Energy Resiliency

Solutions for the Public and Private Sector

An Introduction to Planning Energy Resiliency

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Introduction

Planning for and implementing self-generation and storage technologies to achieve energy resiliency can be a complex undertaking. This introduction will provide an overview of important considerations when planning for energy resiliency, the involved technologies, and a discussion of the interplay between all the elements. This document contains three contextual sections: *Energy Resiliency and Microgrids*, *The Role of Critical Infrastructure*, and *Components of Microgrids as an Energy Resiliency Solution*. The fourth section, *AESC's Approach - from Concept to Design*, explains AESC's role in supporting customers with planning and implementation of energy resiliency solutions. Additional resources on energy efficiency (EE), demand response (DR), self-generation, storage technologies, microgrid components, and utility reliability metrics are included in the Appendices.

About AESC, Inc.

Founded in 1994, Alternative Energy Systems Consulting, Inc. (AESC) is an energy engineering practice that drives solutions in EE, renewable energy, distributed energy resources, energy resiliency and software implementation for utilities, regulators, public entities and private enterprises throughout the United States.

Energy Resiliency and Microgrids

What is energy resiliency?

Energy resiliency is the ability to maintain a reliable supply of energy during a power failure. The majority of electric utility customers draw power from the centralized electric grid, relying on an interconnected array of high-voltage transmission lines, substations, transformers, and generation plants. These systems, while sturdy, are not impervious to failures. Natural disasters, equipment malfunctions, increased demand, and human error periodically threaten their reliability.

In recent years, power outages have become more common, prompting many in the public and private sector to look for ways to maintain power during such events (or achieve energy resiliency). Microgrids can provide energy resiliency when they disconnect (or island) from the utility grid, using only local self-generation and storage to provide power.

What is a microgrid?

A microgrid is a combination of local power sources, or Distributed Energy Resources (DERs), that work together to supplement power from the grid and provide power during blackouts. These include commonly adopted power sources like solar panels and battery storage. Whether at the community, campus or building level, microgrids play a key role in successfully islanding and staying powered during outages.

See the case studies on page 10 to learn how AESC is supporting energy resiliency planning.

A more reliable and cost-effective electric grid

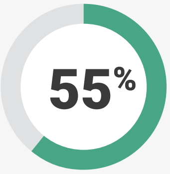
The decentralized nature of microgrids and DERs, when managed in concert with utility and grid operator objectives, help achieve a more reliable grid that delivers power to customers at a lower cost. The electric grid has always been susceptible to localized power outages from damaged power lines or other infrastructure, but widespread catastrophic power failures are occurring with more frequency and severity.

For example, millions of Americans have recently been impacted by outages associated with extreme weather events, such as wildfires and hurricanes, and proactive utility shut offs related to some of these events. Resiliency efforts and microgrids not only help businesses and public services remain open during power failure but give utilities and grid operators additional tools to better manage their work.

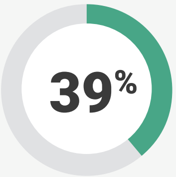
Another growing challenge is managing large swings in energy demand - both throughout the day, and on a seasonal basis. Microgrids and DERs, when constructed in concert with utility and grid operator objectives, help flatten the peaks and valleys across the system, thereby stabilizing operations. The dual benefit of a more stabilized grid is cheaper energy for all rate payers.

The need for a more reliable grid

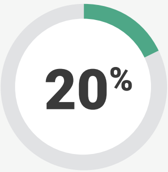
In “S&C’s 2020 State of Commercial & Industrial Power Reliability Report”, 255 energy managers from across the U.S. were surveyed concerning their experience with power outages. Results showcase the need for a more reliable grid.



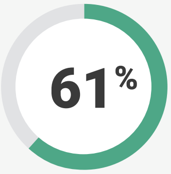
experienced a power outage one to two times a year



lost power for one hour or more



experienced a serious outage resulting in a loss of at least $100,000



plan to own an alternative energy source

“S&C’s 2020 State of Commercial & Industrial Power Reliability Report,” *S&C Electric Company,* 2020

Planning Considerations

For a given building portfolio, which infrastructure is critical? Why?

The Role of Critical Infrastructure

What is critical infrastructure?

Critical infrastructure is any equipment, building, campus, or portions thereof, without which the organization could not operate. For example, a sheriff's department may consider their entire station as critical, while an office building may only require their data center to remain powered on in order to maintain operation.

Identifying and prioritizing critical infrastructure

There are various criteria by which infrastructure can be defined as critical. Organizations should determine their specific criteria and then identify the critical infrastructure based on that rubric. It is important to prioritize the energy needs of critical infrastructure.

Sector	Examples of Critical Infrastructure	Impact of Power Loss
Healthcare and Public Health	Hospitals, community evacuation centers (such as schools), medical equipment at nursing homes	Lives would be at risk
Commercial Facilities	Grocery store refrigeration, electric vehicle charging along evacuation routes, gas station pumping	Basic necessities cannot be met
Transportation Systems	Traffic signals, air traffic control	Safety issues would arise
Water and Wastewater Systems	Wastewater treatment plants, water distribution	Public health risks
Information Technology	Data centers, cell towers, internet access	Core business functions stop
Government Facilities	Prisons, jails, courts, police stations, fire stations	Security issues would arise

Planning Considerations

What is the risk of outage for a given site?

Determining locational risk of outage

Grid reliability indices, such as those developed by the Institute of Electrical and Electronics Engineers, can help give a clearer picture of a building's risk for an outage. These indices have been adopted by most utility grid managers in the U.S. to track and report the reliability of their power supply. They include the System Average Interruption Frequency Index (SAIFI), the System Average Interruption Duration Index (SAIDI), and the Customer Average Interruption Duration Index (CAIDI). These indices measure the number of power outages an average customer experiences within a year, the time in minutes that an average customer experiences a power outage within a year, and the average duration of a power outage, respectively. Together these indices are an additional variable that may be used in planning for outages. As such, many utilities make their reliability metrics publicly available online.

Another variable to consider is locational issues related to extreme weather events, their recent frequency and the impact they have had in the infrastructure's region. What do past experiences indicate about potential future impacts?

Planning Considerations

In an event of an extended power outage, how long does the infrastructure need to stay powered?

(For example, just long enough for evacuation purposes, or through safety shut down protocols, or longer so the site can serve as a community resource for the duration of the outage.)

Which renewable sources are most appropriate for each location?

Components of Microgrids as an Energy Resiliency Solution

The dual roles of the microgrid

Microgrids stay connected to the larger grid and can import energy when needed. Additionally, they can use their own local supply when desired. For example, if utility demand charges are high and solar access is available, a building can draw power from solar panels to reduce demand charges. Alternatively, when the sun has set, the building can draw power from the main utility grid. In the event of a blackout, a microgrid can island itself (or, disconnect from the utility grid) and remain powered on through its own power supplies. For longer duration islanding, the microgrid will need a way to both generate power and store power – so that when the generation source is unavailable (say, due to lack of wind or solar access), the power it previously created is still accessible to the building.

Renewable on-site generation

On-site generation requires technology that transforms a local resource into energy. Many organizations prefer to use renewable resources such as solar, wind, and biogas. These offer a tremendous environmental benefit as they generate little to no greenhouse gas emissions and create new economic opportunities for the community.

Each renewable resource has its drawbacks. Some resources can only produce power intermittently. For example, solar energy produces power with sun access, while wind turbines produce power when the wind is blowing. Other resources are less variable, but are highly dependent on location. For instance, biogas projects may only be possible near wastewater treatment plants, landfills, or confined animal feedstock operations, such as dairy farms.

Planning Considerations

Which storage technologies are most appropriate for each location?

What is the baseline energy use for each site?

How can energy consumption be reduced?

What EE measures are possible and realistic?

Will DR measures provide additional benefit?

Knowing the benefits and drawbacks of renewable resources can help determine which type of onsite generation technology is most appropriate for an organization. For more information about self-generation options, see the Appendix.

Renewable on-site generation + energy storage

The key to a productive renewable energy microgrid is pairing the energy generation with energy storage. Developing a microgrid is more complicated than simply installing solar panels and a battery. True microgrids have sophisticated communications and control systems to connect and disconnect from the grid, modulate the voltage and frequency, and ensure the proper protections are in place. Artificial intelligence and advanced software are commonly integrated into the generation and storage solution to guarantee a reliable flow of energy.

For more information about connecting the microgrid to the utility grid, see the Appendix.

Importance and impacts of system sizing

On-site generation and storage technologies must be sized correctly. A microgrid that is too small will fall short of providing sufficient power for the facility. Likewise, a microgrid that is too large can result in overspending on an asset that is never fully utilized.

Correctly sizing a microgrid requires understanding the current energy use, knowing what EE improvements are appropriate, and establishing how long the microgrid should be relied on as the sole source of energy. For example, consider how long the infrastructure must remain powered during an extended outage. In addition, the site's willingness and ability to shift energy use or leverage energy storage to participate in utility DR events should be considered.

For more information about EE and DR, see the Appendix.

AESC's Approach - from Concept to Design

Building portfolio assessment

Planning across multiple buildings, campuses and critical infrastructure requires a holistic view. It is important to compare the sites to determine which will be most successful in achieving energy resiliency. The quickest and most cost-effective approach is to remotely analyze and assess each building and then rank them all according to potential. Careful up-front planning will save time and money later by prioritizing in-depth studies for those locations best suited to support a microgrid.

Planning Considerations

How does each site rank for the following considerations?

- Overall potential for energy resiliency
- Potential to reduce and/or shift load through EE and/or DR
- Ability to support most appropriate generation and storage technology solution
- Ability to cost-effectively provide sufficient generation and storage to meet duration needs

Feasibility study and initial design

For each location, an on-site, in-depth engineering study is important to understand the exact details and specifications for the microgrid. This study should include:

1	investigation of future changes that could increase energy use, such as: pending new construction and addition of electric vehicle chargers (keeping in mind that EV chargers can serve as an energy source as well as energy user),
2	exact energy efficiency and demand response measures to be pursued,
3	exact sizing and location of generation and storage,
4	single line drawings showing equipment selected and interconnections,
5	equipment specifications and cost estimates,
6	power flow analysis, and
7	initial feedback from and engagement with the local utility to advise on interconnection and other issues.

The engineering study should include key content that can transfer to a procurement RFP for microgrid and resiliency solution vendors.

Case Study 1

Planning Energy Resiliency for One California State Agency

When one California state agency needed energy resiliency for their building portfolio, they started by creating a plan.

AESC's Building Energy Resiliency Planning Services helped this effort by first analyzing the energy use of over 70 of the agency's buildings, resulting in 45 buildings that had sufficient potential to warrant further study. A follow up analysis provided energy efficiency recommendations in concert with solar and storage financial modeling designed to meet their required six hours of energy self-sufficiency.

The resulting plan paved the way for implementing energy resiliency solutions at these critical locations so they can stay powered on during utility outages.

To read the full case study, visit:
aesc-inc.com/energy-resiliency-case-study

Case Study 2

Energy Resiliency Planning On Campus

In 2019 a community college in Northern California was impacted by numerous power outages, resulting in millions of dollars of lost revenue and unreimbursed expenses. Anticipating additional costly power outages, the college needed to understand their options for remaining powered during future events.

AESC's Building Energy Resiliency Planning Services furnished the college with a comprehensive, unbiased view into their energy resiliency options. The college now has the data they need to select the best solution and avoid future outages, providing benefits to the college, their students, and the community at large.

To read the full case study, visit
aesc-inc.com/in-depth-energy-resiliency-study/

Conclusion

Achieving energy resiliency is an important, yet complex, undertaking. Reaching a final solution will involve the engagement of business decision makers, on-site facility management personnel, and electrical and mechanical engineers. AESC is equipped to help at any step along the way – we can leverage our software platform, Praxis, to quickly prioritize a portfolio of buildings, or we can employ our staff of engineers to advise on and/or create site-specific resiliency feasibility studies and provide initial design. Our team of energy experts is here to provide advice and support at any point as you pursue your path to resiliency. Contact us at: info@aesc-inc.com.

Appendices

The role of EE and DR

Reducing Energy Use	The less energy a microgrid needs to provide, the smaller it can be. A smaller capacity translates to less costs and a more cost-effective solution. Consequently, the first step in implementing a microgrid is to reduce the amount of energy required on a daily, ongoing basis by identifying and implementing EE measures.
Shifting Energy Use	In addition to lowering overall use, there are benefits to shifting when energy is used. Many utilities charge more for energy at certain times of the day and have programs that incent shifting energy use when they call a DR event. It is important to consider how energy use patterns can change to minimize the amount of energy drawn from the utility's grid during more expensive periods or DR events. There are operational solutions, such as pre-cooling a space that will limit the energy draw at certain times. Additionally, when considering the microgrid, it pays to investigate options to have the battery serve as the primary energy source during peak pricing times when connected to the utility's grid, thus gaining benefit from the technology outside of a resiliency event.
Types of EE and DR	EE and DR can take a variety of forms, for example: • capital equipment upgrades such as new, more efficient chillers, boilers, HVAC units, and energy management systems, • regular maintenance actions such as recalibrating occupancy sensors, repairing window/door weather stripping, or cleaning heating/cooling coils in air handlers, • and no-cost operational changes, such as adjusting thermostats to increase cooling setpoints, resetting schedules to more closely align with occupancy, or locking out boilers during summer months.
EE and DR Considerations	The best EE and DR measures will vary by building age, type, use, and operational needs, and the ones that make the most sense to implement will be driven by business priorities. Many utilities across the country have programs that can help offset the costs of EE measure implementation and that provide financial benefits for participating in DR events.

Self-generation options

There are a variety of self-generation technologies available, each appropriate based on a given set of circumstances. Some of the considerations are laid out below.

Solar panels

Site Considerations	Cloud coverage, shading by trees and other structures, roof area, parking lot area
Financial and Environmental Considerations	Lowering solar panel costs make them an attractive source of energy if the site can accommodate the footprint. Power Purchase Agreements can reduce upfront costs.

Wind turbines

(large and small)

Site Considerations	Average wind speed, turbine height, height of nearby obstructions such as buildings and trees, siting restrictions
Financial and Environmental Considerations	The cost per kW of wind turbine generators drops significantly as the size increases. However, siting becomes more of an issue.

Combined heat and power (CHP)

(including fuel cells, microturbines, gas turbines and internal combustion engines)

Site Considerations	Availability of natural gas, size of thermal load, size of electrical load, footprint of CHP system, local air quality restrictions, local noise restrictions
Financial and Environmental Considerations	Fuel cells are the highest cost generators. However, they also have the smallest environmental footprint. Internal combustion engines are the lowest cost generators with the largest environmental footprint.

Renewable natural gas powered generation (biogas)

(including fuel cells, microturbines, gas turbines and internal combustion engines)

Site Considerations	Onsite availability of biogas, footprint of biogas plant and gas cleanup equipment, local air quality restrictions, local noise restrictions
Financial and Environmental Considerations	As compared to CHP, the costs for biogas systems are higher due to the cleanup required to remove biogas fuel impurities. However, GHG emissions are lower since the biogas fuel source is terrestrial biomass rather than fossil fuels. Fuel cells have been used with biogas fuel, with some fuel cleanup required. Internal combustion engines require the least amount of fuel cleanup in a biogas system.

Pressure reduction turbines

(including steam turbines and inconduit hydro)

Site Considerations	Availability of high-pressure steam or water distribution network requiring reduction to a lower pressure
Financial and Environmental Considerations	This technology is applicable to water districts and industrial customers that use process steam. The technology is fairly expensive but can payback fairly quickly since water flow and steam flow in these types of distribution networks is typically high. This technology has low environmental impact.

Waste heat to power

(including organic rankine cycle and steam turbines)

Site Considerations	Availability of a high temperature waste heat source
Financial and Environmental Considerations	This technology has a low environmental impact since it uses waste heat. Costs can be fairly high depending on the size of the installation. However, pay back can be relatively fast, especially if the source of the waste heat is continuous, such as in an industrial process.

Energy storage technologies

Battery energy storage

(including lithium ion batteries, lead acid batteries and flow batteries)

Site Considerations	This is primarily an electric load shifting technology therefore the size of the electric load and the duration of the needed shift is a primary consideration. Some jurisdictions are requiring adherence to strict fire codes if lithium ion batteries are installed inside.
Financial and Environmental Considerations	The size of the electric load and the duration of the needed shift is a primary driver for cost. Of the three batteries listed, flow batteries tend to be the highest cost, followed by lithium ion, and then lead acid. The operational characteristics of lithium ion batteries exceed their competitors in power density. However, flow batteries have better cycle lives. Lead acid batteries have the most robust recycling industry, given these batteries have been used in automobiles for years. Environmental benefits depend both on the paired renewable energy source and, if charging from the grid, the alignment of the customer's time of use (TOU) rates with the grid's marginal emissions rates.

Thermal energy storage (TES)

(including refrigeration and HVAC based TES)

Site Considerations	This is primarily a thermal load shifting technology. Therefore, the size of the addressable thermal load is a primary consideration. Refrigeration based TES can be used in the form of phase change material in refrigeration warehouses or as ice storage in grocery stores with refrigerated cases. HVAC based TES can offset an HVAC's energy use during the hottest part of the day while providing cooling to a building or group of buildings. Larger HVAC based systems can use ice or chilled water storage and are operated in conjunction with the building or campuses chilled water plant. Smaller HVAC systems use ice storage and are paired with roof top units that use DX cooling.
Financial and Environmental Considerations	Installed cost varies based on size. Operating costs and energy savings depend on the availability of TOU rates and how the TOU rates match up with building operating schedules. Environmental benefits depend on operating schedule for the TES and the building, and the alignment with the grid's marginal emission's rates.

Factors involved in integrating the microgrid with the utility grid

Microgrid Controllers	A microgrid controller is essential in not only managing the loads and power generation sources in the microgrid but also to ensure two-way communication between the utility grid and the microgrid. This controller ensures that the right amount of utility grid power is used to supplement the renewable power in the microgrid and allows switching to islanded operation when circumstances require.
Automatic Transfer Switches	An automatic transfer switch is required at the point of common coupling, along with protection relays that allow a smooth transition between operation in parallel with the utility grid and operating in islanded mode. These devices are necessary to protect equipment in the microgrid from poor power quality and to protect human life when utility linemen are working on the utility grid and the microgrid is powered up in islanded mode.
Involving the Local Utility	Interconnection of a microgrid requires close coordination with the utility's interconnection department. It involves understanding the protection requirements imposed by the utility and the ability to provide electrical plans and specifications in response to the questions raised during the interconnection study.

SAIDI, SAIFI, and CAIDI indices

Using reliability indices can help customers understand their electrical utility's performance. SAIFI, or the System Average Interruption Frequency Index, is the average number of power outages a customer experiences in a year and SAIDI, or the System Average Interruption Duration Index, is the average outage duration a customer experiences in a year. SAIFI and SAIDI can be used together to estimate the total average downtime for a given location.

$$\text{Total Average Downtime} = \text{SAIFI} \times \text{SAIDI}$$

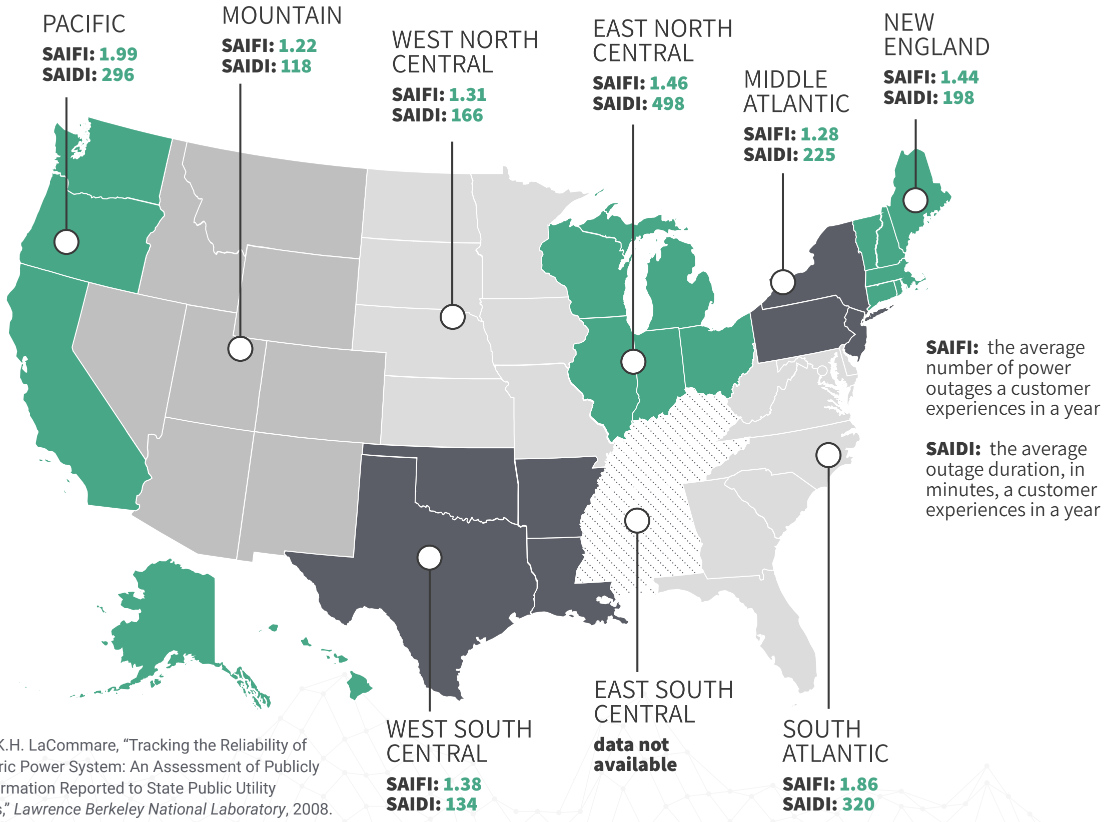
Based on the data in the map below, a building located in Colorado would have a SAIDI index of 118 (minutes/outage/customer) and a SAIFI index of 1.22 (outages/customer). This would mean the building is likely to experience 143.96 minutes of downtime per year.

Additionally, SAIDI and SAIFI can be used to determine CAIDI, or the Customer Average Interruption Duration Index. This index measures the average duration of a single outage.

$$\text{Average Duration of a Single Outage (CAIDI)} = \frac{\text{SAIDI}}{\text{SAIFI}}$$

Using the same example as before, a building located in Colorado is estimated to have an average power outage duration of 96.72 minutes.

The Reliability Utility Energy Supply in Eight U.S. Regions



J.H. Eto and K.H. LaCommare, "Tracking the Reliability of the U.S. Electric Power System: An Assessment of Publicly Available Information Reported to State Public Utility Commissions," *Lawrence Berkeley National Laboratory*, 2008.