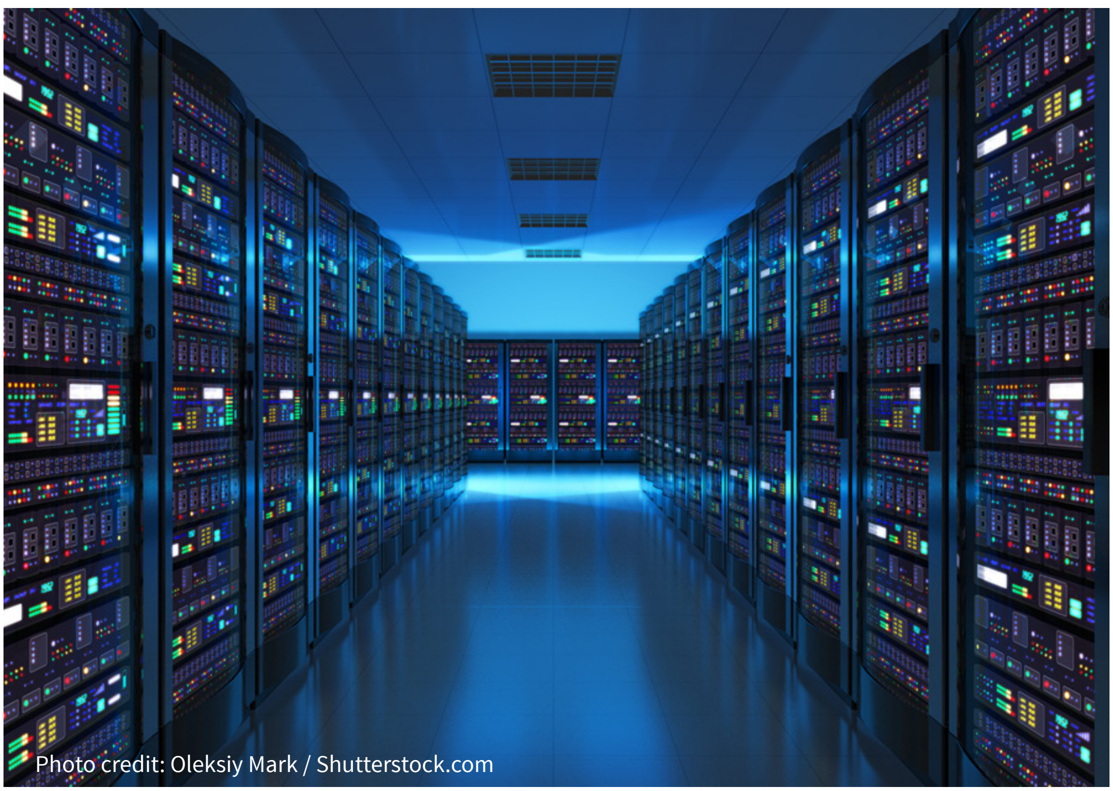
MICROGRID KNOWLEDGE SPECIAL REPORT

Microgrids: Data Center Energy Delivery for a Digital Economy

How microgrids are changing the paradigm on data center power delivery, uptime, and efficiency

Written by Bill Kleyman, Contributing Editor



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Microgrids: Data Center Energy Delivery for a Digital Economy

Executive Summary

The data center industry continues to meet society's increased demand for constant connectivity, content delivery, and myriad business and personal necessities. As the data center industry expands, whether in traditional facilities or at the edge, data center leaders seek ways to deploy better, more resilient mission-critical operations, including power systems. Meanwhile, severe weather events, cybersecurity threats, and aging equipment strain the electric grid.

> In an environment where downtime is not an option, microgrids provide a useful tool in allowing data centers to adapt to the changing landscape of our new digital reality.

Uptime and performance are critical for data centers, but they can not continue to rely on diesel generators for reliable backup power, especially as they respond to price pressure and environmental sensibilities. The answer? Microgrids. Unlike traditional diesel backup generators, microgrids offer data center and colocation operators a resiliency solution that reduces emissions, increases availability, and provides economic advantages that diesel cannot.

In this special report, we'll explore why microgrid use is on the rise and how microgrids improve resiliency, uptime, and a data center's environmental profile. We'll explain their economic value and the different purchasing models that can adapt to your facility's needs. We'll demonstrate how microgrids fundamentally change power delivery for primary and even edge users, and we'll take a look at real-world examples of microgrids in action. In an environment when downtime is not an option, microgrids are a proven technology that allow data centers to adapt to the changing landscape of our new digital reality.

Introduction

Data center power consumption has increased with the industry's rapid growth. As a result, data center and business leaders are tasked with delivering much more power capacity while still retaining optimal efficiency levels. A recent U.S. Department of Energy **report** indicates that U.S. data centers' energy consumption has been steadily rising since 2000. Today's connected world and heavy reliance on data center solutions are a significant indication that this pattern of growth is not slowing down.

This leads to some big questions: Will your existing architecture support emerging power requirements, new data center applications, and higher levels of density? What about reliability? In a world where outages and downtime cost more than ever before, what are you doing to support emerging power needs? Finally, how do you keep these critical systems operating more resiliently?

When it comes to resiliency, **studies** by the Institute of Electrical and Electronics Engineers (IEEE), the National Renewable Energy Laboratory (NREL), and others show that emergency diesel generators tend to fail. In some cases, the average downtime of these generators can be as high as 478.0 hours per failure. Is that something you can afford? Microgrids offer a much higher level of resiliency, and they are better for the environment. Additionally, they offer better economics.

To support critical data center (and even edge computing) operations, reliable power delivery is an absolute requirement. The rapid growth of these power-dense facilities combined with the existing strain on the electric grid means that data centers need additional strategies to increase resiliency and decrease downtime. The challenge there is that some diesel generators come with serious flaws, such as testing limitations and higher-than-preferred failure rates.

So, how do you keep up with the pace of demand? How can you ensure that your data center supports business requirements, power efficiency, density, delivery, and improved economics?

Microgrids and related smart grid technologies offer the answer. As self-sufficient energy systems, microgrids are capable of serving discrete geographic footprints. These locations and geographies include college campuses, hospital complexes, business centers, or entire neighborhoods.

Market strategies are built around the capabilities of data center facilities. Changes around governance, uptime classification, economics, and even weather patterns all impact facility power delivery.

However, a microgrid is more than a collection of energy resources. Advanced microgrids are differentiated by their ability to island from the central grid during a power outage and activate energy resources, all of which are done intelligently without human intervention. Further, by leveraging data analytics and even machine learning, modern microgrids support new security capabilities, simplify overall energy management, and power the data center autonomously.

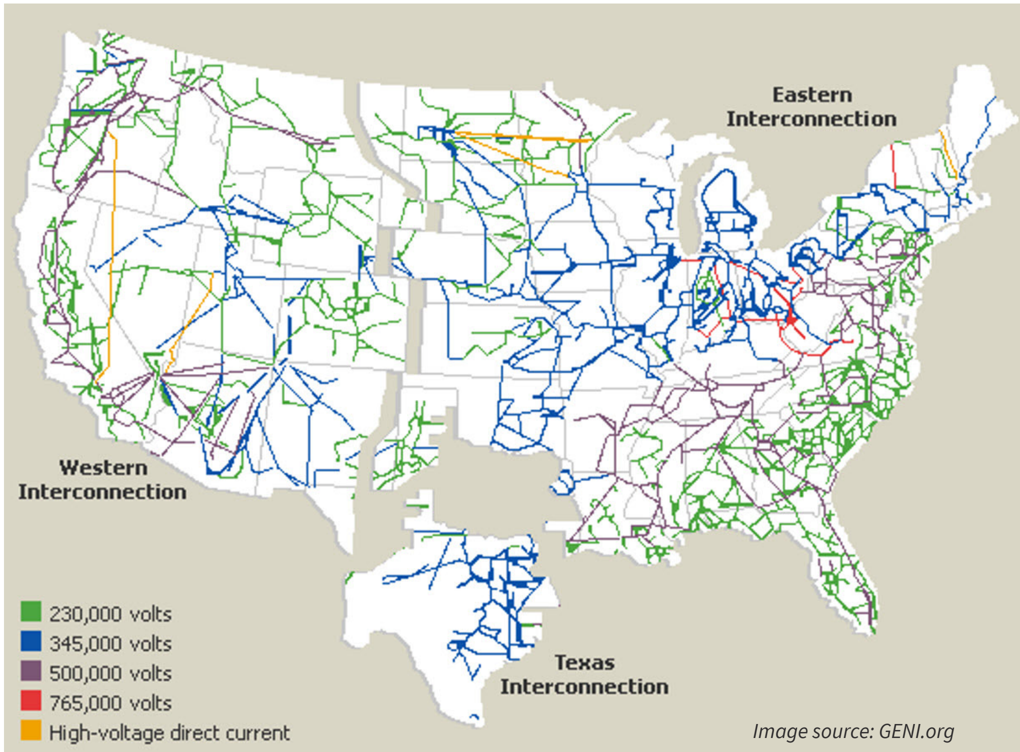
The industry is shifting to microgrid solutions to support an ever-changing market that is more reliant on both the data center and the power that feeds it. Market strategies are built around the capabilities of data center facilities. Changes around governance, uptime classification, economics, and even weather patterns all impact facility power delivery.

Consider this:

- **Changing Legislation Is Helping Transition to a Sustainable, Low-Carbon Future**
  A recent California state carbon tax (**AB32**), the first program in the country to take a comprehensive, long-term approach to address climate change, is driving data centers to install on-site renewable generation for economic and environmental reasons. At the same time, some parts of California are now mandating cleaner backup generators.
- **The Need for More Power Sources**
  Peak demand for power, especially during extremely hot or cold days, continues to strain grid resources, spiking power prices—a situation at times exacerbated by the addition of intermittent renewable energy on the grid.
- **New Requirements around Sustainability**
  Many organizations are trying to green their energy supply through bilateral renewable contracts or green tariffs.
- **Critical Uptime and Resiliency**
  The latest Tier 4 Uptime Institute classification of on-site power generation means data centers need to be rated for prime power delivery.
- **Rise of the Superstorms and Environment Impacts**
  As superstorms and other severe weather disasters become more frequent and intense, the grid is prone to lengthy outages. Many companies do not want to be left without power if, for example, wildfire threats cause power shutoffs.
- **Living on the Edge**
  Distributed computing, like edge, is taking data center infrastructure where it is never been able to live before. In those sparse areas, reliable and economical power delivery is often a challenge.

This report will look at the convergence of the emerging microgrid market with the mission-critical data center market. We'll examine real approaches to mission-critical data center microgrids that are being adopted by multiple end-users already.

Chapter 1
The Data Center and the Environment – We Can All Get Along



Today, the data center industry consumes about as much power as the entire global airline industry. And, based on research from the field, these levels of energy consumption will only continue to increase. Research studies estimate that ongoing power costs are growing at least 10% per year due to cost per kilowatt-hour (kWh) increases and underlying demand. This power increase is especially true for high-power density servers. Approximately 10% of data center operating expenditure (OPEX) is power, and that number is likely to increase to 15% of data center OPEX within five years.

As more organizations place their new IT systems into the data center (colocation, hyperscale and private/enterprise), energy efficiency and procuring data center power are extremely important. And, they are essential for multiple reasons. First, data center administrators are working hard to cut costs, but it is not always easy. Those same administrators are also working overtime to minimize fragmented management overhead and improve infrastructure efficiency.

Consider this:

A recent report by the Natural Resources Defense Council indicates that data center electricity consumption is projected to increase to roughly 140 billion kWh annually in 2020, the equivalent annual output of 50 power plants, costing American businesses $13 billion annually in electricity.

But it is not just at the core data center locations where energy consumption is increasing. Organizations are also investing in distributed computing and edge environments to support more users and more use cases. These hyperscale data centers are commonly sited where power is the least expensive, which is frequently in remote areas. Often, in rural areas, working with reliable power solutions can be a challenge. Moreover, environmental conditions in these locations, such as storms, fallen trees, high winds, or intense heat, do not help, either. Organizations need ways to support critical, ongoing operations at the edge and beyond.

Before we go on, let's examine today's power grids and delivery systems.

Power grid solutions and general power availability

When you are building edge, critical infrastructure, or data center solutions, it's essential to understand the regional power grid infrastructure. Just because a geographic area has access to ample power does not mean that the energy can always be delivered to the data center. Further, it does not always mean you will have multiple sources of reliable power for a particular site.

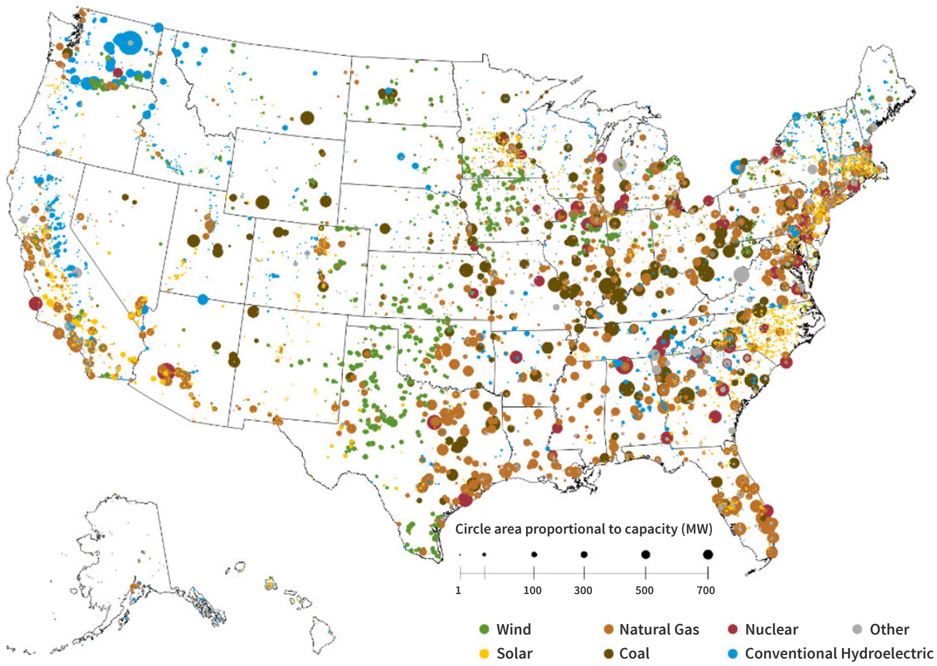
Look for the location with power stations, substations, and electrical feeds to the facility as well as redundancy throughout the delivery system. Also, research recent area outages to understand the time-to-repair for the utility provider. When working with critical infrastructure, it's essential to understand the age of the equipment as well as the security and redundancy metrics of the local power grid. Take time to understand the regional power utilities, their capabilities and how that ties into the data center provider and power source you are selecting.

In emergencies, there must be a plan for your redundancy and power availability.

Looking at the chart to the right, notice areas with significant power sources versus those areas that are poorly covered. As the digital economy picks up steam, there will be more initiatives to get more people to connect into the cloud. And these new clients of the cloud will require reliable power sources. So, if you are in a rural region and you only have one power source, how are you managing redundancy and efficiency? How can you ensure the effective delivery of stable power to the edge and beyond?

Or, maybe you're in an urban area, and you're having some issues finding reliable, redundant energy sources for your core or edge deployments. And, if these are critical systems, such as healthcare, what can you do to ensure minimal downtime?

Operable Utility-Scale Generating Units as of November 2019



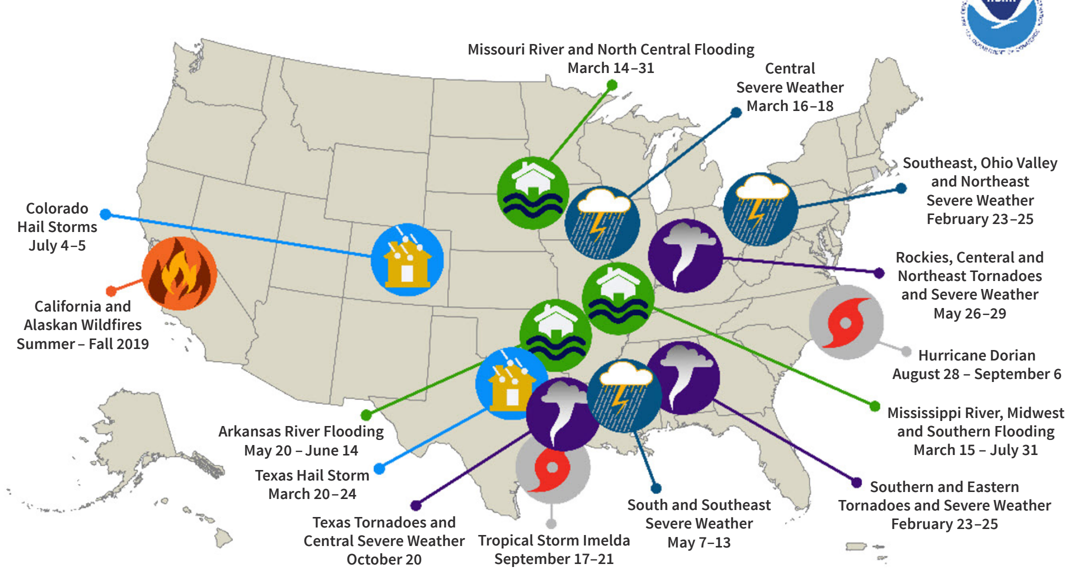
U.S. Energy Information Administration, Form EIA-860, 'Annual Electric Generator Report' and Form EIA-860M, 'Monthly Update to the Annual Electric Generator Report.'

Image source: EIA.org

Weather and climate disasters will impact power delivery

Weather patterns play a significant role in power availability and pricing. For example, wildfires like those in California, earthquakes, flooding, high winds, and extreme temperature all have the potential to cause frequent or extended power outages. NOAA **recently** pointed out that the U.S. has sustained 258 weather and climate disasters since 1980, where overall damages/costs reached or exceeded $1 billion (including CPI adjustment to 2019). While not always large scale, localized severe weather occurs virtually every week somewhere in the U.S. These events often damage the fragile electric grid and knock out power for hours, or even days.

U.S. 2019 Billion-Dollar Weather and Climate Disasters



This map denotes the approximate location for each of the 14 separate billion-dollar weather and climate disasters that impacted the United States during 2019.

Image source: NOAA

Unfortunately, extreme weather events are becoming more frequent, more intense, and more expensive. According to **NOAA**, in 2019, there were 14 weather and climate disaster events with losses exceeding $1 billion each across the U.S. The 1980-2019 annual average is 6.5 $1 billion events (CPI-adjusted), and the yearly average of the most recent five years (2015-2019) is 13.8 events (CPI-adjusted).

Ranking All 50 U.S. States by Number of Blackouts: 2017

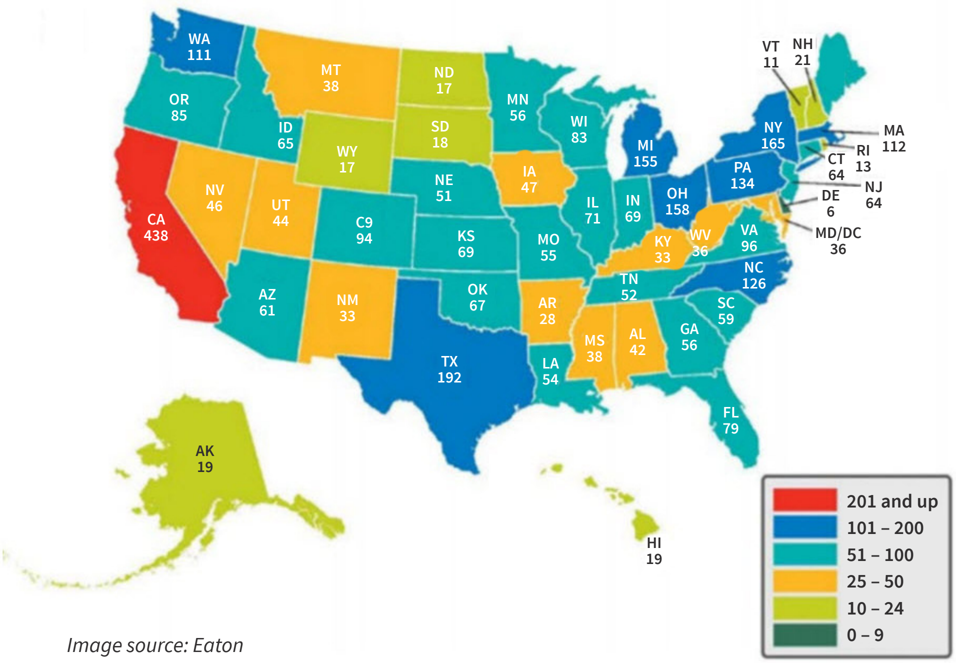


Image source: Eaton

In its analysis of 28 years of U.S. power outage data, Climate Central shows a tenfold increase in major power outages between the mid-1980s and 2012.

Extreme Weather is Causing More Major Power Outages

(major = at least 50,000 customers affected)

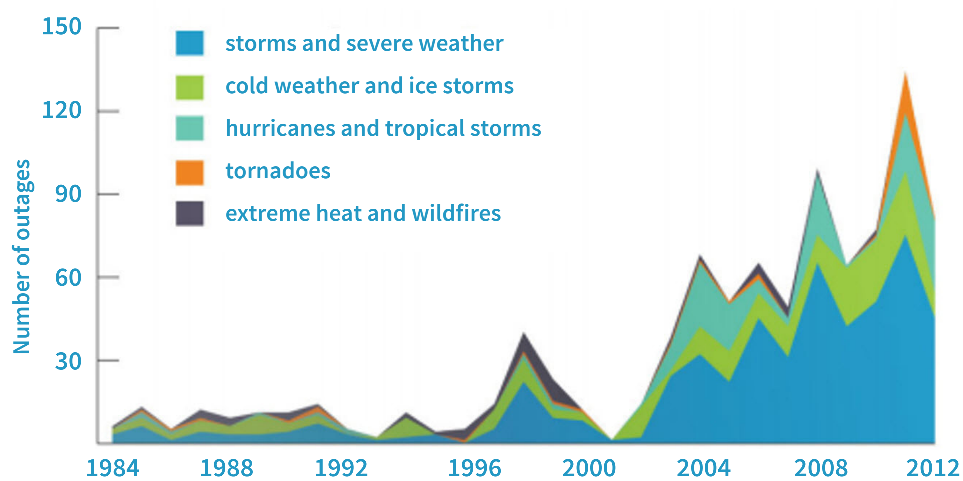


Image source: ClimateCentral.org

CLIMATE CENTRAL

Severe weather is one of the biggest causes of power outages in the U.S., and **Climate Central** reports that weather-related power outages are on the rise. In its analysis of 28 years of U.S. power outage data, Climate Central shows a tenfold increase in major power outages between the mid-1980s and 2012.

To combat these outages, organizations, governments, and regional power suppliers should look for reliable, alternative solutions, such as microgrids, to ensure their critical infrastructure stays up and running. The U.S. Department of Energy (DOE) Office of Electricity already has a **comprehensive portfolio** of activities that focus on the development and implementation of microgrids to further improve the reliability and resiliency of the grid. These microgrids help communities better prepare for future weather events and keep the nation moving toward cleaner energy strategies.

According to the Office of Electricity, the microgrid program goals are to develop scalable microgrid systems capable of reducing the outage time of required loads by more than 98% at a cost comparable to nonintegrated baseline solutions, while reducing emissions by more than 20% and improving system energy efficiencies by more than 20% by 2020.

The private sector is already adopting microgrid solutions to help offset power requirements, create more resilient systems, and improve the delivery of essential services. However, not every microgrid is built the same. And, if you believe that microgrids are simply here to replace a backup generator, you might be missing out on some key benefits of an advanced microgrid power delivery system.

Chapter 2
Why a Microgrid is So Much More than Just Backup Generation

We defined microgrids a bit earlier, but just as a refresher:

As a self-sufficient energy system, microgrids are capable of serving discrete geographic footprints. These locations and geographies include college campuses, hospital complexes, business centers or entire neighborhoods.

If you look at the U.S. power grid, you will see that it's pretty big and sometimes complicated.

According to the Environmental Protection Agency (**EPA**), the electrical power transmission grid in the U.S. is made up of over 7,300 power plants. The architecture includes nearly 160,000 miles of high-voltage power lines, millions of miles of low-voltage power lines, and distribution transformers, connecting 145 million customers throughout the country. It is often referred to as the largest operating machine in the world.

Our primary grids bring electricity—along with all of its comforts and conveniences—to everyone connected to it. It is great until it breaks. Unfortunately, it breaks too often. The grid is aging, exposed, and overcrowded, causing it to be especially volatile. Because it is all connected, a single down wire will disable and bring down another, creating a domino effect that results in a massive outage. This power outage can then spread for miles, sometimes over several states.

When these all-too-common grid failures occur, microgrids have the potential to keep the lights on while offering additional vital benefits. With that in mind, it is essential to look at what makes a microgrid so different.

United States Transmission Grid

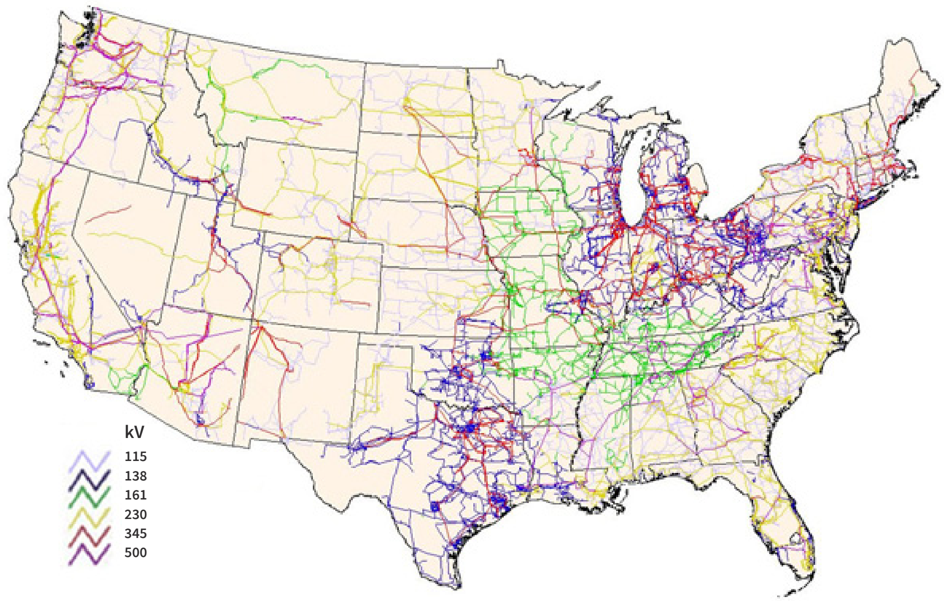


Image source: FEMA

Microgrids are smart, more capable than a simple generator

Rob Thornton, president and CEO of the 105-year-old International District Energy Association, often says that microgrids are "more than diesel generators with an extension cord." In other words, a **microgrid** is not just a backup generation mechanism but should be a robust, 24/7/365 asset. Also, an advanced microgrid may provide grid and energy management services.

Consider this list of microgrid capabilities:

- Produce on-site generation and, in some cases, thermal energy
- Sell capacity, energy, and ancillary services to the grid and participate in demand response—activities that create a potential revenue stream for the asset owner
- Optimize energy resources to priorities set by the host
- Manage load to reduce energy waste and achieve superior efficiency

A fundamental feature of a microgrid is its ability to **island**—meaning it can disconnect from the central grid and operate independently and then reconnect and work in parallel with the grid. Whenever there is a significant storm or other natural weather event that has the potential to cause an outage on the power grid, the microgrid islands and activates its on-site power generators. When the power outage ends, the microgrid reconnects to the grid.

A microgrid controller gives the microgrid its islanding capability. Also known as the central brain of the system, **the controller** can manage the generators, batteries, and nearby building energy systems with a high degree of sophistication. The controller meets the goals established by the microgrid's customers by increasing or decreasing the use of any of the microgrid's resources—or combinations of resources. Therefore, an "on-demand" power intelligence can be leveraged.

Microgrid adoption is growing fast

In general, the pace of microgrid installation has picked up and is expected to grow dramatically as **distributed energy prices** drop and worries heighten about electric reliability. In fact, Guidehouse Insights forecasts a **$39.4 billion** microgrid market by 2028.

Guidehouse expects global microgrid capacity to reach 20 GW by 2028, up from under 5 GW in 2020. The research firm sees North America and Asia as the centers of growth.

There has already been a lot of adoption around a variety of use cases. You can even find a 400-kW solar microgrid on **Alcatraz** Island! According to the DOE, the island is equipped with a solar-diesel hybrid power system that most visitors probably would not notice. Its solar array sits on top of the main prison building. It connects to a battery bank and power inverters that help power the island, instead of relying solely on diesel generators.

Annual Total Microgrid Power Capacity and Implementation Spending by Region, World Markets: 2019 – 2028

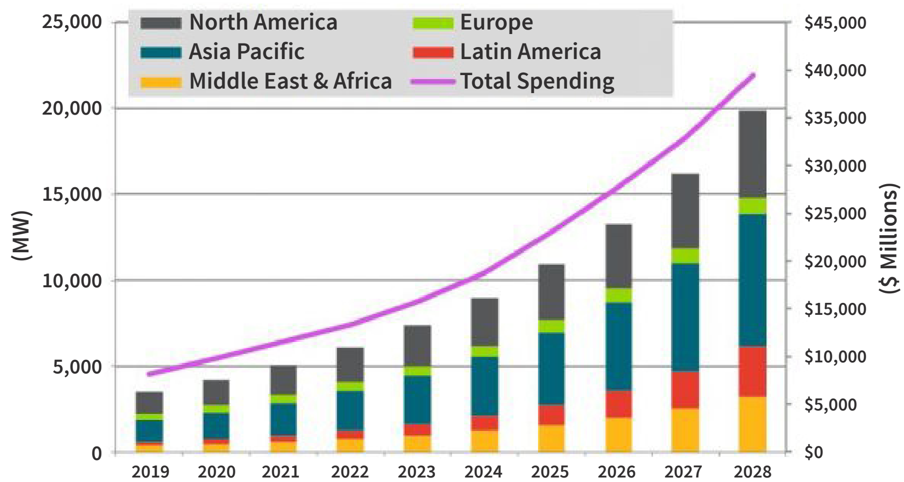


Image source: Guidehouse Insights

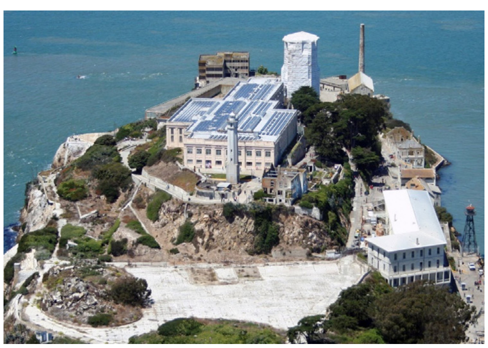


Image source: Department of Energy

Image source: Department of Energy

In addition to Alcatraz Island, there are several real-world use cases of microgrids impacting the way critical power services are being delivered.

- **Universities and colleges**
  College campuses are significant users of microgrids. For colleges, this type of design makes a lot of sense. First, the natural composition of a college campus is a perfect set up for microgrids because campuses already have many buildings close together. For another, campuses often have research facilities and campus housing for which power reliability is crucial. For example, The University of Texas at Austin houses what is often described as one of the most integrated and **largest microgrids** in the United States. The university is known for its premier research facilities, which demand high quality, reliable power. The microgrid has saved the campus energy and money, and it has delivered with 99.9998% reliability over the last 40 years.

  Several universities in California also have microgrids or are considering their installation. In cases of emergency, such as the California wildfires, universities are at risk of losing power to crucial research facilities, which could result in dozens of years worth of research and experiments lost or destroyed.

  Without reliable backup power, some California schools would have to pack their research into a refrigerated truck and transport it to remote facilities to keep samples viable. Microgrids remove this challenge entirely.

- **Cities**
  Cities are increasingly installing microgrids for "critical facilities," such as hospitals, emergency shelters, police stations, and grocery stores — places that need electricity in a crisis. These are called *community microgrids.*

- **Businesses**
  In a digital economy, an outage or any extended downtime is very costly. And that cost only continues to rise. According to a research **study**, the average cost of IT downtime is $5,600 per minute but can be as much as $540,000 per hour.

  Many organizations have realized the high cost of power outages and taken proactive action. For example, H-E-B, a Texas-based grocery chain with more than 370 stores in the U.S. and Mexico and $23 billion in annual sales, invested in a microgrid project to protect them from costly outages. H-E-B's microgrids have saved them from several outages, including those caused by Hurricane Harvey in August 2017.

H-E-B uses microgrids that utilize a 24/7 Microgrid Network Operations Center (MNOC) to monitor the electric grid. As Harvey made landfall on the Gulf Coast, the MNOC islanded H-E-B's microgrids from Houston's primary power grid, and the stores received power from Enchanted Rock's on-site generator system. Eighteen H-E-B stores received full-facility backup for five consecutive days during the storm, which enabled uninterrupted service to their grateful customers.

- **Healthcare**
  Healthcare facilities require constant power to perform life-saving tasks and keep critical services running. Although hospitals are required to have a form of emergency generation, many hospitals are looking to microgrids to back up their entire facility rather than just certain critical areas needed for compliance.
- **Military**
  Not surprisingly, the military was an early adopter of microgrids on U.S. bases to ensure mission resiliency. They also use remote microgrids in places like Afghanistan. When operating in rural or remote theaters, reliable power is critical for forward operating bases. Microgrids deliver reliable, green electricity to soldiers in remote spots 24/7, 365 days a year.

These are just some examples of the growing trend of microgrids being used to promote resiliency in a variety of industries.

The additional benefits of adopting a microgrid architecture

Again, these microgrid users are not only trying to maintain uptime, but also make an impact on cost while creating greener and cleaner options. Drivers for microgrid adoption include:

- **Designing the highest possible levels of resiliency**
  In an era of critical workloads, ensuring maximum possible uptime is vital. According to **survey results** released by the Uptime Institute, nearly one-third of all data centers had an outage during the study period. The study further noted that there was a year-over-year increase in disruptions occurring within the data center. However, the increase was not due to a computer virus or malware attack.

Designed to work in tandem with the grid, or in an island fashion, microgrids ensure you don't incur million-dollar outage costs while keeping your critical infrastructure running efficiently.

Instead, the top cause of downtime was, in fact, power outages. And these outages are costly. Around one-third of all reported outages cost more than $250,000, with many exceeding $1 million.

To resolve these outage issues, microgrids are specifically deployed to ensure the highest possible levels of resiliency. Designed to work in tandem with the grid or in an island fashion, microgrids ensure you do not incur million-dollar outage costs while keeping your critical infrastructure running efficiently.

- **Reducing energy costs**
  Through the efficient management of energy supply, microgrids not only reduce costs, but they also can generate revenue. Think of areas where electricity costs are high, for example, the Northeast and California come to mind. In those locations, microgrids can provide energy at a lower price than the grid. By providing ancillary services to the central grid, microgrids can also earn revenue. **Ancillary services** provide support functions for the grid, such as frequency control and spinning reserve.
- **Shifting to green operations**
  In today's world, going green is essential. Microgrids can actively leverage a wide array of green power technologies, including solar, wind, fuel cells, renewable natural gas, combined heat and power (CHP) plants, and energy storage technologies. Even natural gas generators have far lower emissions than traditional diesel backup generators.

  Microgrids also can intelligently integrate renewable energy into the energy mix. These microgrids are capable of seamlessly balancing the variable output of renewable energy with conventional generation assets. Furthermore, new types of advanced microgrids can be programmed to achieve specific sustainability goals. These sustainability goals include the use of the lowest carbon resources to the maximum extent possible.
- **Improving cybersecurity**
  Cybersecurity is a big reason that the military and others are deploying microgrids. A massive ransomware attack in May 2017 heightened worldwide concern about cybersecurity. Affecting 150 nations, the malware infected hundreds of thousands of businesses and institutions from British hospitals to FedEx™ in the U.S.

  As for now, the U.S. power grid has not been the target of a cyberattack that causes loss of power. Still, many experts are concerned about its vulnerability and are taking proactive measures. Microgrids can alleviate the effects of cyberattacks because of their ability to island. In cases of an attack, facilities can completely disconnect from the grid and ensure that they are still connected to reliable power sources.

Overcoming common challenges

Another significant benefit is the maturity of the microgrid market. In the past, microgrids were seen as a new technology with the same old power and data center energy delivery challenges. These included voltage and frequency stability, hazardous commissioning, operation, or maintenance work, the inability to operate traditional energy resources to their most significant effect, and increased complexity in the power delivery architecture.

The good news is that the vast majority of challenges have already been overcome. Improved service level agreements (SLAs) ensure optimal operation alongside promised levels of resiliency and uptime. Furthermore, the microgrid-as-a-service solution prevents customers from being burdened with microgrid management. For example, advanced microgrid systems are truly connected in the sense that they leverage data, machine learning, and data analytics to proactively maintain optimal operating environments. Engineers and operators can leverage this data to see inefficiencies or other issues before they arise.

With a microgrid-as-a-service model, third-party finance owns and manages the system. Therefore, data centers can have reliable backup power without needing to interact with the technical and transactional complexities behind the solutions. Microgrid-as-a-service features can include:

- 24/7 secure Network Operations Center (NOC) operation
- Maintenance scheduling
- Asset management
- Market operations
- Billing and settlement
- Weekly site visits and loaded test runs
- 24/7 technician availability

Here's the other key point — all of this is driven by data. Modern and sophisticated microgrid solutions produce data points that are then analyzed by AI and machine learning engines. This data can be used to provide information about the abnormal behaviors of system components, maintenance needs, unexpected power fluctuations, or even security metrics around access. Most of all, this information allows your microgrid to become predictive and prescriptive.

Furthermore, leaders in the space do not just operate one or two microgrid solutions. Instead, they have multiple sites that all aggregate management data. Microgrid innovators can then use this information to improve efficiencies at your site. All of this enhances reliability, helps you avoid product loss, reduces noncompliance, and ensures that you have constant capacity when it comes to power.

For the microgrid industry, this is revolutionary. The leading microgrid providers are leveraging data to make better decisions and improve overall operation. All of this brings further benefits to the customer without increasing complexity.

The leading microgrid providers are leveraging data to make better decisions and improve overall operation. All of this brings further benefits to the customer without increasing complexity.

What is Microgrid-as-a-Service?

The "as-a-service" model has been great for cloud, software, and even infrastructure. Leaders in the power delivery space, specifically microgrids, want you to do what you are best at doing. Maybe you are a school, a grocery chain, or a hospital. The point is that microgrid-as-a-service partners allow you to focus on your business and not the operation or management of your microgrid.

Microgrid-as-a-service delivers a fully managed, data-driven solution to help you with your power delivery requirements. Advanced data gathering from numerous operational microgrid deployments allows leading partners to make better decisions and proactively service units. This type of managed offering will enable customers to never worry about their microgrid unit; it's all serviced, monitored and maintained by your microgrid provider.

Perhaps most significant, microgrid-as-a-service spares data centers from making an upfront capital investment since it is absorbed by the third party.

Working with Edge solutions? Consider a Microgrid

One of the most significant benefits of working with microgrids is their ability to help future-proof your deployment initiatives. If you are looking to deliver edge or distributed computing services to rural, remote, or even urban locations, you need to adopt a microgrid system.

Edge solutions are critical for data analytics and bridging the data proximity challenges (latency) that are associated with content and service delivery in these areas. They are not just "small data centers" that are deployed in distributed locations. These are essential pieces of infrastructure that need to stay up. That said, can you expose critical infrastructure to weaker grids? Remote and urban areas alike can be more challenging when it comes to power. With microgrids, this challenge is alleviated as you will have a reliable and secure source of energy.

Chapter 3
How Microgrids Introduce New Data Center Economics

Data centers are increasing in number across the U.S. and around the globe. They are the new industrial factory of the modern digital economy and require a massive amount of power to support their high-tech operations. Data centers are located in every state, but the largest hyperscale data centers are sited where power is the least expensive. However, low-cost power does not ensure highly reliable power, so the standard data center design includes backup power systems that can carry the facility, computing and infrastructure loads without interruption during a power outage.

These backup power supplies are typically large arrays of diesel generators connected in parallel strings to create maximum resiliency when coupled with battery-based uninterruptible power supplies (UPS). However, diesel generators present a handful of challenges to data center operators. For example, they have high emissions, which makes environmental permitting and reporting burdensome. Additionally, they are expensive to own because of the high upfront cost and ongoing operations and maintenance costs. They also sit idle for most of the year and do not provide grid services, which makes them an expensive drag on both the balance sheet and income statement of the data center operators.

These generators are an essential component in mitigating operational risk in the data center. Still, they lack the higher level of resiliency as well as other key benefits that a microgrid system offers.

With all of this in mind, let's take a few minutes to break some legacy paradigms around economics and the overall cost of today's microgrid solutions.

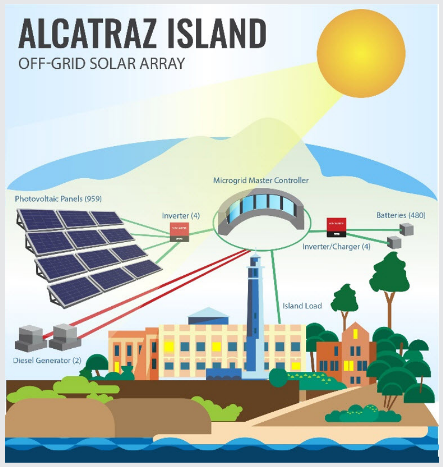


Image source: U.S. Department of Energy

With the Alcatraz Island example, you can probably imagine that it's not easy to power that island. If you look back at history to understand the massive costs it took to run the prison, you'll quickly see that a big reason why the prison closed in 1963, after only 29 years of operation, was because of power. To power the location, the National Park Service ferried up to 2,000 gallons of diesel fuel a week to Alcatraz for its electric generators.

Today, Alcatraz Island is equipped with a solar-diesel hybrid power system where the solar panels connect to a battery bank and power inverters that help power the island instead of relying solely on diesel generators. In microgrid systems, generators can easily be coupled with renewables, such as solar power, to meet environmental goals while ensuring the needed resiliency. How have microgrids changed the economics of a location that gets more than 1.5 million visitors a year? This $7.1 million **project**, funded initially through the **American Recovery and Reinvestment Act**, has reduced the island's fuel consumption by 45% since its 2012 installation. It also saves more than 25,000 gallons of diesel fuel a year in the process — proving historic preservation and renewable integration is possible.

Switching gears to edge environments, data center locations and rural infrastructure deployments, you can quickly see how these economics and benefits apply to a variety of use cases.

The **University of Texas at Austin microgrid**, as another example, has effectively delivered 99.9998% reliability over the last 40 years. With that in mind, let's talk about economics. While some microgrids sell power or services to the grid, UT Austin does not. This is because its energy plant is sized to be net-zero, to produce only what it needs.

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

So why is reliable and continuously available energy important for UT Austin? Eighty percent of the campus space is dedicated to research valued at about $500 million. That's certainly not something the school would want to lose during a power outage.

Overcoming common economic myths surrounding microgrids

The first challenge we often hear about is that microgrids are expensive to deploy and maintain. The reality is that it depends on a variety of factors, and with innovative business models, it can be significantly cheaper than traditional alternatives.

It is crucial to consider the total cost of an outage, in dollars, lost time, reputational damage, and so on, and then compare it to the price of a resiliency microgrid system. For example, a Stanford University climate and energy expert estimated that a 48-hour outage to 800,000 California customers in October 2019 cost about $2.5 billion. Just a 30-minute interruption could cost a medium or large business or factory more than $15,000. A microgrid can help companies save this money, which makes working with microgrids that much more attractive.

Additionally, microgrid costs have been falling in recent years. This is primarily due to a decline in cost of the kind of supply assets used by many contemporary microgrids. Falling prices due to standardization and for renewable energy and battery storage heavily influenced a 30% decline in microgrid costs from 2014 to 2018, according to Peter Asmus, research director for Guidehouse.

Another misconception is that you might need to pay for everything upfront. In some cases, this is true. However, with microgrid-as-a-service (also called energy-as-a-service) offerings, contracts require little or no upfront capital paid by microgrid customers. Instead, customers pay for their microgrid service in a budgeted manner, much as they do if they buy it from a utility, except they have the added benefit of backup power during grid outages. A third party owns the project and takes the operational and financial risk.

It is important to note that microgrids vary dramatically in size and complexity and, more importantly, purpose, which creates a wide cost variance. The cost of your design depends on where and why the microgrid is built and what kind of power generation it leverages. Nanogrids, for example, can cost in the tens of thousands of dollars, while a highly sophisticated urban microgrid in Cleveland has an estimated $100 million price tag. For data centers, an advanced microgrid should cost less than an equivalent diesel back-up plant.

With microgrid-as-a-service offerings, customers pay for their microgrid service in a budgeted manner, much as they do if they buy it from a utility, except they have the added benefit of backup power during grid outages.

To further help with costs, government grants and other clean energy incentives can drive down customer costs. California, Connecticut, Maryland, Massachusetts, New Jersey, and New York are among the states that give grants for microgrids or resiliency projects. On the federal level, tax credits for renewable energy can be applied to microgrid projects that use the applicable forms of generation.

Key microgrid economic and deployment considerations

When working with microgrid solutions, consider the following:

- **Tightening reserve margins**
  Texas has recently seen a narrowing of its reserve — the cushion between supply and demand margins — as power plants retire. This has caused a spike in wholesale power costs when demand for electricity is high. While the problem may be unique to the state right now, it offers a warning about the risk of being grid-dependent.
- **Rising utility rates**
  Utility rates have risen historically, so it's reasonable to expect your costs to rise. Microgrids can offset those cost increases.
- **Providing assured on-site power supply in a variety of use cases**
  If you are in a rural or remote location, finding reliable sources of power can be a challenge. Even in urban areas, staying resilient and maintaining uptime becomes more challenging because of severe weather and aging grid infrastructure. It's essential to understand what an outage costs for you and where a microgrid makes sense.
- **Improving power efficiency**
  As compute density increases, you have to look at the economics of power. That means working with power most efficiently and doing your best to reduce energy waste. The UT Austin example points to a microgrid architecture that is sized to be net-zero, to produce only what it needs, therefore never wasting resources. Equally important, an advanced microgrid can manage the load for maximum efficiency. Portions of your facility may require less power at certain times. Air conditioning, for example, can be reduced in offices not in use.
- **Leveraging better pricing**
  Microgrids give you options. You can leverage on-site power sources or you can purchase grid power, depending on which offers the best pricing as electricity costs change throughout the day.
- **Improving power quality**
  Data centers are sensitive to fluctuations in power quality. A microgrid helps maintain steady voltage and frequency.

If you are still concerned about one of the economic considerations above, take the time to understand your use case and where microgrids can make an impact. Additionally, microgrid partners can support potential users in understanding their use case and how an efficient and clean microgrid can help.

Chapter 4
What's New? The Microgrid is a Lot More Efficient — and Effortless to Run

Advanced microgrid controllers leverage machine learning and data-driven solutions to track real-time changes in the power prices on the central grid.

Smart is the new normal as we enter and expand in a digital era. Driven by data, autonomous systems, and more demand around the data center and edge solutions, leaders in the space need smarter options to help them go from reactive to predictive and prescriptive.

Modern microgrids are more intelligent than ever before

Advanced microgrids are smart – they have sophisticated software and controls. Among other things, this intelligence allows them to island from the primary grid. That means when they see trouble on the primary grid beginning to occur, microgrids can separate and protect themselves. They stop relying on the grid's power plants and instead rely only on their own. But they can also work intelligently in unison.

When everything is working right, the grid and the microgrid operate in tandem and serve one another. For example, on blue sky days, the main grid is used for supply. But if the main grid experiences an outage or runs low on power supply — as it sometimes does on hot summer afternoons when we all are running our air conditioning — it can turn to the microgrid for help. The grid can be a source of revenue for microgrids that provide services known variously as capacity, emergency reserves, resource adequacy, demand response, and ancillary services.

Furthermore, modern microgrids are data- and software-driven. Advanced microgrid controllers leverage machine learning and data-driven solutions to track real-time changes in the power prices on the central grid. If energy prices are low at any point, a solar + storage microgrid may choose to buy power from the primary grid to charge its battery systems. Then, as grid power becomes pricey later in the day, the microgrid may sell services to the grid or discharge its batteries rather than use grid power.

Because microgrids are intelligent, software-driven solutions, the data they produce can be leveraged to influence end-user power decisions. Additionally, microgrid providers can capture this data to ensure that the microgrids are operating optimally. They can use predictive analytics around the information that's being gathered to forecast issues, power requirements and maintenance cycles. In some service models, you never have to touch the microgrid once it goes in. Governed by software and smarter microgrid controller systems, today's microgrids work together via complex algorithms, data-driven solutions, and advanced analytics to ensure that the microgrid's resources are consistently and adequately used. These software-driven tools deliver system performance to a level of efficiency that is difficult to achieve alone. The orchestration of this microgrid ecosystem is managed in a near-instantaneous fashion — autonomously. There is no need for human intervention.

Unlike many traditional backup generators, microgrids can support continuous operations and provide grid reserve capacity. Either way, microgrids can be available to operate 24/7/365, managing and supplying energy to their customers.

Microgrids and next-generation generators can get along nicely

When it comes to greener and cleaner power, many leading organizations have actively committed to reducing emissions and running more optimally. However, working with traditional legacy backup generators can pose some environmental efficiency challenges. As it relates to environmental performance, most data center operators are in a class by themselves. Their focus on improved energy efficiency inside the data center has achieved tremendous improvement in the last decade, and the decarbonizing of energy supplies is unsurpassed by any other industry.

However, the diesel generator fleets at most data centers run counter to these achievements. Although some new, modern **Tier-4 generators** use low sulfur diesel and additional pollution controls, they are not emission-free. Diesel fuel is higher carbon-emitting, higher particulate-emitting, and higher VOC and NOx-emitting when compared to natural gas.

Microgrid providers use predictive analytics around the information that's being gathered to forecast issues, power requirements and maintenance cycles. In some service models, you never have to touch the microgrid once it goes in.

Natural gas is becoming an increasingly popular fuel choice for microgrids due to its robust fuel delivery network and lower environmental impacts. According to a **paper** by the National Renewable Energy Laboratory, natural gas has a more reliable fuel supply compared to diesel, and it is able to efficiently combat long-duration outages without interruption. These generators can perform like a diesel, with fast ramp times, transient performance, and a compact footprint, but are cleaner and quieter than even Tier 4 generators.

Natural Gas vs. Diesel

- Natural gas has lower particulate emitting qualities and is not a high carbon-emitting fuel source.
- Natural gas has different testing capabilities where they are not limited by diesel emission limitations per generator.
- Diesel generators that operate on cleaner, low-sulfur diesel fuel are usually more expensive.
- With Tier-4 diesel generators, you will have higher operating and maintenance costs.

> If you're a hyperscale data center with many microgrids running on diesel, you might run into some testing and validation issues. So, during the planning process, be sure to understand your requirements and work with the right solution that won't put you at risk.

Microgrids can also combine a variety of energy sources to met environmental goals as well as resiliency needs. For example, solar and storage microgrids utilize renewables to provide environmentally-conscious power, but they are limited in the number of hours they can provide backup capacity. By adding a natural gas generating element to the mix, customers receive long-duration backup power for extended utility outages that last days or even weeks.

With that in mind, there is sometimes the notion that fossil fuels are always dirty. The good news is that there are cleaner options with some new, modern solutions. Additionally, these microgrids can be made even cleaner with options like renewable natural gas or **Neste renewable** diesel, which was used by a microgrid in San Francisco, California, during Super Bowl L. Although cleaner, these solutions may be more expensive to operate and maintain.

Another critical point when it comes to working with diesel generators is the ability to test your backup solution and microgrid. In some states, testing backup generators that run on diesel is limited. If you are a hyperscale data center with many microgrids running on diesel, you might run into some testing and validation issues. So, during the planning process, be sure to understand your requirements and work with the right solution that will not put you at risk.

Chapter 5
Microgrid Partners Aim to Change Power Delivery, Efficiency, and Economics

In today's connected world, a microgrid is a real technology making a real difference. These are the solutions that enable true energy-as-a-service designs, leveraging advanced data analytics to create predictive and prescriptive decisions around power delivery. Far beyond a simple generator, microgrids alleviate reliance on the grid, allow you to deliver much cleaner and reliable power, and remove the scare and risk of major outages.

Enchanted Rock's solution was provided at a substantial discount in both upfront capital and ongoing O&M costs as compared to traditional backup systems.

Getting started on this journey is as simple as asking the leaders in the space what some of today's most innovative use cases look like. In a range of verticals, microgrids are being deployed to serve many scenarios.

Here's a specific example. Founded in 2006, Enchanted Rock builds, operates, and manages cost-effective resiliency microgrids that help companies efficiently manage the risk associated with electricity interruptions. In 2010, Enchanted Rock became the first in Texas to provide utility-grade backup power as a service.

And, in the same state, they helped revolutionize the way power was delivered to a primary university campus.

Image source: Enchanted Rock

Texas A&M RELLIS Campus microgrid use-case

- **The Client**
  Texas A&M RELLIS Campus (RELLIS), located in Bryan, Texas, is a facility that fosters cutting-edge research, technology development, education, and workforce training. Texas A&M, along with academic, corporate, and private partners, conducts valuable research for world-changing technologies, processes, and products, with state-of-the-art labs, testing, and proving grounds.
- **The Challenge**
  The RELLIS Campus boasts a growing list of multimillion-dollar state and national research facilities, testbeds, and proving grounds that depend on high availability power supply for their mission. The facility was served by a single radial transmission service and was vulnerable to power disruptions. They needed a reliable backup power system for minimal capital outlay.
- **The Solution**
  After a competitive solicitation process in Fall 2017, Texas A&M University System signed a Master Service Agreement with Enchanted Rock for the RELLIS Campus. Enchanted Rock's 10 MW, medium voltage system backs up the Texas A&M Transportation Institute, the Texas A&M Experiment Station, the Blinn College Education Center, and other research, educational, and extension facilities. Enchanted Rock will operate and maintain the system for the life of the agreement
- **The Real-World Results**
  Construction on the RELLIS site began in early 2018 and was completed ahead of schedule. The system was fully commissioned in Summer 2018 and provides full electrical reliability to the entire campus so that public institutes and private investors can be confident that their investments on the RELLIS Campus are safe. Additionally, Enchanted Rock's solution was provided at a substantial discount in both upfront capital and ongoing O&M costs as compared to traditional backup systems.

Image source: Enchanted Rock

The company is responsible for the design, project management, installation, and commissioning of over 380 MW of distributed generation and over 160 microgrid sites. The company currently has 100 MW of customer resiliency microgrids under construction.

Enchanted Rock's microgrids have significantly lower emissions than Tier 2 and even Tier 4f diesel generators.

Enchanted Rock uses an alternative approach to data center backup with its natural gas microgrids, which support on-site backup power needs, power grid capacity, and energy and ancillary service opportunities. The dual-duty mission increases data center reliability, reduces operating and capital costs, and provides clean power locally and for the broader grid when compared to typical diesel installations. Enchanted Rock's natural gas generators, like diesel generators, offer fast ramp time and transient performance, with the added benefits of a compact footprint with low noise levels. Additionally, Enchanted Rock's microgrids have significantly lower emissions than Tier 2 and even Tier 4f diesel generators. For example, Enchanted Rock's zero-hour emission factor for nitrogen oxide is 4,000 times lower than Tier 2 diesel engines and 400 times cleaner than a Tier 4f diesel engine.

To further differentiate the way it delivers power, the Enchanted Rock solution, based on operating principles of the U.S. Nuclear Navy and NASA, runs its generators more frequently than only during power outages and testing. These frequent runs allow the generators to be tested continuously, which means a problem can be identified and solved before an emergency or a grid outage.

The generators are synchronously interconnected so they can provide grid support when local or regional conditions present opportunities for capacity and energy as well as ancillary services. In one wholesale market, the Enchanted Rock generators run an average of 400-800 hours per year. As part of their turnkey solution, they have a 24/7 secure microgrid network operations center (MNOC) that proactively monitors the activities of more than 160 active microgrid deployments. This level of data intelligence and aggregation allows Enchanted Rock to respond to power and security issues faster than anyone else.

Modern microgrids – leveraging a full turnkey solution

A significant innovation in microgrid solutions has been the intelligence the data can provide, coupled with some of the best microgrid-as-a-service options in the market. Working with a partner that can deliver on these solutions ensures you are working with people who have a lot of experience in the field and can also completely manage your microgrid architecture. This includes:

- **System Design and Engineering**
  Site evaluation, electrical, mechanical, and civil engineering, architectures around the grid, synchronous and island mode.
- **Construction and Commissioning**
  End to end EPC, complete project management, and full commissioning of the microgrid ecosystem.
- **Finance**
  Ready access to capital, 10-to-20-year horizon, and—this one is important—Enchanted Rock wears all energy market risk.

Finally, a fully managed microgrid platform will also focus on and include advanced operations services, including:

- O&M of more than 600 generators
- Always-in-stock critical spares
- Weekly site visits, loaded test runs
- Technicians on call 24/7

As a microgrid-as-a-service provider, Enchanted Rock allows you to focus on your business and what you are best at doing. That means never worrying about resilient power and always knowing that someone is helping ensure your systems stay up.

Getting Started with a Microgrid Decision Checklist

Looking more closely at microgrid solutions does not need to be a challenge. New solutions such as microgrid-as-a-service have become a reality as these designs leverage data and advanced analytics to ensure your power delivery is consistent and does not get interrupted.

To help you get started, here's a high-level decision-making checklist to follow.

Key: You'll want to do this for each solution you review. That said, in doing this checklist, you might find that a given solution meets more requirements than others. However, you might also find that those requirements that are achieved are lower in importance. You'll want to find a solution that meets your "must-have" requirements as far as importance to your use-case.

Feature/Requirement	Availability / Meets Requirements Yes = 1 / No = 0	Importance Rating (0 – 3): Not Needed (0) Nice to Have (1) Important (2) Must Have (3)
Example Feature	Yes 1	3
Physical Location (regions)		
Redundant Power		
Power Delivery (with scalability)		
Metered Power		
Efficient Cooling		
Green Technology Adoption		
Customer Service		
Microgrid-as-a-Service Capabilities		
Data Analytics and Integration		
Engineering Expertise		
Emergency Call-out Response Time ('x' minutes/hours)		
Contracts and SLAs		
Customer Satisfaction		
Physical Security		
Cybersecurity Capabilities		
Expansion Capabilities		
TOTALS		

Final Thoughts and a Look into the Future

Working with reliable power solutions as well as improving overall data center economics is key to helping a business grow. Remember, very soon, we're going to see an explosion around connectivity. Cities, hospitals, governments, and the edge will all influence the way we connect and conduct business in our daily lives. A significant part of this will be leveraging reliable services to ensure uptime, resiliency, density, and cost awareness. This is precisely where microgrid technologies come in to help. Throughout this paper, we've discussed use cases ranging from Alcatraz to universities. And each of these use cases has seen benefits around power consumption and delivery, economics, and, most of all, their levels of resiliency. High impact events will continue to affect how power is delivered in a fragile grid. Microgrid deployments have specifically helped curb outages by providing continuous power during emergencies.

Cities, hospitals, governments, and the edge will all influence the way we connect, leverage advanced services, and conduct business in our daily lives.

Still, to some, microgrids are new solutions that require further research. If you're building an edge ecosystem or a primary data center, you need to see if a microgrid design is right for you. It might be a source of reliable and clean secondary energy. Or it might help you power an entire campus or edge environment.

The point is that you need to get started on that journey. A provider such as Enchanted Rock will give you an actual perspective on the industry as a real business partner and advisor. Enchanted Rock guides you through every consideration and requirement to ensure you have the right power solution in place. So, fill out that checklist and get to know your own use cases.

For more information, contact Enchanted Rock:

info@enchantedrock.com

(713) 429-4091

www.enchantedrock.com

About the author:

Bill Kleyman is EVP of Digital Solutions at Switch Data Center and regular contributor to Data Center Frontier and Microgrid Knowledge.

