.”*
>
> Chris Bilby | Holy Cross Energy

PRIMARY BACKUP RESOURCE:

The way a microgrid generates backup power is also a critical cost factor. Generally speaking, long-duration (i.e., a day or more) backup power provided by a supply of fossil fuels such as onsite diesel or natural gas is likely less expensive than a technology mix of renewables and battery storage. One utility noted they were looking for a microgrid that was primarily clean energy based, while also seeking long operational capabilities and costs comparable to fossil fuel-based solutions. “We are asking for a unicorn,” the speaker admitted.

SECTOR AND SCALE:

The sector in which the microgrid operates also plays an important role in the cost of the microgrid because rates and power quality needs vary. Microgrids that are more geographically expansive generally require more investment than limited scale microgrids. All else being equal, full backup power services are also typically more expensive than a design type focusing instead on limited, but critical loads.

EXISTING INFRASTRUCTURE:

Siting a microgrid near existing infrastructure such as a natural gas supply or centralized or decentralized generation can lower the overall cost. For industrial sites, existing infrastructure may allow the design to utilize thermal energy or waste heat for cogeneration purposes. This is commonly considered for microgrids at manufacturing facilities, wastewater treatment facilities, and hospitals.

OVERALL MICROGRID COMPLEXITY:

A 2018 study by the National Renewable Energy Laboratory (NREL) categorized microgrid costs as a function of their overall complexity according to six increasing levels of costs. In this analysis, the mean normalized total microgrid costs ranged from about $2 million/MW to $4.4 million/MW. The complexity can encapsulate all of the previously noted cost factors and many more such as regional electricity price and exposure to grid outage events (frequency and magnitude). Controllers add to both the complexity and cost of a microgrid, with the NREL study reporting microgrid controller costs ranging from $6,200/MW-$470,000/MW with a mean of $155,000/MW.

Battery Energy Storage Systems

Integrating battery energy storage is one of the drivers of microgrid development for the utilities that participated in the *Voices of Experience* discussions. Utilities are taking advantage of state and federal incentives to study how they can best utilize the combination of battery storage, solar generation, and other controllable DERs to provide grid services. Grid interconnected batteries can provide distinct system services that have market value as well. Utilities are increasingly seeking to understand and implement the multi-purpose capabilities of batteries for their customers. For more information on potential battery energy storage services, see Appendix B.

While the cost of the battery can be a significant factor in the overall cost of the microgrid, average global lithium-ion battery pack prices have declined significantly since 2010 according collected by Bloomberg News Energy Finance as shown below.

Lithium-ion battery price survey results: volume–weighted average Battery pack price (real 2018 $/kWh)

***Source**: Bloomberg New Energy Finance*

Value Stacking

"A microgrid makes sense when you can stack benefits--green initiatives, energy savings, peak reduction and flexibility… - the business case makes a lot more sense when you are able to stack benefits."

Christina Alston | Georgia Transmission Corporation

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Value stacking is defined as the bundling of grid applications, creating multiple value streams, which can improve the economics of a microgrid.[5] Because grid-connected services drive the majority of the economic benefits of microgrid projects, identifying the values that come from these services is the key to financial viability.

Value streams from grid-connected services include reducing customer or system peak demand, capacity value, providing grid reliability or energy services, deferring or replacing traditional grid investments, reducing emissions, and integrating DERs. Utilities, customers, and third-party developers are beginning to explore innovative financing techniques and business models to monetize these microgrid services, like participating in the wholesale market and entering into non-wires alternative agreements.

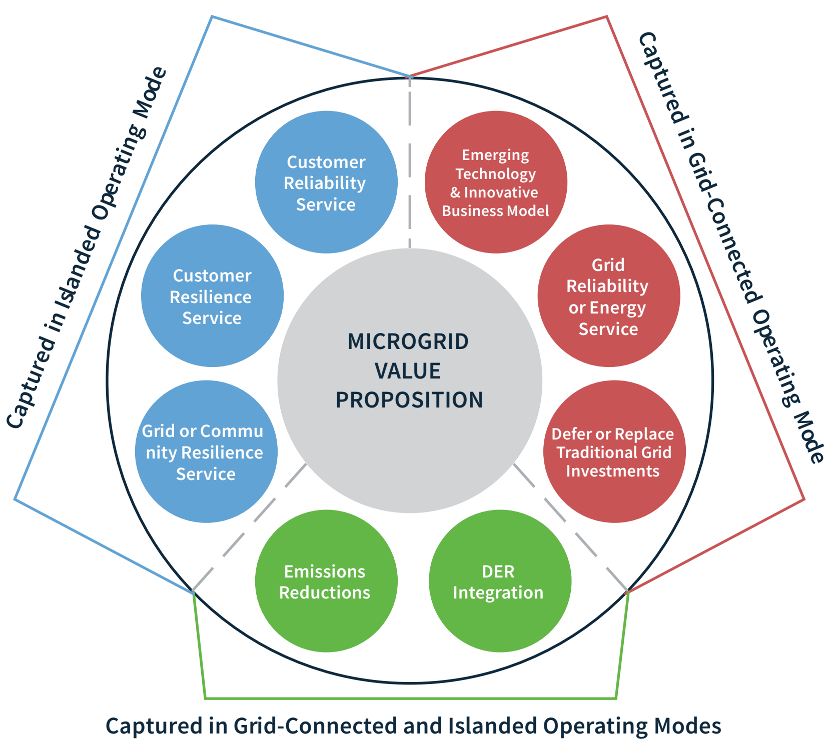
What Utilities Value

A sample of 30 utilities were asked to rank the value of different microgrid characteristics. The data shows that utilities most value the ability of microgrids to provide grid and community resiliency. Second, they value a project s ability to demonstrate emerging technologies and innovative business models, as well as to facilitate the integration of DERs. The utilities did not value emission reductions or customer reliability service highly in the context of microgrid characteristics.

MOST VALUED	SOMEWHAT VALUED	LEAST VALUED
– Providing a grid or community resilience service – Demonstrating emerging technologies and innovative business models – Integrating DERs	– Providing a customer resilience service – Deferring or replacing traditional grid investments (non-wires solution or alternative)	– Providing a grid reliability or energy service – Providing a customer reliability service – Reducing emissions

Value streams are dependent on microgrid operations. The majority of the time, operating in normal, grid connected mode, microgrids can help communities meet their green energy mandates, realize energy savings, reduce peak demand, and provide flexibility to help balance and optimize the larger grid. Microgrids can also provide grid resilience services, offering societal value to all end-use customers with the provision of power to facilities such as hospitals, police stations, and water treatment plants. When operated in emergency islanded mode, microgrids can provide resilience and reliability services to customers within the microgrid boundary, offering certain customers a needed insurance policy against economic losses from major storms or cyber-attacks on the grid. Figure 3 shows microgrid value streams mapped to operating modes.

FIGURE 3: A SUMMARY OF MICROGRID VALUE STREAMS MAPPED TO OPERATING MODES



***Source**: Smart Electric Power Alliance, 2020*

PGE categorizes microgrid value streams by bulk system services, transmission and distribution (T&D) services, and customer services as shown in Table 8. PGE is planning to utilize their microgrid resources for benefits now and into the future.

TABLE 8: TYPES OF VALUE STREAMS FROM MICROGRIDS

Bulk System Services	**Generation Capacity**	The planning value of generation capacity to meet IRP or day-ahead capacity needs
	Black Start	A NERC resource supporting widespread system restoration as a part of PGE's official Black Start Plan
	Regulation	Regulating resources responsive to the system's ACE signal for compliance with NERC BAL-001
	Load Following	Economic dispatch of a participating resource in the Western Energy imbalance Market (EIM)
	Contingency Reserves	Spinning and non-spinning reserves required for compliance with NERC BAL-002
	Frequency Response	Resources to help stabilize and recover WECC frequency excursions in compliance with NERC BAL-003
T & D Services	**Transmission Congestion Relief**	Placement of energy resources to relieve congested transmission paths during periods of high system demand
	Transmission Upgrade Deferral	Placement of energy resources to support reliability for a portion of the transmission system, thus delaying the needs for upgrades
	Distribution Congestion Relief	Placement of energy resources to relieve congested distribution circuits during periods of high demands
	Distribution Upgrade Deferral	Placement of energy resources to support reliability and power quality on the distribution system, thus delaying the needs for upgrades
	Volt-VAR Support	Energy resources contributing VAR support to the distribution system for improved voltage management and power factor correction
Customer Service	**Demand Charge Management**	Behind-the-meter (BTM) resources capable of reducing facility demand charges through peak shaving
	Retail Energy Time-Shift	Behind-the-meter (BTM) resources capable of time-shifting metered energy according to time-of-use (TOU) schedules
	Reliability (Outage Mitigation)	Placement of energy resources and back-up supply to mitigate against customer outages

Source: *Portland General Energy*

Financing and Business Models

As microgrid technology emerges, so are the financial and business models used to fund and operate them. In addition to rate recovery, which may be an option for some IOUs, utilities are developing innovative mechanisms to finance microgrids.

> ***"100-year old utility business models are not going to sustain into the future. In order to push innovation as we look to a more distributed energy future, we need stakeholders to listen and to buy-in. The challenge is using innovative distributed solutions without compromising delivery of secure, reliable and affordable electricity."***
>
> Ettore Ciampa | American Electric Power (AEP)

PUBLIC/PRIVATE PARTNERSHIPS

Many projects—especially those demonstrating battery storage and other DERs—use federal and/or state grants and financial partnerships with cities and customers. One example of a partial city investment is where a city purchases components that will become part of the microgrid, such as installing PV on a public building. A partnership with a customer might include joint ownership or a land-lease agreement to reduce some of the financial burden.

> *“Identify mutual goals with possible partners, leverage existing relationships with communities to identify good partners and select a partner that you have or can develop a successful working relationship with.”*
>
> Andre Gouin | Xcel Energy

MARKETS AND TARIFFS

Markets and tariffs can unlock the grid and customer benefits of microgrids. During normal blue-sky operation, grid services can be monetized through wholesale energy market participation, capacity markets, reducing peak demand charges, wholesale ancillary services, or entering into a distribution non-wires alternative contract with a utility. During emergency islanded operations, microgrids can provide resilience services for the customer or the entire system.

Holy Cross Energy (HCE) uses tariffs to enable value streams associated with distribution flexibility by providing incentives for customers to own DER and microgrid assets while allowing utility control. HCE uses their access to low-cost capital to invest in DERs the same way they make capital investments in poles and wires. They then created program offerings that allow their customers to purchase the DERs through “on bill financing” so in effect, the customer is in a lease-to-own contract with the utility. This model was a true partnership, since the customer permitted the utility to control these behind-the-meter assets.

FIGURE 4: HCE PROGRAM OFFERINGS

Distributed Energy Resource Service Agreement (DERSA) Low interest on-bill payments for DERs	**Distribution Flexibility (DF)** Credit for allowing HCE to control DER assets
Peak Time Rewards (PTR) • Credit for voluntary reduction in consumption during forecasting peak events • Pilot complete. March 1 available to all members	**Dynamic Renewable Pricing (DRP)** • Credit for voluntary increase in consumption during forecasted oversupply" events • Pilot starts March 1
Time of Use (TOU) Method of measuring and charging a member s energy consumption based on when energy is used	**Purchase Renewable Energy (PuRE)** The green pricing program

***Source**: Holy Cross Energy*

> *“That's where I think some innovative rate structures can provide compensation for the benefits that DERs provide: peak load reduction, voltage regulation, some microgrid and resilience capabilities. I think we can be creative about how those services can be paid for in a way that benefits both the consumer and the utility.”*
>
> Bryan Hannegan | Holy Cross Energy

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Other utilities, like **ConEd**, take a different approach and work within the confines of existing tariffs to provide microgrid customers in New York options to choose from based on what makes sense. Third parties and/or customers who are operating microgrids can monetize energy grid services through wholesale energy market participation, wholesale ancillary services or entering into a distribution non-wires alternative contract with a utility. In California and Hawaii, utilities such as **HECO** and **PG&E** are developing microgrid tariff structures to compensate microgrids for providing resilience services. Although microgrid tariffs are in the early stages of development, they provide a mechanism to monetize microgrid services which can increase their financial viability.

ConEd's Existing Tariffs Used for Microgrid Compensation

- Standby Service
- Standby Pilot Rate Program (Rider Q)
- Electric Buy Back (SC 11)
- Wholesale Distribution Service

Who Pays and Who Benefits?

The regulatory compact, which states that utilities have an obligation to serve and are allowed to recover investments through socializing of rates, introduces the microgrid cost recovery problem. The dilemma is characterized by two simple questions: who benefits from the microgrid, and who pays for the microgrid?

RATE-BASED COST RECOVERY

One perspective suggests that microgrids can and do have benefits to all customers and the grid as a whole. They cite the benefits of utility learnings and experience from the emerging technology class, peak load reduction, capacity value, direct technical services to the grid such as frequency regulation, and community-resiliency benefits like backup power capabilities to support critical infrastructure (e.g., fire stations, cooling centers, etc.). This perspective favors ratebasing microgrid costs to all utility customers, as is typically done with other grid assets. While the Illinois Commerce Commission (ICC) granted cost recovery to **ComEd** on the basis of a demonstration project, Maryland regulators rejected **BGE and Pepco's** proposal on the basis that it was not successful in demonstrating the microgrid benefits into the community enough to allow for socialization of cost. According to their 2015 microgrid proposal filing, BGE proposed a surcharge on all its ratepayers to recover the cost of a $7 million, 2 MW microgrid, as well as a $9.2 million, 3 MW microgrid, both of which were rejected. In Pennsylvania, **PECO** also intentionally withdrew its microgrid filing with the commission based on similar concerns.

> ***"In October of 2016, we withdrew our microgrid filing with the PUC to engage in collaborative discussions with stakeholders regarding issues such as utility ownership of distributed generation assets necessary to operate the microgrid, as well as the size and scope of the project."***
>
> George Sey | PECO

JOINT INVESTMENT MODELS

A more novel perspective encouraged leveraging multiple sources of financing, striking a balance between individual customers, utility, and public sources of funding. In this model, one entity does not cover the overall microgrid costs; instead, costs were split into portions that benefit the utility or grid as a whole, and those only supporting the customers within the microgrid area. These types of partnerships may include a combination of federal grants, state grants, partial investments from cities, unique partnerships with customers, and lastly, traditional cost recovery. **ComEd**'s Bronzeville Community Microgrid and **SDG&E**'s Borrego Springs are using this model.

HYBRID MODELS

Several other proposed billing alternatives generally strike a balance between the individual customer and the "all-customers" cost recovery mechanisms. In one model, cost recovery is borne by customers in the immediate geographic range of the microgrid at one rate, as well as adjacent customers who are near the microgrid and can relatively easily travel to the islanded grid in an outage that are charged a presumably lower rate. In another model, the overall microgrid costs are not decided on an all or individual basis, but instead are split into portions that benefit the utility or grid as a whole, versus those only supporting the customer within the microgrid area.

The gap is closing, but a lack of regulatory clarity around asset ownership and microgrid operations exists. Where IOUs are allowed to own generation assets, it usually helps the value proposition. The Northeast and Mid-Atlantic have a large presence of wires only IOUs. When it relates to microgrids, asset ownership is a key challenge. There is a general trend of wires only utilities owning energy storage and procuring generation through independent power producers. The regulatory landscape in deregulated states such as MA, NJ, NY, CT, RI, and PA allows for third party electricity supply, which has created a market for non-utility owned microgrids. Utilities see this as a potential threat to the safety and reliability of the grid if not done properly.

Key Insights

- Because most of the time the microgrid is connected to the grid, the economics are primarily driven by grid-connected services; identifying and "stacking" the values that come from these services is the key to financial viability.
- Microgrid project costs vary on location-specific factors and can be complex to estimate. Some considerations include backup power duration, the primary backup resource, scale, and overall microgrid complexity.
- The financial analysis should account for the full value and cost of the reliability and resiliency to the community (including peak demand reduction) and grid services it will provide to the utility (system support, capacity value, and other grid services).
- Unless the benefits of resiliency can be monetized and included into a benefit-cost, least-cost, or least-risk analysis, microgrids at current equipment cost structures are difficult to justify economically.
- Societal values are challenging to quantify. The value of demonstrating emerging technologies and innovative business models, integrating DERs, and reducing emissions are hard to estimate and monetize, but these should be noted where applicable.
- Most microgrid projects to date have utilized multiple funding sources, including federal or state grants, customer or community resources, and member or ratepayer cost recovery. Joint investment spreads the risk and garners wider support toward success because more stakeholders benefit.

ADDITIONAL RESOURCES:

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• Distributed Energy Resources Capabilities Guide, SEPA, September 2018. https://sepapower.org/resource/distributed-energy-resources-capabilities-guide/
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[5] **https://sepapower.org/resource/distributed-energy-resources-capabilities-guide/**

Appendix A

PARTICIPATING COMPANIES

This list includes companies that participated in this project by attending a workshop or online discussion, or participating in an interview. The leadership team would like to thank everyone who supported this initiative, especially those who shared their experience with the readers of this guide.

Thank you to the Steering Committee members who provided insights and direction for this project:

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Reading Municipal Light Department
Rocky Mountain Power
Sacramento Municipal Utility District
Salt River Project
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Silicon Valley Power
Snohomish County Public Utility District
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Tampa Electric
Taylor Electric Cooperative
Tennessee Valley Authority
Toronto Hydro
Tucson Electric Power
Virgin Islands Water and Power Authority
Wake Electric Membership Cooperative
Wellesley Municipal Light Plant
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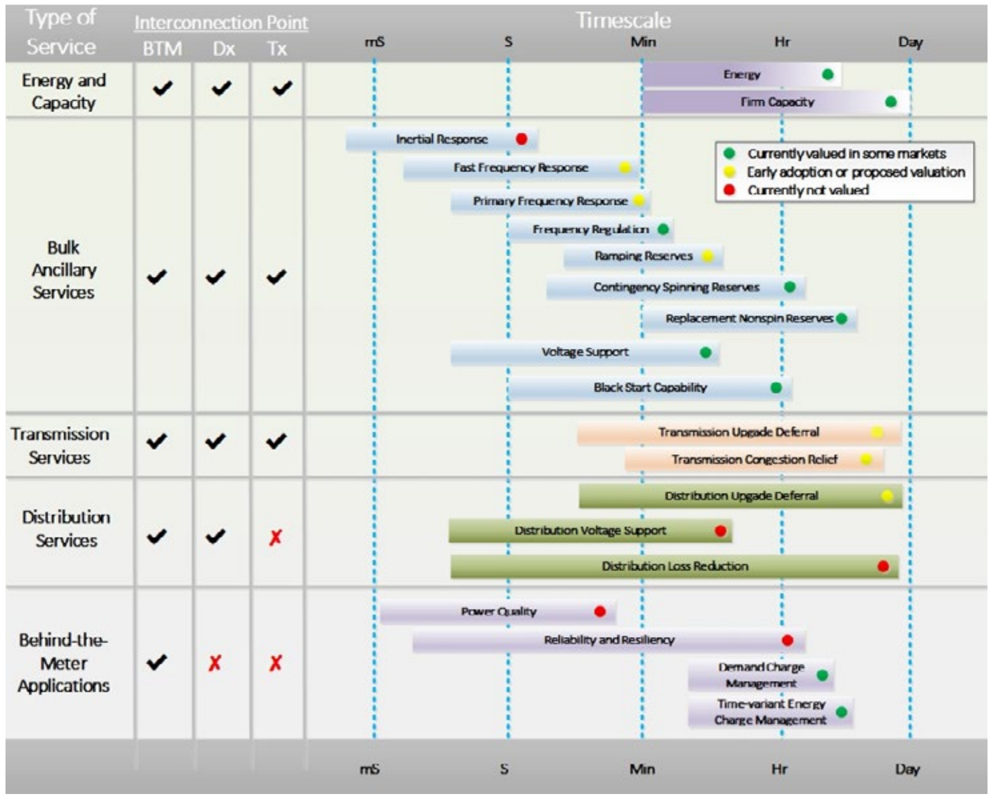
Appendix B

BATTERY ENERGY STORAGE SYSTEMS

Grid-interconnected batteries can provide distinct systems services that have market value. Utilities are increasingly exploring the value batteries bring not only to the microgrid, but also to the larger grid. The table included here summarizes potential battery energy storage services and required response times and durations.

Summary of potential battery energy storage services and required response times and durations



Source: *Zinaman, Owen; Thomas Bowen, , and Alexandra Aznar. 2020. An Overview of Behind-the-Meter Solar-Plus-Storage Regulatory Design. USAID-NREL partnership.*

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