Climate change and the growth of renewables presents California hospitals with many challenges, but also opportunities

Microgrids for Healthcare Facilities

A White Paper on Technology, Supply Chain, Codes, Regulations, Operations and Maintenance

By the Hospital Building Safety Board – Energy Conservation and Management Committee

Presented to OSHPD

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Background

Hospitals are facing the challenge of power disruptions which are much longer than those previously anticipated due to Public Safety Power Shutoff (PSPS) programs in California. To continue to provide even basic patient care, facilities must provide backup power exceeding the 96 hours currently code required. Backing up hospitals for the purpose of life and safety, however, is only a first step in addressing power needs during PSPS. Providing energy for full business continuity for operating rooms, emergency departments and medical office buildings, to meet the full spectrum of needs of staff and patients in PSPS-affected area, fulfills bigger picture, comprehensive, emergency management goals.

The Energy Conservation and Management (ECM) Committee was charged with developing a white paper to present to OSHPD as a guide to develop code modifications to support the adoption of microgrid technology to reduce or eliminate the need to rely on generators as the source of emergency power for hospitals in California.

The Hospital Building Safety Board (HBSB), ECM Committee has been tracking developing solutions for several hospital microgrid pilot projects, including the Kaiser Permanente Richmond Hospital and the San Benito Health Foundation Community Health Center. The Committee has hosted several presentations on microgrid solutions during regular meetings. The HBSB ECM Committee has also been working closely with the California Energy Commission, which is mandated with implementing California's Net Zero Energy (NZE) goals. Committee members also visited the Santa Rita Jail microgrid project in August of 2019.

Under the leadership of the ECM Committee, this white paper is the work of industry experts who volunteered and spent countless hours to share their knowledge and experience with this technology. The intent of the white paper is to describe microgrid technology, the need for its use in California hospitals, and the standards and justification for its implementation.

Abstract

Climate change and the growth of renewables presents California hospitals with many challenges, but also opportunities.

This white paper investigates the role microgrids can play in addressing the challenges of climate change while also better utilizing available renewables. It explores the needs, challenges and solutions necessary to deliver this more reliable and sustainable power distribution system for California's hospitals.

To effectively deliver healthcare microgrids in California, all aspects need to be addressed. We have therefore broken this white paper into three distinct sections to ensure each aspect required to implement these solutions is discussed. The categories are: Technology/ Supply Chain, Codes/ Regulations and Institutional/Financial.

Introduction

As hospitals are essential facilities, they require a reliable source of alternate power in events of planned or unplanned interruptions. Hospitals also consume large amounts of energy, which is traditionally provided by non-renewable sources.

Evolving microgrid solutions provide the ability to toggle seamlessly between primary, secondary, and tertiary sources of power. Microgrid solutions increase reliability and enhance utilization of renewable generation.

Implementing hospital microgrids is not an overnight change, but rather a process. The aim of this white paper is to provide a roadmap for the execution of hospital microgrid solutions in the state of California.

Contributors and Acknowledgements

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Stranded Assets Versus Always-On Assets

The power goes out and backup generators do not kick in – this is a hospital's worst nightmare. Although routine testing of backup equipment is required, the fundamental challenge this technology faces is that backup generation is not continually operating, making traditional diesel-powered backup generators often a stranded power asset, with possible limited run-time capabilities.

The possibility of a stranded power asset is one of the major reasons why baseload sources of energy that are always-on and participate in the day-to-day energy supply of a healthcare facility are so attractive. Such always-on assets may include cogeneration from combined heat and power (CHP), fuel cells, solar power and battery storage. When such always-on assets are coordinated with traditional backup power generation, all assets can provide the desired reliable power generation in times of emergencies.

Fuel Access Restrictions

Based on NFPA-110 (Standard for Emergency and Standby Power Systems), hospitals are classified as critical facilities. This triggers a requirement for at least 96 hours of fuel storage for an emergency standby power plant (Dishel, 2013). This requirement assumes that whatever caused interruption to the normal source of power will be remedied within that timeframe. Or, if a remedy is not possible, it presupposes that access to fuel is readily available to sustain the facility beyond the 96-hour threshold.

For example, in October 2019, the California Governor's Office of Emergency Services said 248 hospitals were in areas where power was intentionally turned off in Public Safety Power Shutoff (PSPS) events due to wildfire threats. In fact, according to the California Public Utility Commission (CPUC), "From 2013 to the end of 2019, California experienced over 57,000 wildfires (averaging 8,000 per year) and the three large energy companies conducted 33 PSPS de-energizations." It goes on to state that, "Over the last decade, California has experienced increased, intense, and record-breaking wildfires in Northern and Southern California." Further, Cal Fire, California's fire protection service, has said publicly that it no longer considers there to be a wildfire "season," because the season is now the entire year (Pamer & Espinosa, 2017).

Thus, it is not a stretch to envision a scenario in which access to fuel is limited during an extended outage. This could be due to road closures from a wildfire, downed vegetation or power lines from severe wind, flash flooding, or even road damage due to earthquakes. The Uniform California Earthquake Rupture Forecast, for instance, suggests that the likelihood that California will experience a magnitude 8 or larger earthquake in the next 30 years is about 7%. An earthquake of this magnitude (much larger than the 6.7 magnitude 1994 Northridge earthquake) could easily limit access to pathways that provide additional backup fuel. By sourcing energy from onsite assets, particularly those enabled in a resilient microgrid, healthcare facilities benefit from an always-on source of energy that is not limited to a set runtime and dependent on offsite fuel availability.

Air Quality Improvement and Short-Duration Outage

These findings reveal that healthcare facilities use a form of energy generation for short-duration, routine outages that would be better suited by an always-on microgrid. Reserving the use of old generator sets for longer-duration outages or simply avoiding them altogether would allow healthcare facilities to minimize their contribution to poor air quality in their communities. And, while it is true that not all alternatives – such as those based on natural gas – are entirely emissions free, they do avoid harmful pollutants such as nitrogen oxides (NOx) and sulfur oxides (SOx). In fact, the California Energy Commission reports that, "the California microgrid resource mix is [based on] 88% clean energy resources (solar, wind, energy storage, biogas, and fuel cell)." (Asmus et al, 2018, p.2).

Advantage of always-On Systems

As mentioned previously, one of the major reasons why always-on alternative baseload energy sources are attractive is they can participate in the day-to-day energy supply of a healthcare facility. When such always-on power assets are coordinated within the microgrid of the healthcare facility, the daily energy supply can also be monetized in ways that traditional sources cannot. Such energy and power incentives may include (Hirschbold & Haun, 2019):

<u>Avoid Demand Penalties</u>

In California, utilities charge based on both electricity usage (kWh) and demand (kW). A microgrid system can be used to dynamically manage loads to reduce peak demand, or "ratchet," charges by consuming more energy from onsite sources or temporarily turning off non-critical loads.

<u>Tariff Management</u>

By taking advantage of time-of-use (TOU) rates implemented by California utilities, healthcare facilities can determine when it makes economic sense to consume each energy resource, shifting some loads to "off peak" periods and storing energy for use at a later time.

<u>Demand Response Participation</u>

With the ability to generate energy onsite, healthcare facilities can curtail load pulled from the central grid in return for financial reimbursement.

Thus, a microgrid system gives hospitals an intelligent, transparent way to manage their always-on energy assets, also known as Distributed Energy Resources (DERs), in a manner that idle generators cannot match. Next to energy savings, the framework of a microgrid allows the healthcare facility to anticipate costly future mandates on power delivery and reduce overall energy costs by the grid services discussed earlier.

Chapter 1 - Technology and Supply Chain

What is a Microgrid?

A microgrid is a self-sufficient energy system that serves a discrete geographic footprint, such as a hospital site or building.

Within a microgrid there are typically one or more kinds of distributed energy (e.g. solar panels, wind turbines, combined heat and power, generators) that produces its power. In addition, many newer microgrids contain energy storage, typically from batteries.

Interconnected to nearby buildings, the microgrid provides electricity and possibly heat and cooling for its customers, delivered via a control system.

Microgrid Characteristics

A Microgrid is Local

First, this is a form of local energy, meaning it creates energy at the site or building it serves. This distinguishes microgrids from the kind of large, centralized grids (macro-grid) that have provided most of our electricity. Central grids push electricity from power plants over long distances via transmission and distribution lines. Delivering power from afar is inefficient because some of the electricity – as much as 8-15% – dissipates in transit. A microgrid overcomes this inefficiency by generating power close to those it serves; the generators are near or within the building, or in the case of solar panels, on the roof.

A Microgrid is Independent

Second, a microgrid can disconnect from the central grid and operate independently. This islanding capability allows them to supply power to their customers when a storm or other event causes an outage on the power grid.

While microgrids can run independently, most of the time they do not. Instead, microgrids typically remain connected to the central grid. As long as the central grid is operating normally, the two function in a kind of symbiotic relationship, as explained below.

Microgrid Controller

The microgrid controller is the central brain of the system, which manages the generators, batteries, and nearby building energy systems with a high degree of sophistication. The controller orchestrates multiple resources to meet the energy goals established by the microgrid's customers. They may be trying to achieve lowest prices, cleanest energy, greatest electric reliability, or some other outcome. The controller achieves these goals by increasing or decreasing use of any of the microgrid's resources – or combinations of those resources – much as a conductor would call upon various musicians to heighten, lower or stop playing their instruments for maximum effect.

A software-based system, the controller can manage energy supply in many ways. One example is that an advanced controller can track real-time changes in the power prices on the central grid. (Wholesale electricity prices fluctuate constantly based on electricity supply and demand.) If energy prices are inexpensive at any point, it may choose to buy power from the central grid to serve its customers, rather than use energy from, say, its own solar panels. The microgrid's solar panels will instead charge its battery systems. Later in the day, when grid power becomes expensive, the microgrid may discharge its batteries rather than use grid power.

Microgrid Energy Resources

Microgrids may contain energy resources connected via the microgrid switchgear and controlled by the intelligent microgrid controller – these energy resources may include: solar panels, battery or thermal energy storage, combined heat and power, wind power, fuel cells and reciprocating engine generators, and/or a combination of all the above.

What a Microgrid is Not

It's important to note what a microgrid is not. Some people use the term to describe a simple distributed energy system, such as rooftop solar panels. A key difference is that a microgrid will keep the power flowing when the central grid fails; a solar panel alone will not. Many building operators with solar panels are unaware of this fact and are surprised that they lose power during a grid outage.

Simple backup generators also are not microgrids. Such systems are only employed in emergencies; microgrids operate 24/7/365 managing and supplying energy to their customers.

The Department of Energy Formal Definition for a Microgrid

A microgrid is 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. Microgrids can connect and disconnect from the grid to enable them to operate in both grid-connected or island mode.

Microgrid Control Systems

Functional Resiliency

A hospital-based microgrid (HBM) is, in many ways, no different from modern microgrids that typically aim for coordination of a heterogenous set of energy resources to optimize power delivery to loads within its microgrid. Furthermore, an HBM may be also be used to reduce energy costs during day-to-day operations due to the ability to manage external power delivery to and from the main grid when energy resources are configured to be always-on and loads are differentiated by essential and non-essential (switchable) loads. However, one of the most important distinctions of an HBM is the functional resiliency the HBM provides: the possibility of fail-safe islanding of a hospital's life safety emergency power branch and reliable power backup services during grid outages (Bliss, 2019).

In characterizing the degree of functional resiliency of an HBM it is worth discussing how seamless the transition is from available external power to no main grid and vice versa. Such a transition can be either planned or unplanned, the latter being most difficult as Loss of Utility (LoU) or Recovery of Utility (RoU) power is unanticipated. Next to LoU and RoU, the utility may also send a Demand to Disconnect (DtD) in case of anticipation of LoU due to utility power interruptions (e.g., rolling brown outs, wildfire conditions). In addition, the HBM may issue a Request to Reconnect (RtR) in case of RoU, where reconnection typically requires the HBM to follow Rule 21 regulations (see Code and Standards) to avoid accidental powering of utility assets. For the functional resiliency of an HBM we make the distinctions summarized in Table 1.

Table 1.
Levels of resiliency and power availability for critical loads in an HBM in the case of Loss of Utility (LoU), Recovery of Utility (RoU), Demand to Disconnect (DtD), Request to Reconnect (RtR), or Maintenance Mode (MM).

	1. Not Resilient	2. Partially Resilient, Not Seamless	3. Resilient, Partially Seamless	4. Resilient & Seamless
LoU	Loss of critical loads	Loss of critical loads	Short term critical loads supported	Short term critical loads supported. Continued demand control and automated power flow supported.
	No disconnection from utility	Manual/Auto disconnection from utility	Automatic synchronized disconnection from utility	Automatic synchronized disconnection from the utility
	No available back-up power	Manual/Auto startup of back-up power	Automatic ramp-up of back-up power	Automatic load balance or ramp-up of power
RoU	Manual critical load restoration	Manual reconnection to utility	Manual/Auto reconnection to utility	Automatic synchronized reconnection to utility
		Manual/Auto disconnection and shutdown of back-up power	Manual/Auto disconnection and ramp-down of back-up power	Automatic load balance or ramp-down of power
DtD	NA	NA	NA	Scheduled Automatic synchronized disconnection from utility
				Automatic load balance or ramp-up of power
RtR	NA	NA	NA	Scheduled Automatic synchronized reconnection to utility
				Automatic load balance or ramp-down of power
MM	Loss of critical loads	Loss of critical loads	Possible manual disconnection of a resource for maintenance without loss of critical loads	Ability to disconnect a resource for maintenance without loss of critical loads

It is worth noting that a resilient HBM requires a synchronized disconnect and startup of a (short-term) critical load support when LoU to provide a so-called "flicker-free" critical load demand. In a fully seamless HBM, such (short-term) critical load support should also be available in case of a DtD to allow the HBM to anticipate planned or unplanned outage of the utility. A further distinction is made in the availability of backup power in a resilient and seamless HBM: the backup power is typically assumed to be "always-on" to provide the resiliency of being available when critical load support is needed.

Always-On –Time of Use and Peak Demand Reduction

The always-on backup power typically used in a fully resilient and seamless HBM also provides additional services when the HBM is connected to the grid to reduce electricity costs due to:

- Time of Use Energy Cost
- Peak Demand Tariffs

As previously discussed, time of use (ToU) refers to the price of electric energy (typically measured in kWh) as a function of the time of day in a week and is seasonally adjusted. Peak demand is the measured maximum power peak during a monthly billing cycle. Reducing both can lead to a significant reduction of electricity costs. Especially for large facilities, peak demand tariffs may be up to 40% of the total monthly electricity bill.

An always-on DER in the HBM can produce energy at times where the ToU pricing is high. The concept is illustrated in Figure 2 below where a comparison is made between controlled and uncontrolled power, showing a significant reduction in power and energy demand between 12:00 noon and 7:00 PM. Such reduction can often be achieved by careful day-ahead planning of a photovoltaic (PV) output in conjunction with energy storage (battery) to provide power after the sun has set and PV power production has been diminished.

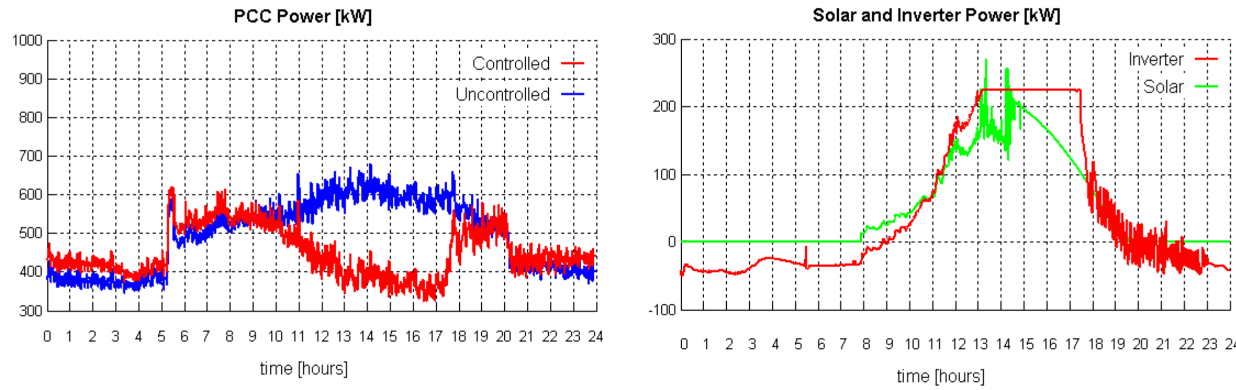


Figure 2. Illustration of Point of Common Coupling (PCC) utility power flow with and without microgrid control (left) and coordinated power flow out of a solar and battery AC-DC inverter to reduce ToU pricing and peak demand tariffs, (Bliss, 2019).

In addition, by measuring the real-time power flow over the Point of Common Coupling (PCC) to the utility, additional power peaks can be reduced to limit peak demand charge tariffs. The reduction of power peaks can often not be accounted for by day-ahead planning as power peaks may be unpredictable. In such cases, real-time power measurements used by a microgrid controller can be used to coordinate DERs and reduce peak demand (Valibeygi, 2018 and Prabakar, 2020). Additional demand side management is achieved by monitoring the load in real time and having the ability to allow more load to be added or subtracted from the supply distribution via direct control and feedback of various devices such as circuit breakers, transfer switches, or communication to larger monolithic loads that have the ability to manage their own power demand typical of large HVAC systems.

Switch Logic, Power Control and Planning Capabilities

Fundamental to the autonomous operation of a resilient and possibly seamless HBM is the unified concept of an automated microgrid management system, often referred to and collectively called the "microgrid controller." A schematic pictorial diagram often places the microgrid controller as a central processing unit for the coordination of energy resources and loads in the microgrid. However, in practice microgrid control may be organized both centrally and distributed throughout the microgrid, depending on the time scale at which such coordination needs to take place.

The example in Figure 3 illustrates the different time scales: dedicated communication and logic decisions between switchgear and an AC-DC inverter is needed at the rate of milli-seconds for fail-safe islanding of a hospital's life safety emergency power branch (Konakalla, 2020). On the other hand, power flow coordination between intermittent renewable energy sources (such a solar) and loads may be operating at the rate of seconds to ensure power quality and voltage levels within the microgrid (Valibeygi, 2019). Last, but not least, planning of energy storage in the form of batteries or cold-water storage may be done at 15-minute or hourly intervals to ensure energy storage constraints (Valibeygi, 2020).

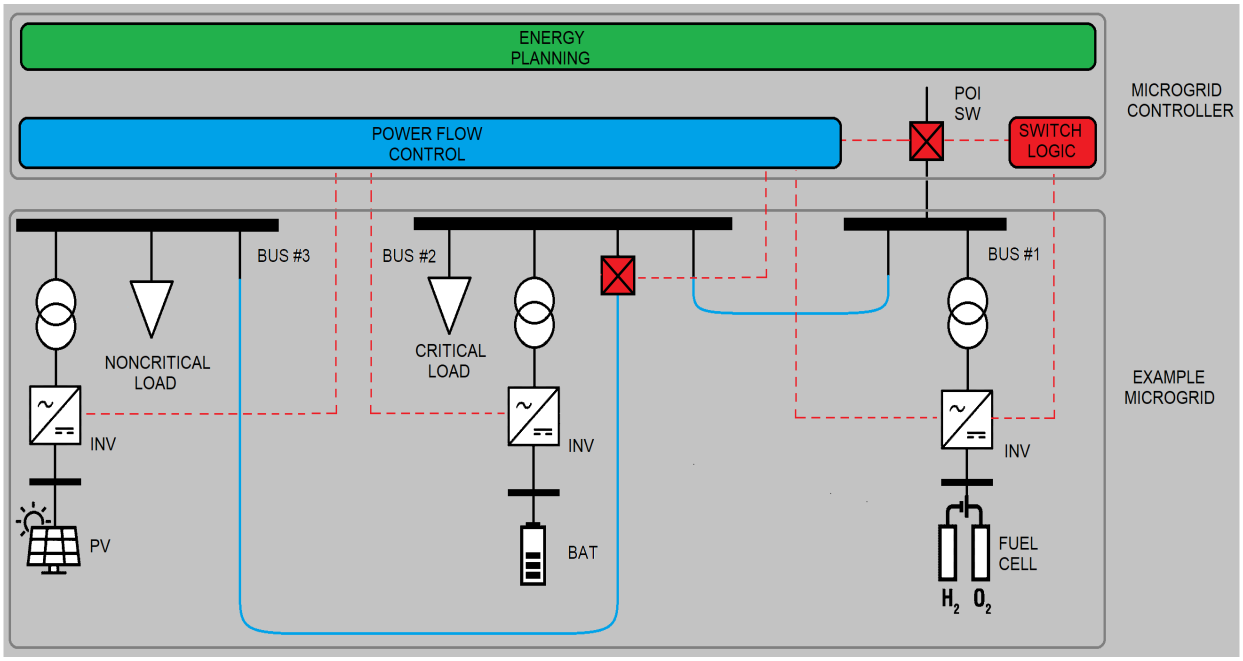


Figure 3. A microgrid with buses for critical load and (switchable) non-critical load, distributed energy resources (DERs) consisting of PV, energy storage, and a fuel cell. The microgrid controller consists of three parts operating at different time scales and focusing on switch logic (red), power flow control (blue), and energy planning (green).

In describing the best practices for the selection, installation, and operation of a microgrid controller for an HBM, it is worth making a distinction in the different time scales and the corresponding services a microgrid controller should provide.

Table 2.
Separation of time scales for a microgrid controller for services during grid-connected or islanding conditions.

Functionality	Time Scale	Location	Purpose	When
Switch Logic	AC cycle Ts < 20msec	Switch gear, disconnect switch, protection circuitry, AC-DC inverter firmware	Synchronized disconnect and startup/switching of inverter	Transition from grid-connected to Islanding
Power Flow Control	0.1sec – 5 sec intervals	Central computer	Power flow coordination between energy resources and possible non-critical load switching maintain power demand, power quality, voltage levels and minimize peak demand	Either during grid-connected or islanded condition
Energy Planning	5min – 15 min intervals	Central computer	Keeping energy storage within constraints, planning for Time of Use (ToU) optimization	Typically during grid-connected condition

Important elements that decide on the required capabilities of the microgrid control include:

- Ability to integrate existing and new energy resources as the HBM expands over time.
- Ability to provide services to manage utility costs (ToU costs and peak demand tariffs).
- Ability to be reconfigured for contingency events and guarantee continuity of critical loads.
- Ability to seamlessly island in case of LoU or on demand.
- Ability to adapt the planning for daily energy demand (e.g. ToU costs) when energy storage capability requirements change over time.
- Despite autonomous operation, allows for intervention by qualified personnel.
- Provide a history and communication of system status of each DER and planning.
- Configurable cybersecurity requirements to protect the security of the microgrid.

Grid Services

Essential to the requirements of a microgrid controller for a HBM is to make a distinction between grid-connected services and islanded (grid-disconnected) services as mentioned in Table 2 and to allow integration of the services with the new and existing energy resources in the HBM, while providing at least a resilient and (partially) seamless microgrid. A resilient HBM that decides to improve its resiliency by providing always-on DERs opens the possibility to participate in grid services that provide cost savings for the microgrid operator by reducing electricity costs. It is also able to participate in financial incentives that help in the stability of the grid. Such grid services may include:

1. *Voltage and Frequency Services*. During the utility-connected mode of operation, a microgrid owner can utilize DERs to opt into paid service by the utility companies. This feature commands the system to assist the utility in maintaining localized grid power quality via a direct command control sequence that the controller will receive from the utility grid operator. It issues commands to one or all the DERs to respond to the requirement.
2. *Utility Demand Management*. Depending on the selection of the DERs and their capability, along with the owner's utility rate structure, a demand charge may be present that can be avoided by deft management of a battery storage resource should it be part of the microgrid resources. This capability is expected to monitor and predict the client's load and respond to daytime power consumption peaks by activating the output of the battery to avoid setting a high demand charge. This results in reduced utility costs.
3. *Time of Use Load Management*. Although the microgrid controller is expected to manage the load during an islanding event, it can also do so during grid-connected mode. The controller can be installed with the ability to recommend and activate loads at various times of day when utility rates are favorable yet not overly impacting client operations. During the utility-connected mode of operation, a microgrid owner can utilize the always-on DERs in the grid to opt into paid service by the utility companies. This feature commands the system to assist the utility in maintaining localized grid power quality via a direct command control sequence that the controller will receive from the utility grid operator and issue commands to one or all of the DERs to respond to the requirement.

Ultimately, the switch logic implemented as part of the microgrid control and used to make the decision on whether to be connected to the grid (for grid services) or disconnect from the grid (for resiliency purposes) highly depends on the capabilities of the switchgear hardware. The switchgear must be chosen carefully to allow the control capabilities desired for the (islanding) microgrid of a hospital facility.

Switchgear

Connection Hardware

Switchgear is a key technology consideration that allows microgrids to physically connect and disconnect from the grid and operate in an islanding mode for extended periods of time. According to the National Electrical Manufacturers Association (NEMA), switchgear is made up of electrical disconnect switches, fuses, or circuit breakers that control, protect, and isolate electrical equipment. Switchgear is also used to de-energize equipment to allow critical maintenance work to be done and to clear faults downstream. Products that make up the switchgear category include:

- Breakers
- High-voltage fuses
- High-voltage outdoor power circuit breakers and switches
- Low- and medium-voltage power circuit breakers
- Medium-voltage load interrupter switches
- Pad-mounted switching equipment
- Power switchgear assemblies
- Reclosers
- Sectionalizers

Furthermore, a switchgear assembly typically has two types of components:

- *Power-conducting components* such as switches, circuit breakers, fuses, and lightning arrestors that conduct or interrupt the flow of electrical power.
- *Control systems*, such as control panels, current transformers, potential transformers, protective relays, and associated circuitry that monitor, control, and protect the power-conducting components.

Switchgear is located on the high- and low-voltage sides of large power transformers in substations and can be used with voltages up to 1,100 kV. On the low-voltage side, switchgear can be used in conjunction with medium-voltage (MV) circuit breakers for distribution circuits, metering, control, and protection equipment.

Microgrid Assessment

From a reliability, security, and cost effectiveness standpoint, hospitals that are looking to deploy a microgrid should utilize as much of their existing essential electrical system as possible. This includes preinstalled onsite switchgear, electrical distribution feeders, backup generators, etc., thereby reducing microgrid implementation costs. However, each circumstance and set of requirements to deploy a microgrid are unique and must be considered carefully when developing the strategy and execution plan to provide energy reliability. For that reason, it is important that a careful analysis of risks and needs specific to each situation are fully reviewed and understood.

To help with this process, hospitals should first consider utilizing a "microgrid assessment" or "microgrid feasibility study." The microgrid assessment service should provide a comprehensive and tailored analysis along with a detailed energy action plan. The microgrid assessment service will inventory and identify each critical asset in the hospital's existing essential electrical system, including the main switchgear and associated electrical distribution, to determine if those existing assets can fully support the proposed microgrid or if modifications to existing switchgear or additional switchgear capacity is required. As example, the microgrid assessment service will examine critical aspects of the proposed microgrid including load sizes, load profiles, switchgear location, metering, control capability, etc. to determine if those assets can adequately support the proposed microgrid.

In addition to investigating existing switchgear capacity and functionality, the microgrid assessment should also analyze and make recommendations on the following:

- Current electrical power system infrastructure.
- Existing generation sources and available utility incoming sources.
- Identification of microgrid configuration and point(s) of interconnection with utility grid.
- Existing and future distributed energy resources (DERs) such as solar, wind, combined heat and power (CHP), fuel cells, and energy storage.
- Plant site visual audit of electrical equipment types, ratings, and operating conditions.
- Development of scenarios to address options for short- and long-term microgrid system configurations, which could include critical load uptime and black-start/extended outage capabilities (e.g., 1-hour vs. 1-day vs. 1-week).
- Harmonics and power quality issues and transient response and system restoration.
- Microgrid conceptual design including preliminary sizing and siting of DERs along with preliminary electrical one-lines and control system architecture.
- Modes of operation and switching sequences.

One of the top priorities of the microgrid assessment service should be to review any existing electrical infrastructure drawings, such as one-line diagrams and site distribution plans. These important documents will help identify and illustrate key electrical system components such as main distribution switchgear, feeders, and building transformers along with accurately mapping key isolation and connection points. Electrical one-line drawings and maps assist with understanding how the existing electrical distribution system was constructed. It is critical to validate and ensure the accuracy of these drawings, as site projects may have added or changed system components over time. Typical electrical drawings for hospitals should include the following electrical areas:

- Building "one-lines" (commonly 120V/208V or 277V/480V).
- Information on building-tied standby generators and automatic transfer switches along with any related paralleling switchgear.
- Service transformers, secondary distribution, and any electrical metering or monitoring.
- Switchgear and electrical distribution one-lines.
- Substation/switching station one-lines (commonly include power transformation equipment and switching and protection devices).
- Sub-transmission or transmission one-lines (commonly held by the utility).

- Installation map with distribution system and building numbers (commonly includes locations for manholes, poles, switching devices, and building transformers).

Part of the microgrid assessment service should be to analyze the electrical drawings and infrastructure maps closely identifying and examining major items such as loads, means of connecting to the distribution system, generation sources, line ratings, protection and switching devices, available physical space, and circuit breaker locations available for the proposed microgrid. All these items are critical when considering electrical distribution upgrades that will lead to a successful microgrid.

Major components of the electrical drawings that are relevant to the proposed microgrid include: load connections, generators, circuit protection and switching, conductors, transformers, and utility feeds. This will help ensure that the existing electrical distribution system can support the proposed microgrid or will reveal if modifications, upgrades, and/or expansion capacity are required. This is very important because a microgrid using the hospital's installed electrical distribution system to connect generation and loads could be impacted by the existing system's limitations. When considering a microgrid, the existing electrical distribution system must be adequate and robust and must not become a potential failure point for the microgrid system or jeopardize system reliability.

Isolation Points

Another crucial component of the microgrid assessment service is the identification of isolation points to safely isolate a microgrid from other electrical systems during various scenarios. As example, the point of common coupling (PCC) between the installation and the external utility's power system must be established. Microgrids could have multiple PCCs, and some PCCs could be in a normally open position, with no power flowing during normal conditions.

Several microgrids have used existing switchgear or protection devices as the isolation point at the PCC but upgrades to those systems and devices could be required. As part of microgrid assessment service, potential isolation points should be identified on the one-line drawings and examined during any on-site visits.

Isolation for the microgrid could occur further down the electrical distribution system from the PCC if the microgrid were going to include only a subsection of the installation loads, such as one particular feeder.

In summary, before pursuing a microgrid, it is highly recommended to embark on a microgrid assessment service to assess the existing electrical distribution system that will support the microgrid. This will identify any areas of concern along with upgrades and capacity expansion that may need to be completed before or during the microgrid construction. Crucial during the decision process is addressing how to maintain and support the microgrid control software and switchgear, addressed in the following section.

Microgrid Operations and Maintenance

Categories in O&M

Once a microgrid is installed, ensuring it stays fully operational and functions as intended is essential. As a best practice, healthcare facilities should clearly define the party responsible for ongoing microgrid operations and maintenance (O&M), along with whom is responsible when something goes wrong.

Microgrid O&M typically falls into three main categories (S&C, 2018):

1. **Do-It-Yourself.**
   Microgrid O&M utilizing onsite personnel is the least expensive way to maintain an installation. In addition, facility staff is onsite and readily available to act in the event of a malfunction. However, because each microgrid is unique, there is no "owner's manual" to turn to in times of need. A great deal of training is often required to equip staff with the knowledge necessary to fix problems if they arise.

   Facilities considering this O&M approach should factor in rates of employee turnover and access to training materials. For example, if the microgrid integrator has a simulation of the system (which this white paper's authors suggest as best practice), the simulator will serve as a useful training tool to avoid interruption to the actual microgrid.

2. **Third-Party Contractor.**
   A variety of energy companies specialize in microgrid O&M services. They can be economical when selected via a competitive request for proposal (RFP) and usually have much greater experience and overall microgrid familiarity than onsite personnel. That said, a third-party contractor will still face learning curves when assessing new projects and their sense of urgency in the event of faults may not be as great as those onsite.

3. **Microgrid Integrator.**
   The team behind the integration of a facility's microgrid is also the team best quipped to tackle O&M. Because of their staff's deep familiarity with the organization's microgrid, solutions to problems are likely to be resolved accurately and quickly. In addition, it is highly likely that at least some form of remote system maintenance will be possible. So, even without an onsite presence, microgrid integrators can often respond in real-time to system faults.

   Healthcare organizations considering ongoing O&M from their microgrid integrator should ensure that this scope of work is contractually agreed upon ahead of time and any costs are factored into the system. Because there is only one microgrid integrator, facilities are beholden to that team's knowledge and availability, so setting clear expectations in writing is a vital best practice. Including examples of potential microgrid O&M tasks that fall inside and outside the scope of the agreement is essential.

Cybersecurity

Another important maintenance consideration is shielding the facility from cyberattacks to ensure reliability of power delivery for the microgrid and the facility itself. Over the last half decade, the world has witnessed a disturbing escalation in disruptive cyberattacks. In 2015 and 2016, hackers snuffed out the lights for hundreds of thousands of civilians in the first power outages ever triggered by digital sabotage. Then came the most expensive cyberattack in history, NotPetya, which inflicted more than $10 billion in global damage in 2017. Finally, the 2018 Olympics became the target of the most deceptive cyberattack ever seen, masked in layers of false flags. Hospitals in the United States were affected during the NotPetya attacks and have made headlines for ransomware payouts. Because microgrid components such as switchgear and controllers are not immune to cyberattacks, strict measures should be taken to isolate microgrids from the internet. (Source Andy Greenberg, Sandworm: A New Era of Cyberwar and the Hunt for the Kremlin's Most Dangerous Hackers Hardcover – November 5, 2019).

Common practices to ensure the cybersecurity of a microgrid are the isolation of digital equipment used in both the microgrid controller, switchgear, and DERs from the internet using firewalls or a separate intranet for all microgrid hardware. Referring to Figure 3, it is common to isolate switch logic, power flow control, and energy planning components of a microgrid controller on a firewalled or even separate network not directly accessible via the internet. Similarly, switchgear with embedded firmware should reside on a firewalled or even separate network not directly accessible via the internet. Any access to microgrid control hardware should only be done via a Virtual Private Network (VPN) connection, where all hardware has additional firewall rules that only accept inbound packages coming from the VPN.

With respect to cybersecurity, O&M of a microgrid does require periodic updates to software components incorporated on the microgrid controller and occasional software updates to switchgear firmware. Most of these processes can be automated but do require additional resources to maintain the quality and reliability of the always-on energy resources in a microgrid. Although extra resources are needed, the presence of a modern microgrid at a healthcare facility can overcome these costs in the long run. As indicated earlier, the framework of a microgrid allows the healthcare facility to anticipate costly future mandates on power delivery and reduce overall energy costs. Ultimately, always-on energy resources used in a microgrid will determine its capabilities to support demand within the healthcare facility. Some examples of DERs that can be integrated within the microgrid follows.

Solar Photovoltaic

The Role of Solar in a Microgrid

Solar photovoltaic (PV) generation is an increasingly common component of microgrid systems. Solar PV converts sunlight into direct current (DC) electricity (see Figure 4).

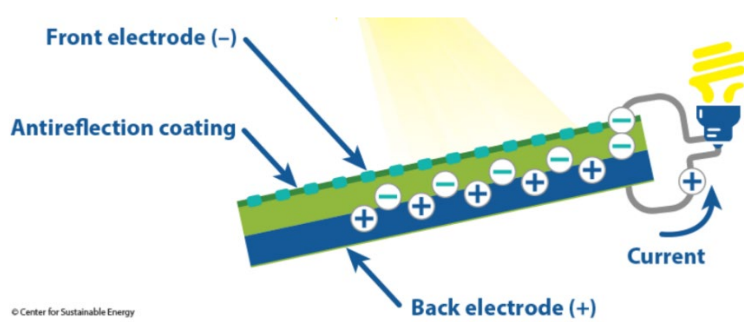


Figure 4. The Photoelectric Effect (GO Solar California).

While solar PV produces DC electricity, electricity purchased from utilities, and used by most end-use technologies, is in the form of Alternating Current (AC). Therefore, an important component of most solar PV systems includes a solar inverter (Figure 5, item 2) that converts DC generated by the solar panels to AC used within the facility, or where regulation permits, sent back to the utility grid. If the electricity is being sent back to the utility grid, there will also be the need for a bi-directional utility meter (Figure 5, item 3). Depending on the jurisdiction and regulation, electricity sent to the utility grid may provide bill credits or generate revenue.

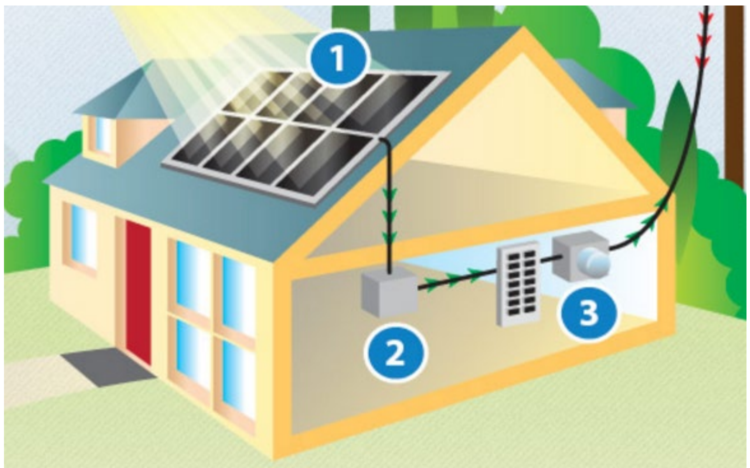


Figure 5. Typical Solar PV Installation (GO Solar California).

Electricity generated by solar PV has no associated fuel costs, greenhouse gas (GHG) emissions, or air pollution, and is increasingly cost effective. Power generated by these systems can be used within the microgrid to offset electricity purchased from the utility or to displace generation from other sources. In modern microgrids, solar PV is typically installed in one of three primary configurations: **carport**, **ground mount**, and **rooftop**.

Solar Carport

In recent years, carport solar PV installations have increased in popularity; these are also sometimes referred to as canopy installations. In this configuration, solar panels are installed on top of parking structures in above-ground parking lots (see Figure 3). Because many commercial spaces include large parking areas, carport configurations can be compatible with significant solar PV installations. Additionally, carport solar configurations do not compete for space with parking needs and, in fact, can enhance parking areas by providing vehicles with shade and protection from various weather elements.

Figure 6. Typical Solar PV Carport Application with integrated EV Charging.

Some of the common considerations associated with carport solar configurations include the following:

- Carport solar structures are not associated with an existing building; therefore, these will have distinct structural considerations. Carport structures are often subject to separate permitting requirements than the associated building. Are there additional permitting requirements to review?
- Electric vehicle charging stations are often co-located under carport solar canopies, both for convenience as well as green economic optics. Will an EV charging co-location strategy need to be incorporated?
- Capital cost implications of carport or canopy solar are typically much greater than adding solar to an existing rooftop. These economics need to be validated for the application and the region. What are the cost implications for building carport solar structures?
- Parking lots are often repurposed for other facility needs throughout the life cycle of the campus. By installing carport solar this flexibility can either be limited, or the investment in solar may go unrealized. What are the long-term expectations for the parking space?

Ground Mount Solar

If an institution has land available for development, ground mount solar PV is often an economical configuration. Ground mounted solar farms are typically built on a racking system that is optimally designed to gather the most solar energy based on the project location. It is also possible to have ground mounted solar that has a mechanical tracking system, which allow the solar PV to move with the sun and generate more energy; however, these systems are more costly and may not be economical.

Depending on the soil and site topography, there may be varying designs and needs for foundations that support the solar PV system. The most common constraint with this type of solar is associated with land availability. Typically, commercial institutions do not have excess land available for development, but where land allows, ground mount solar is worth exploring.

Rooftop Solar

For many commercial buildings solar PV panels are installed directly on rooftops. Panels can be mounted directly to the structure using roof penetrations or can be installed on racking assemblies sitting on the rooftop (ballasted), which do not require roof penetrations. For many commercial buildings, rooftops can represent an underutilized space that is well-suited for solar PV development; however, for hospitals, solar PV may compete with other required rooftop equipment.

There are several factors which need to be considered when planning for rooftop solar PV:

- How much capacity is available (PSI) on the existing roof to accommodate the addition of solar panels, racking, and wiring systems?
- Have regional building codes been considered with respect to wind up-lift, wind shear, snow load (where applicable) and seismic resilience associated with mounting panels and racking on the roof?
- If solar will be added to a new build, how can the construction contract be modified to accommodate installation of solar?
- Where can solar power tie back into the facility electrical distribution circuit?
- Is solar PV competing with other evolving urban rooftop trends such as green roofs, rooftop patios and rooftop gardens?
- What about interference from other rooftop equipment such as air conditioning units, cooling towers?

Cost trends

One of the main reasons solar PV is being considered to augment the energy mix at many facilities is the steadily declining costs in panels and associated equipment for solar installations. According to market research from Stantec, an international professional services company in the design and consulting industry, there has been a tenfold reduction in the cost of solar panels since 2007 and an additional threefold reduction is anticipated in the next twenty years (see Figure 7).

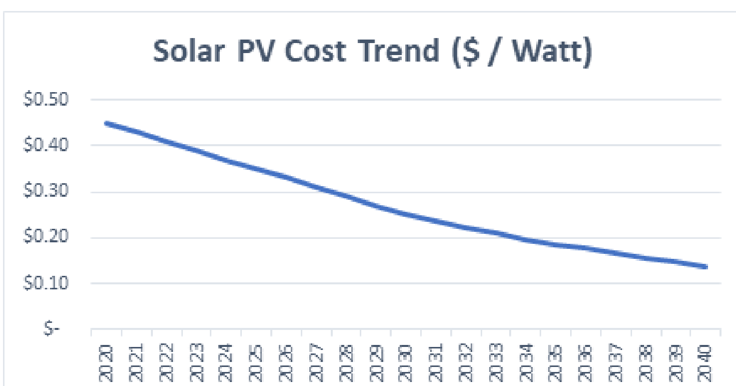


Figure 7. Solar PV Cost Trends.

The International Energy Agency (IEA) (2020) has forecasted that solar will see the most significant growth in the next ten years and will be the predominant source of new generation (see Figure 8).

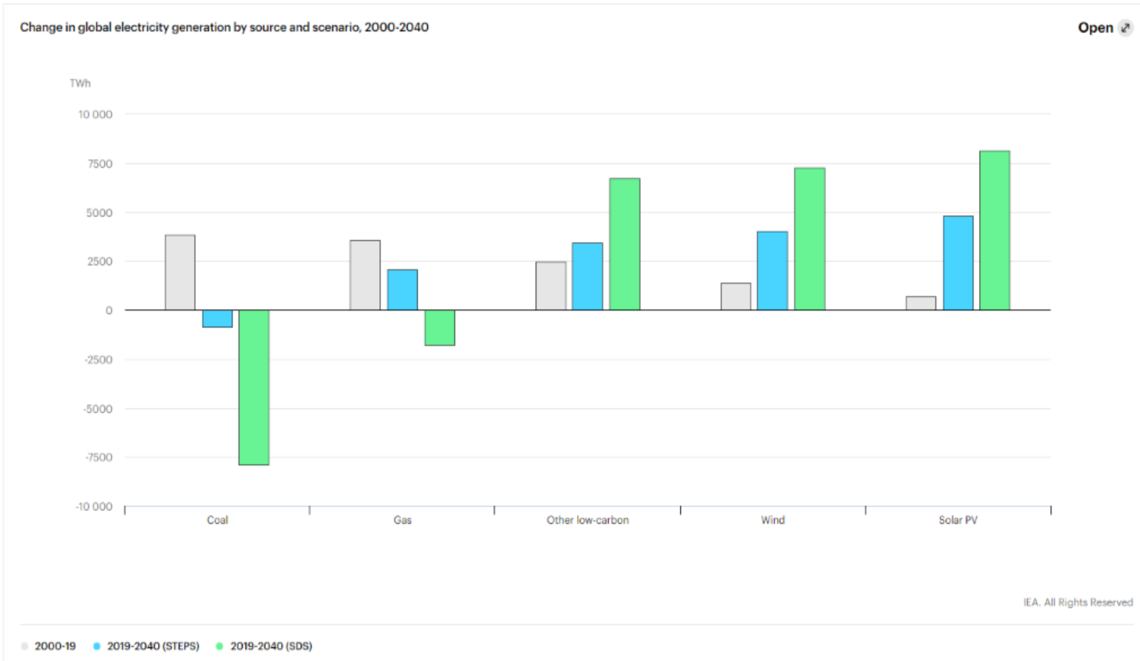


Figure 8. Global Change in Electricity Generation (IEA 2020).

Challenge: Power Density

Renewable energy sources, like solar PV, typically exhibit lower power density than traditional fuel sources; this can create challenges when trying to provide base power for a large campus or hospital. Broadly speaking, renewable energy sources require three times as much land as traditional non-renewable sources to produce equivalent power (van Zalk and Behrens 2018); however, solar PV has among the highest power densities among other renewable energy sources (see Figure 9).

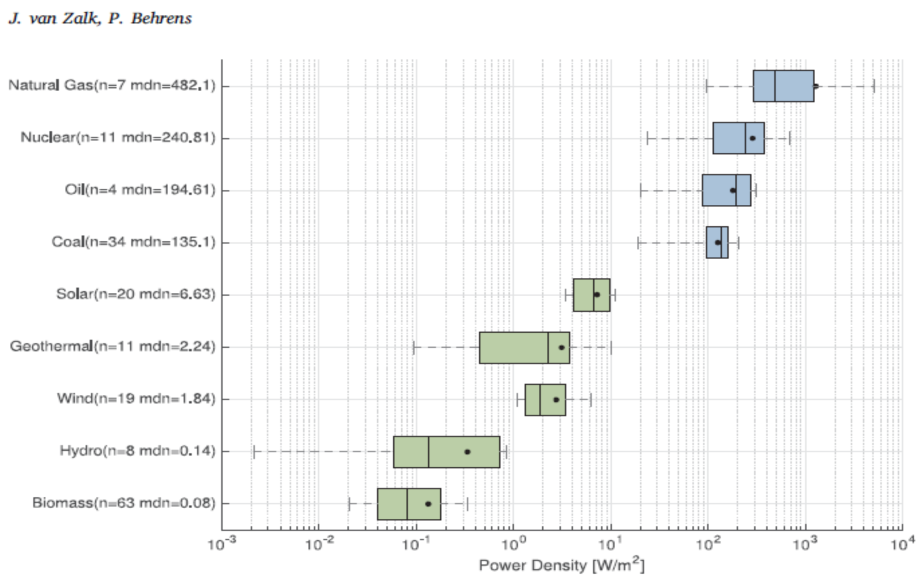


Figure 9. Power Density Comparison of Generation Sources (van Zalk and Behrens 2018).

Urban studies and smart city master planning research has observed that meeting complete electricity needs with on-site solar PV is challenging for buildings with more than three floors when using current commercially available solar panels.

Fortunately, research into solar technologies continues to improve and module efficiencies are expected to yield higher energy densities over time. Market research has shown a solar panel efficiency increase of almost 50% since 2007 with an average estimated increase of nearly 2.5% per year for the next decade and beyond.

Challenges: PV Curtailment

One challenge presented by renewable energy sources like solar and wind power is intermittency. Solar is most effective for about four hours during the day and cannot provide any power relief throughout the evening. In addition, power provided by solar PV will fluctuate based on weather patterns, clouds and the buildup of dust and dirt on the panels. Because the power output from solar PV varies depending on the time of day and weather conditions, it is not possible to rely on solar PV alone for base generation.

Historically, this variability has not been an issue because utility grids have acted as a buffer. When solar generation decreases, more electricity is purchased from the utility, and during times when solar PV produced more than needed, excess electricity was returned to the grid. While this may seem like a relationship that benefits both parties, the intermittency of solar generation can complicate the management of electricity grids and electricity markets.

As solar generation has increased in many jurisdictions, new rules and regulations have been implemented to reduce the impact of solar intermittency on the grid. In California, where significant solar installations have occurred, the impact of solar generation affects the energy profile of the whole state. This has been called the "Duck Curve" (see Figure 10).

One approach to managing this challenge has been to restrict the potential for solar generation to be exported back to the grid, referred to as curtailment. While curtailment reduces challenges for the overall electricity system, it complicates the business case for solar PV owners.

Maximizing install capacity of solar PV may lead to significant curtailment of the energy source and reduce the benefit or minimize the potential for curtailment by installing a smaller solar PV system, but not maximizing the potential generation that might benefit the business case. Energy storage systems provide a potential solution to this problem.

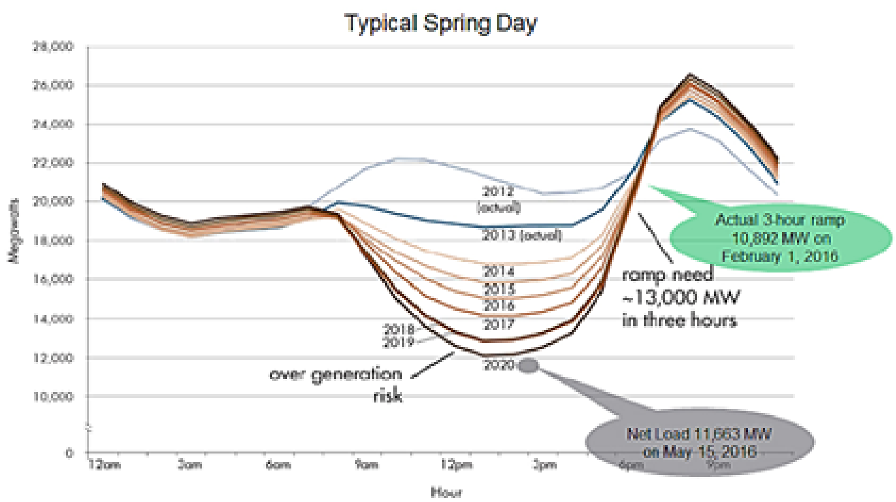


Figure 10. California Duck Curve (California ISO 2016).

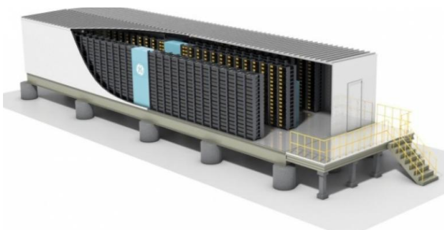
Energy Storage Systems

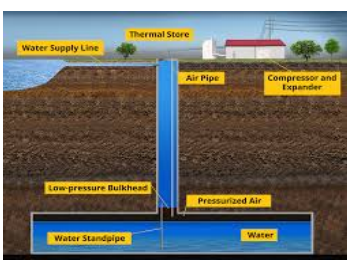
Types of energy storage in a microgrid

Energy Storage Systems (ESS) have been gaining popularity among residential, commercial, and industrial users due, in part, to their ability to help stabilize and flatten intermittent renewable energy and load peaks. An ESS can be an integral part of a microgrid that helps bridge gaps in supply between various DERs and balances energy supply with energy demand.

Batteries may be the most known type of energy storage technology, but there are many additional types of energy storage technologies. Each type of energy storage has different technical specifications and different applications. Some types of energy storage are well-suited for commercial and institutional applications while other types are best applied at the utility grid level. Some different characteristics that determine the application of various energy storage technologies include the size of the system, the capacity of electricity stored, the power produced (i.e., how much electricity can be released at any moment), the responsiveness of the system, how efficiently energy can be stored, and how long energy can be stored for. Table 1 provides a brief overview of available energy storage technologies and their standard applications.

Table 2
Types of Energy Storage Systems (ESS)

ESS Type	Application	Considerations
Lithium-Ion Batteries (LIB) 	Fast acting and flexible, these are based on similar battery cells as electronic equipment and electric vehicles. Batteries are great at providing grid services and peak demand reduction for durations up to four hours.	The high energy density makes LIBs great complements to other DER in a microgrid; however, long-term storage and discharge is not a viable application. Need to consider the number of lifetime cycles possible (generally 5,000-7,000) as well as new fire safety considerations and siting. Will batteries reside in existing building or be provided separately in a container for outdoor installation?
Flow Batteries 	Modular battery based on two liquid electrolytes stored in two separate tanks and passed through a membrane to release electrical energy. Great for long term storage (8-12 hours) since adding duration is possible by simply using larger electrolyte tanks.	Many chemistries being developed and piloted. The most common is the reduction-oxidization (redox) based on vanadium metal. Vanadium is hard to source, expensive and has environmental impacts. Efficiencies of flow batteries have not been as high as lithium-ion based systems and their energy density is also not ideal for some commercial campuses.
Thermal Storage 	Commercial applications where lower rate electricity in the evening is used to produce chilled water or ice. A cooling loop from these ice or chilled water tanks can then be used during the day to reduce the amount of air conditioning or cooling required.	Several commercial products available and successful pilots. Commercial viability depends on the time of use or peak demand penalties. Efficiencies of the thermal conversions need to be considered.

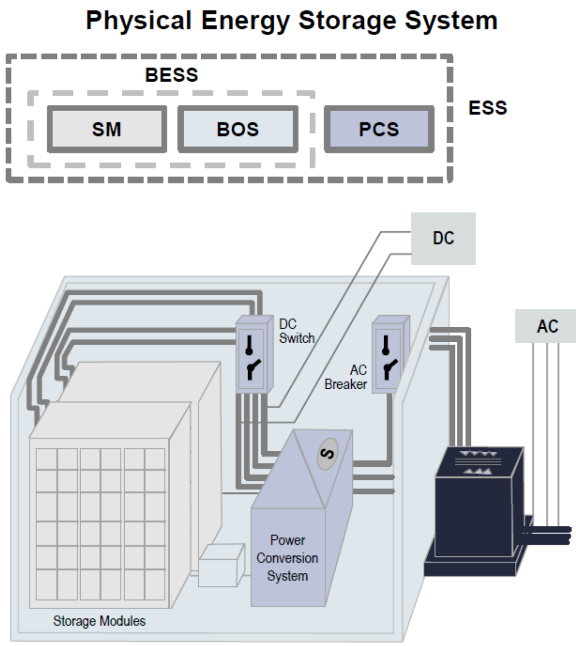
Mobile Batteries 	Better known as Vehicle-to-Grid (V2G), this utilizes the available energy capacity in electric vehicle batteries to be used for facility or grid support. An electric school bus is a good application where the battery from the bus can be used to provide grid or facility services during the summer when the bus sits idle or during the day when the bus is not transporting students.	Evolving technology depends on the ability of the electric vehicle to support bidirectional power flow. Current standards also need to evolve to streamline commercialization.
Flywheels 	Very fast acting, short duration resource based on storing and retrieving energy from a buried flywheel running at ~10,000 RPM. Excellent at providing grid services (voltage and frequency control), very little degradation over time.	Depends on permitting, space and specific application. Not suitable for peak demand management and depends on market participation in RTO markets. Not typically suitable for campuses.
Compressed Air  	Relatively new and evolving long-term energy storage. Excess electricity is used to run a compressor and store compressed air in an underground cavity (often a salt cavern). When electricity is needed, the process is reversed.	Depends on available underground cavities, efficiencies are low based on use of conventional equipment, not applicable to campus settings.

Pumped Hydro 	The most mature ESS. These systems are well-understood and have long-term energy storage capabilities. Excess electricity powers a pump that transfers water into an upper reservoir. When the electricity is needed by the grid, the water is released from the reservoir and run through a turbine.	Dependent on geology and environmental constraints. Can take 10-20 years to develop a project. Not applicable in campus settings.

BESS: Primary Elements

The remainder of this section will primarily focus on battery energy storage systems (BESS) using lithium-ion batteries (LIBs) since their energy density is well-suited to commercial campus settings, like hospitals. There have been some promising commercial and industrial applications of flow batteries, which have long-term storage possibilities (8-12 hours of discharge) in addition to the low degradation over time; however, the declining costs of LIBs, driven by the electric vehicle market, has rendered most of these applications commercially unviable for the time being.

A BESS is typically comprised of the battery cells, which are arranged into modules. These modules are connected into strings to achieve the desired DC voltage. The strings are often described as racks where the modules are installed. The collected DC outputs from the racks are routed into a 4-quadrent inverter called a Power Conversions System (PCS). The PCS converts the power to AC and then routes it through transformers and switchgear where it can be used by the facility or the grid (See Figure 11).



Selected Equipment & Cost Components

System Layer		Component
SM	Storage Module	• Racking Frame/Cabinet • Battery Management System ("BMS") • Battery Modules
BOS	Balance of System	• Container • Monitors and Controls • Thermal Management • Fire Suppression
PCS	Power Conversion System	• Inverter • Protection (Switches, Breakers, etc.) • Energy Management System ("EMS")
EPC	Engineering, Procurement & Construction	• Project Management • Engineering Studies/Permitting • Site Preparation/Construction • Foundation/Mounting • Commissioning
Other (not included in analysis)		• SCADA • Shipping • Grid Integration Equipment • Metering • Land

Figure 11: BESS Primary Elements (Lazard 2017).

BESS: cost trends

Although many types of energy storage are undergoing development to improve efficiency and reduce cost, batteries have, and continue to, experience the most significant cost declines. This has been driven by the electric vehicle market which utilize the same battery cells as stationary battery systems (see Figure 12). The National Renewable Energy Laboratory (NREL) estimates battery storage cost declines of an additional 40-60% in the next 30 years, on top of the already observed 85% reduction since 2010.

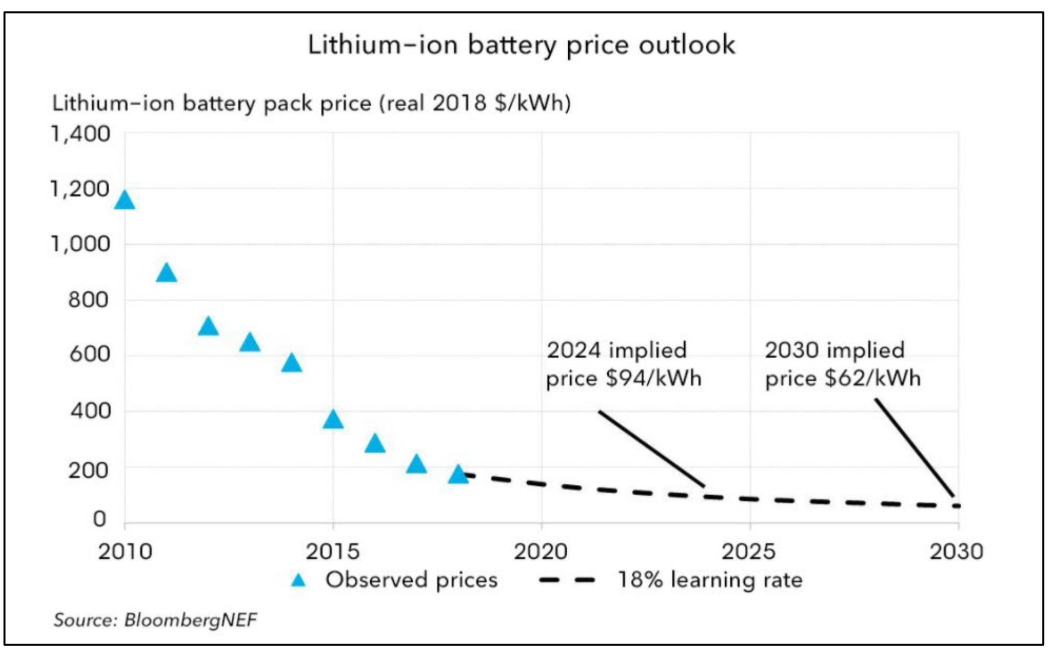


Figure 12. BloombergNEF lithium-Ion battery price outlook (Goldie-Scot 2019).

This cost reduction coupled with excessive demand charges in some regions (see Figure 13) create the "perfect storm" to implement both stand-alone energy storage and ESS's integrated into a microgrid.

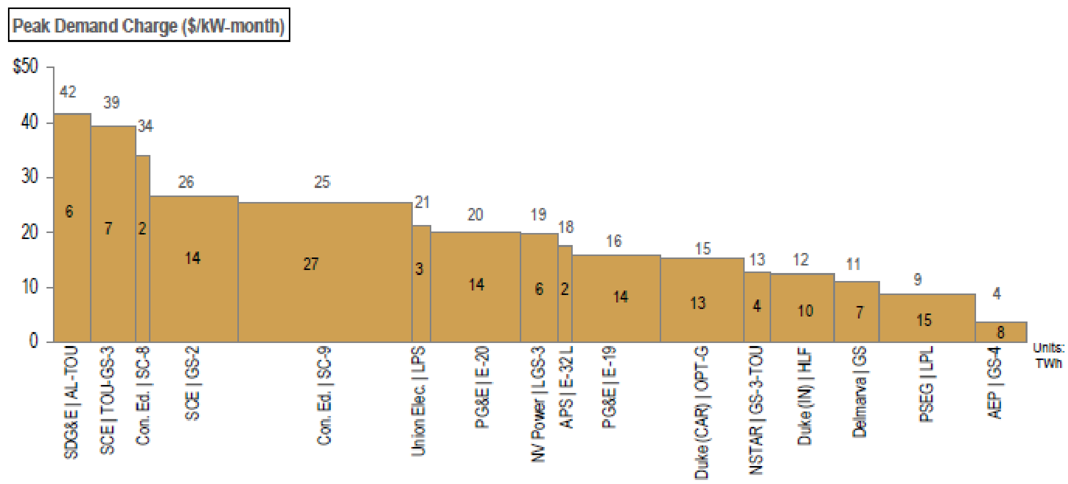


Figure 13. Typical Demand Charges by Utility – 2018 (Lazard 2019).

BESS: Microgrid Applications

Incorporating an ESS into a microgrid can provide many benefits and use cases. In some applications, these benefits can be combined in what is known as "value-stacking," where two or more of these use cases can be leveraged on one site. Several applications, typically implemented by the microgrid controller, are listed below.

Application #1: Peak Demand Reduction. In many jurisdictions, the price of electricity will vary throughout the day. In California, electricity used by a facility during peak periods of the day – when electricity is in high demand across the electricity system – can make up a significant portion of the electricity cost. Many utilities have demand reduction programs that incentivize facilities to reduce electricity consumption during peak periods. These programs may include turning off or throttling back high energy equipment (like refrigeration and air conditioning). In healthcare settings it is neither practical nor possible to participate in these types of programs unless power can be supplemented from another source, such as through a microgrid. Peak demand periods typically last around four hours, which is well-suited to capacity offered by BESS. A BESS can be charged slowly during periods of low demand and low ToU rates and then discharged during peak demand periods to provide all power to the facility, avoiding the use of grid power (see Figure 14). When combined in the context of a microgrid, this peak demand reduction can be done without using other fossil-fuel burning microgrid assets like diesel or natural gas generators.

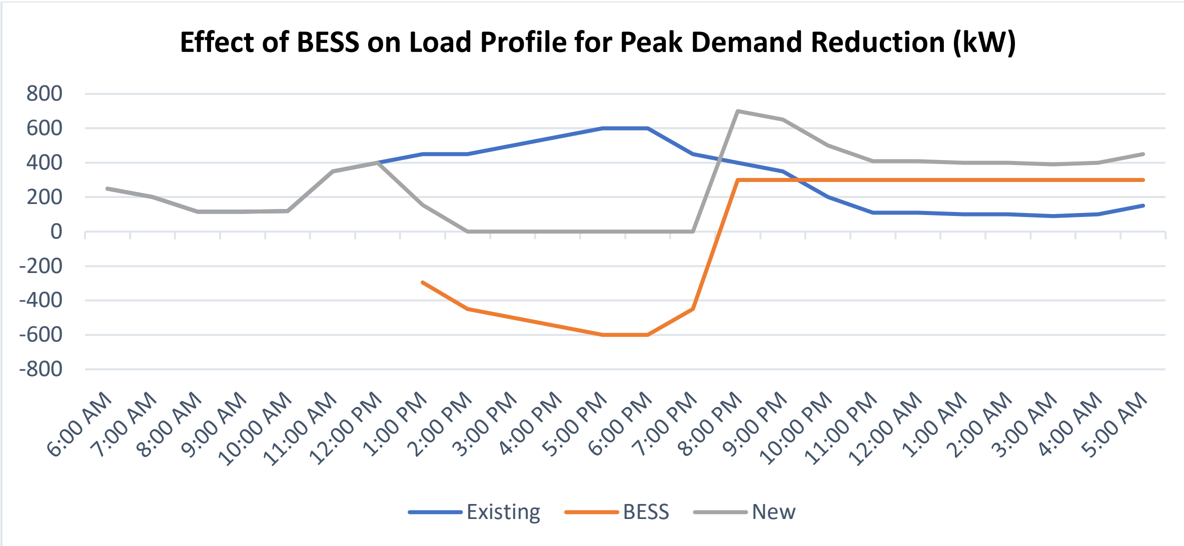


Figure 14. BESS Used to Avert a Peak Demand Event

*Application #2: Renewable Energy Firming***.** One of the better understood applications of ESSs involves coupling with a solar PV installation to smooth out the intermittent fluctuations of solar production (see Figure 15). This application can prevent the need for utility curtailment of solar production and allows harvesting of more solar generation that might be wasted during ramp-up and ramp-down caused by production fluctuations, like cloud cover.

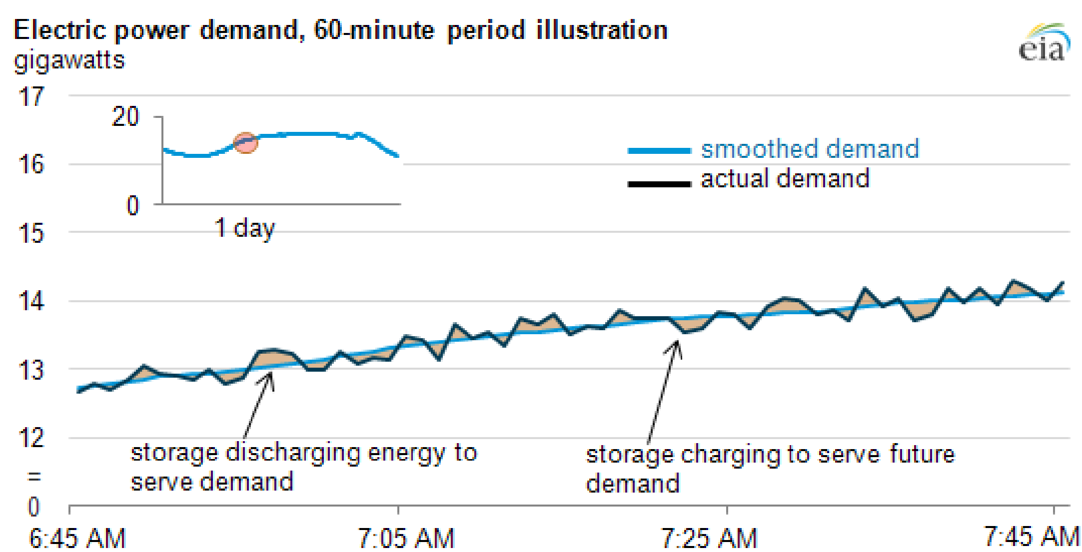


Figure 15. ESS Used for Renewable Firming (U.S. Energy Information Administration 2012).

Application #3: Spinning Reserve. Many microgrids utilize multiple generators to serve the load. Because a microgrid's load will fluctuate, the generators are typically sized in increments to serve "stages" of load need. If the overall load is low, this will be serviced by the first stage of generator capacity. When power beyond the first stage is needed, the second stage of generator capacity will fire up to serve the additional load. The problem with this strategy is that gas generators have a preferred efficiency window to optimize efficiency and fuel consumption. This "sweet spot" is usually around 40%, so if a second (or third) generator is cycling on and off, it reduces efficiency, consumes more fuel, produces more emissions, and reduces the life of the generator (more wear and tear). By combining a BESS with the generator, it can serve the additional, marginal load before activating another generator. This can ensure that the generators are kept within their optimal efficiency windows (see Figure 16).

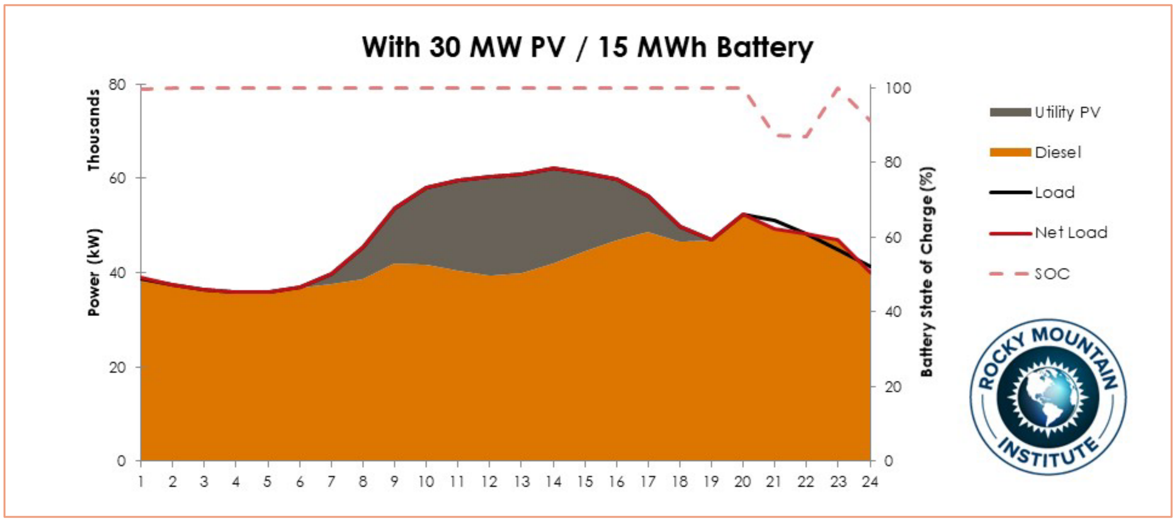


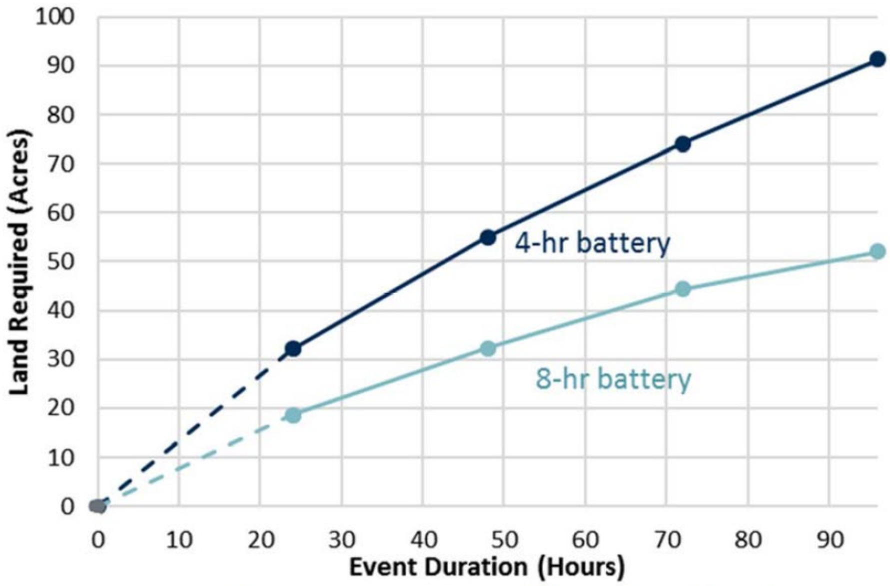
Figure 16. BESS Used for Spinning Reserve (RMI 2017)

BESS: Integration

Planning for ESS integration into a microgrid involves many of the same aspects required to integrate other power generation and T&D assets such as generators and substations with a few considerations specific to ESS and batteries.

Consideration #1: Duration Limitations. The first myth that needs to be dispelled when incorporating a LIB-based BESS into a microgrid is the notion that the BESS can be used to replace the functionality of a backup generator. LIB-based BESSs have a reasonable energy density only when used with discharge durations generally up to four hours. Backup power duration requirements in California are currently in the range of 72–96 hours considering on-site fuel storage requirements. A BESS can either be used as a short-term backup supply for the entire facility or a longer-term backup supply for priority facility loads.

The second myth that needs to be dispelled is the notion that solar plus battery storage can provide an adequate backup power source for a facility. Given the limited energy density of solar as outlined previously and given the four hour discharge limit of LIB-based BESSs, the land use requirements to integrate a completely self-reliant solar plus storage solution become excessive. In a recent analysis completed by the Brattle Group, it was determined that to provide a 100% solar plus storage solution for a 10 MW load would require more than 20 MW of solar PV plus a BESS of ~90 MW / 350 MWh occupying over 90 acres of land (see Figure 17).



Note: Assumes 1-to-4 solar-to-storage capacity (MW) ratio. Dotted line indicates extrapolation to zero.

Figure 17. Solar + Storage Land Requirement as Function of Event Duration (Hledik et al. 2020).

Consideration #2: Capital Cost Barriers. Although costs of energy storage have dropped drastically in the last 10 years, implementation of a complete BESS will still face commercial challenges unless multiple revenue streams can be realized from the BESS. The battery packs currently account for over half the cost of a complete BESS. While the business case will improve in the coming years, as costs decline and BESS-centric regulations continue to evolve, the current business case depends on how the BESS can address several tangible and non-tangible questions, such as:

- What is the magnitude of the annual demand charges?
- Are there frequent short-term outages that impact hospital operations that the BESS could mitigate?
- How good is the power factor at the hospital? If there are power factor challenges, how much does the utility charge for a poor power factor?
- How many incoming utility feeders serve the hospital which would potentially need to integrate with the BESS?
- What are the operational/maintenance costs and fuel costs associated with the current backup generator fleet, if any? How often are the generators operating outside their peak efficiency windows?

Consideration #3: Fire Safety of a BESS. Fire safety of stationary BESSs is a major consideration for urban installations. There have been recent fire incidents in Arizona as well as frequent battery fires in South Korea in 2019. LIBs exhibit several characteristics that can cause both explosive gases (off-gassing that occurs prior to a thermal event) as well as thermal runaway events that occur when a battery cell separator is bridged (See Figure 18). LIB fires cannot be easily extinguished with conventional fire suppressions methods and therefore require additional considerations. The new NFPA-855-20 Standard for the Installation of Stationary Battery Storage Systems should be applied.

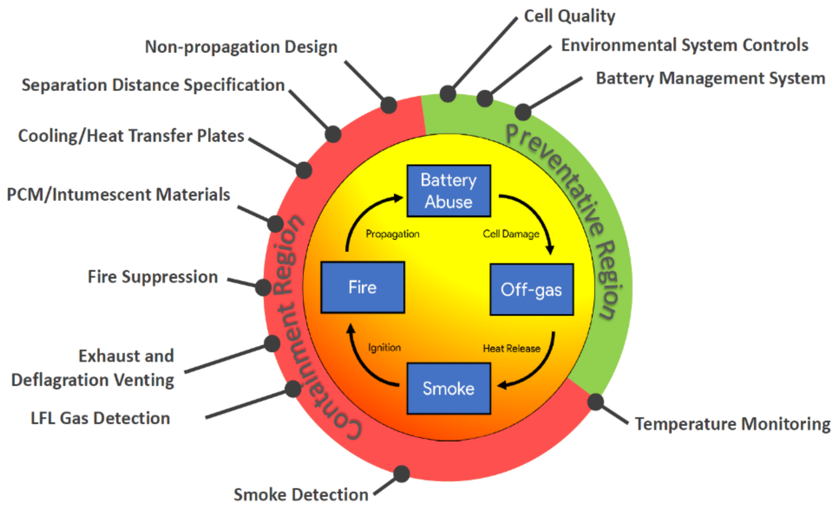


Figure 18. LIB Thermal Event Cycle (American Fire Technologies 2018).

In conjunction with NFPA-855, the following should be considered prior to procuring a BESS:

- Does the BESS supplier adhere to the requirements of NFPA-855?
- Is the complete battery system certified to meet UL9540A, which ensures that, in case of a thermal event, fire will be contained within a single rack?
- What has been provided for fire suppression? Traditional clean agents and aerosols are not effective for containment of LIB thermal events since the explosive off-gasses from the batteries need to be exhausted which would also exhaust these clean agents. Water deluge has been found to be the best method to cool the batteries.
- Has an electrolyte gas detection system been provided to detect off-gassing before a thermal event starts?
- If water is used to cool a thermal event, how is the spent water disposed of (floor drain may not be suitable)?

BESS: Utility Interconnection

Integrating a BESS within the context of a microgrid with respect to the electrical utility is often like interconnecting other DER such as generators and PV solar farms. The PCS used for the BESS will need to comply with the same standards as solar PV inverters (such as IEEE-1547-18). Yet, what if a facility never intends to export power to the grid but wants to use the BESS to simply support facility loads? One might argue that the BESS is merely a load and should not be treated as a generator. In fact, the protection and control (P&C) system can be configured to trip the BESS if it ever tries to send power back to the grid (this is called a “32 reverse power flow element”). The concern that the utility has, however, is possible reactive and/or short circuit power contributions the BESS could still present to the grid. Many standards in this respect are evolving as well as enhanced functionality within the PCS to prevent any impacts; however, current utility interconnection standards are not consistent. The Electronics Power Research Institute (EPRI) and their sub-group, Energy Storage Integration Council (ESIC), are diligently working on research and efforts to help inform new standards in this space, though facility owners who wish to integrate a BESS into their facility or microgrid will likely have issues to deal with when interconnecting.

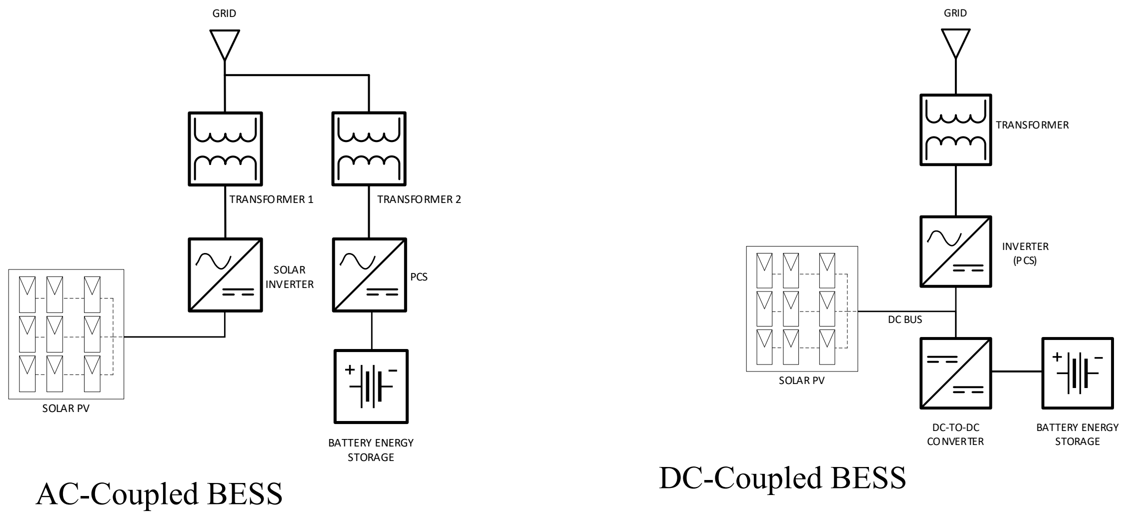


Figure 19. Comparison of AC and DC-coupled BESS

One solution to this issue is to change the way the BESS interconnects to the facility. As shown in the previous simplified architecture, most BESSs store DC power that is converted to AC to serve facility loads or to export to the grid. This is called an AC-coupled BESS. In the new evolving world of microgrids, there is much research focused on DC microgrids where the major facility loads are DC rather than AC. This architecture complements other modern DER, such as solar PV and electric vehicle fast chargers, which also natively operate on DC. In such a DC microgrid, the BESS can be connected in a DC-coupled manner thereby eliminating all utility interconnection requirements (See Figure 19). Other benefits from such a configuration when pairing with solar are a reduction in equipment (one less inverter and one less transformer) and improved solar energy harvest since all DC power from the solar PV can be stored in the BESS without losses and clipping performed by typical solar inverters.

Fuel Cells

Technology Overview

Fuel cells were invented over a century ago and have been used in most NASA space missions since the 1960s. Fuel cells are a non-combustion technology that reduce greenhouse gas emissions and produce virtually zero smog-forming pollutants. They are unique in that they can be used for a wide range of applications, from generating power for satellites and space capsules, to powering fuel cell vehicles like automobiles, buses, or boats, and even generating primary or emergency backup power for buildings.

There are many types of fuel cells, but they all share a single common design and process: a negative electrode (an anode) and a positive electrode (a cathode) sandwiched around an electrolyte undergo an electrochemical reaction to produce an electric current. The electrolyte is an ion conductor that moves ions either from the fuel to the air or the air to the fuel to create electron flow. Electrolytes vary among fuel cell types, and depending on the electrolyte deployed, the fuel cells undergo slightly different electrochemical reactions, use different catalysts, run on different fuels, and achieve varying efficiencies.

For decades, experts have considered solid oxide fuel cells (SOFCs) to hold the greatest potential of any fuel cell technology due to their extremely high electrical efficiencies and low operating costs. Operating at high temperatures inside the system, ambient air enters the cathode side of the fuel cell. Meanwhile, steam mixes with fuel (natural gas or biogas) entering from the anode side to produce reformed fuel. As the reformed fuel crosses the anode, it attracts oxygen ions from the cathode. The oxygen ions combine with the reformed fuel to produce electricity, steam, and carbon dioxide.

The steam that is produced in the reaction is recycled to reform the fuel. Because of this recycling process, SOFCs do not require water during normal operation. The electrochemical process also generates the heat required to keep the fuel cell warm and drive the reforming reaction process. As long as fuel and air are available, the fuel cells continue converting chemical energy into electrical energy, providing an electric current directly at the fuel cell site.

Microgrid Benefits: Redundant, Modular, Always-On Design

Individual fuel cells are the first (and smallest) building block of the solution, as can be seen in Figure 20. The cells are then combined to form a fuel cell stack. Multiple stacks are combined to create power modules. Modules combine to form a solution that produces power in a small footprint compared to other generation technologies. Concurrent maintenance or replacement of one module can occur while the others are in operation, maximizing power availability.

Each power module generates DC voltage and is concurrently maintained and operated. Power modules then aggregate their power output into a set of IEEE 1547 DC-AC inverters to provide facilities with AC power. All power modules and AC inverters are built in with independent operation and redundancy in mind to ensure maximum uptime and availability of the fuel cells.

This architecture ensures that fuel cell microgrids can operate 24/7 without the need for a full system shutdown for any scheduled service or routine maintenance. Power modules are scalable to provide a dense power footprint for facilities. The modular design also allows for any number of systems to be clustered together in various configurations to form solutions that range from hundreds of kilowatts to many tens of megawatts. This flexibility means that a system can be scaled to meet a facility’s energy needs today and continue growing with the facility in the future as their requirements change or grow. Systems can also be remotely monitored and controlled, giving unprecedented controllability, measurability, and observability necessary in a true microgrid.

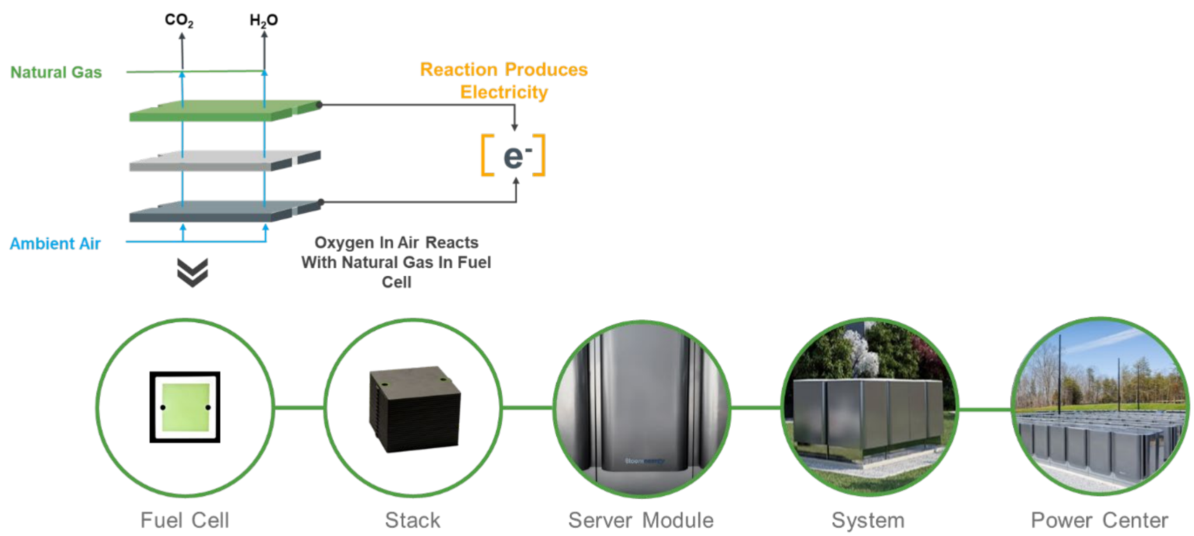


Figure 20. The Components of a Fuel Cell

Long Range Resiliency and Reliability

NFPA 110 requires up to 96 hours of fuel supply onsite. However, with the threat of sustained Public Safety Power Shutoffs (PSPS) lasting more than 96 hours, this requirement has come into examination. Because fuel cells are typically powered by the underground natural gas pipeline, they can provide long-term back up if gas lines are not ruptured.

Typically, when facilities are forced to run on alternate source or backup power, elective procedures must be cancelled or rescheduled. During multi-day outages, postponing elective procedures is not only inconvenient for patients, it can be harmful to patients' health. Further, rescheduling procedures impacts the hospital's revenue and bottom line. Facilities are known to have millions of dollars in losses per day when they lose power. Fuel cells can be connected on the normal source side of a hospital EES. With this architecture, hospitals can choose to perform elective procedures even during grid outages.

Outages lead to lost patient care days as patients go to other facilities. Setting up of call centers or other resource centers to manage information to patients during an outage is an additional challenge. There will also be productivity loss as doctors and nurses wait to treat patients. If there is an outage at the hospital's data center, patient care may be affected as physicians could be treating someone with outdated medical information since they cannot access the latest patient records. There can be a loss of lab material such as blood samples and specimens. Finally, there will be the cost of recovery from an outage, including costs of syncing patient data and updating systems and patient schedules.

By connecting a fuel cell microgrid in the normal source configuration, hospitals constantly save on energy costs and save against a loss of revenue due to short or long outages. Fuel cells also provide the following resiliency and reliability aspect to a healthcare facility:

- **Fuel source flexibility puts hospitals in control of lower-carbon pathways.** Fuel cells are clean in two ways. First, they avoid emitting harmful criteria air pollutants, including nitrogen oxide and sulfur dioxide, which have been linked to severe respiratory diseases and poor air quality worldwide. Second, they reduce greenhouse gas emissions as compared to the grid. Depending on the fuel source need, availability, and economics, various fuel sources can be consumed. Some fuel cells are fuel-flexible to run on natural gas, renewable biogas, or hydrogen. When running on natural gas, the CO2 that is generated during the electrochemical process is 50% less than the carbon emissions generated from the electricity that the fuel cell replaces on the grid. Fuel cells also do not use a combustion cycle, so pollutants and particulate matter are avoided. As we move toward a lower-carbon future, fuel cell systems will run on 100% renewable biogas or hydrogen, where emissions are carbon-neutral and zero-carbon, respectively. By utilizing hydrogen and biogas, hospitals can achieve net zero carbon or zero carbon with no smog-forming particulates.

- ***Reliability of Natural Gas Pipeline vs. Utility Electric Grid.*** The reliability of the natural gas pipeline, by which natural gas fuel cells are powered, is greater than the vulnerable surface electric grid. Disruptions to natural gas service are extremely rare, and disruptions do not often result in an interruption of scheduled gas delivery since the network has few single points of failure. Unlike the surface grid, the gas network can run unattended and without power. In contrast, the electricity grid has many single points of failure, few generating points, requires constant oversight to balance supply and demand, and is susceptible to extreme weather events. Because it is underground and protected, extreme weather has very limited impact on the gas network. According to data from the EIA Electric Monthly Table and the American Gas Association, in 2016, fewer than 100,000 gas customers nationally experienced outages, while 8.1 million Americans experienced disruptions in electricity.
- ***Proposed Microgrid point of electrical service as normal source.*** With recent code changes, fuel cell microgrids can now be incorporated in the normal source capacity of a hospital's electric system alongside the utility grid. This means that when a utility outage occurs, fuel cell microgrids can carry the hospital's load as indicated in Figure 21. While backup power must still be available, this reduces the necessity to run on backup generators in the case of a grid outage. This also helps mitigate the risk of diesel supply issues in the case of long-term outages, which can be difficult to replenish in extreme weather emergencies as road closures and transportation roadblocks are common. Relying on backup power is risky – 16% of emergency medical services organizations during Superstorm Sandy in 2015 reported that diesel generators did not perform as expected, according to a report from the American College of Emergency Physicians. Utilizing a microgrid as normal source adds a third generation source, providing additional redundancy to existing infrastructure and delivering value 24/7. Existing alternate power systems that sit idle will remain available for worst-case scenarios.
- ***Integrating additional DERs with fuel cells.*** Additional onsite generation resources can be integrated into a fuel cell microgrid. For example, if a facility has onsite solar that is interconnected with anti-islanding, when the grid goes down the solar also must go down. In this scenario, the solar cannot power the facility during the outage and becomes a dead asset. However, with the right architecture, such a solar resource can easily be converted into an active resource during outage conditions and can be utilized to its maximum capacity. Similarly, onsite batteries and engine generators can also be integrated. In these scenarios, the fuel cell system will be the base firm power, and the other sources will be dispatched to cover the variability in load.

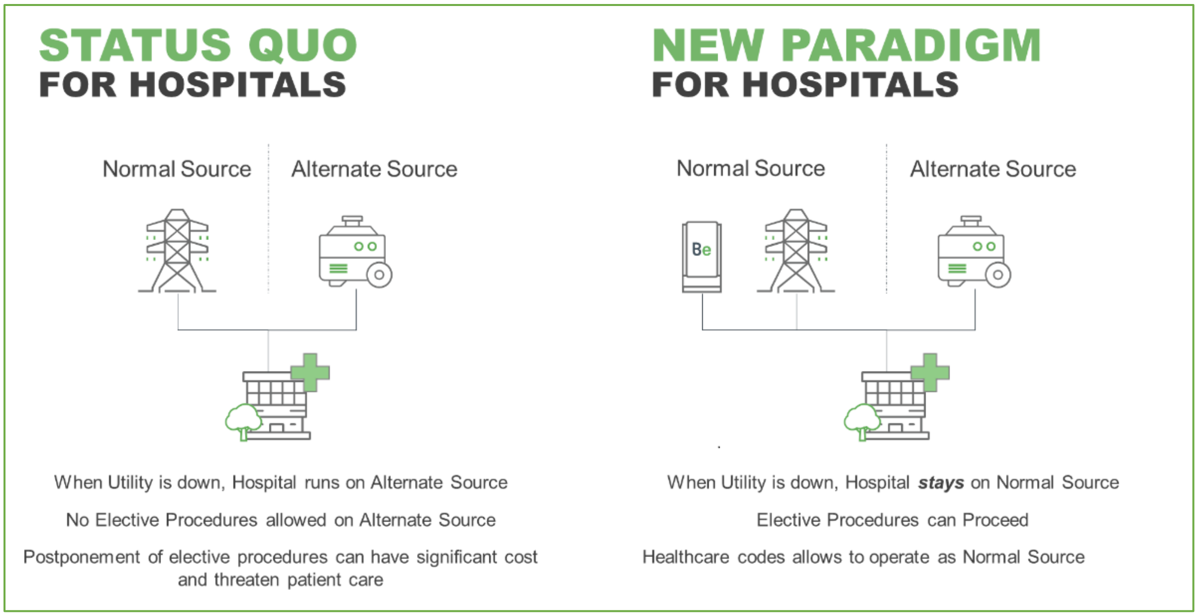


Figure 21. Healthcare's New Resiliency Paradigm

In summary, fuel cell microgrids provide long-term energy cost predictability while also providing long-term reliability and resiliency to hospitals and healthcare facilities. They help maintain good air quality and use a range of fuels that can improve the emissions profile and carbon footprint of the facility. By running off pipeline fuel, fuel cells provide long-duration resiliency without the need for extensive fuel supply onsite. By connecting at normal source and becoming an extra redundant power source, fuel cells can insulate the hospital from revenue risk from long-term outages due to cancelled procedures, missed patient care, and more. Fuel cell microgrids can also combine with other onsite energy assets, like solar and storage, to provide a truly clean, resilient, and long-range reliable microgrid.

Cogeneration / Combined Heat and Power (CHP)

Modern natural gas fueled engine-generator sets have 40-50% efficiency when generating electricity and the remaining 50-60% of the energy is discharged as waste heat to the atmosphere through the oil cooler, engine jacket water, turbocharger aftercooler, and exhaust. Cogeneration ("cogen") or combined heat and power (CHP) equipment can be added to the natural gas fueled generator set to increase the overall efficiency to 70-90%. This is done by simultaneously providing electricity for electrical loads and extracting waste heat energy for a facility's thermal requirements including hot air, hot water, or steam.

Many natural gas-fueled engines can be configured specifically for CHP applications to help customers reduce operating costs and lower their emissions footprint. In general, CHP systems are cheaper to install and operate, and have lower greenhouse gas emissions than separate heat and electrical generation systems. Key components of a CHP system include:

- Natural gas fueled engine-generator set
- Heat exchangers

- Pumps and flow valves
- Radiators/Coolers
- Bypass valves
- Switchgear
- Control system
- Absorption chiller
- Back-up steam boiler
- Back-up electric chiller

As indicated in Figure 22, skids containing heat exchangers, valves, pumps, and bypass are used to extract heat from the engine jacket water, oil cooler and turbocharger aftercooler to produce warm or hot water at temperatures up to 210°F for space heating or other facility processes. Exhaust heat recovery skids are available to capture engine exhaust heat to provide far higher temperature and greater heat output. Exhaust temperatures over 800°F can generate intermediate-pressure steam for boiler feedwater heating and other low-pressure steam processes.

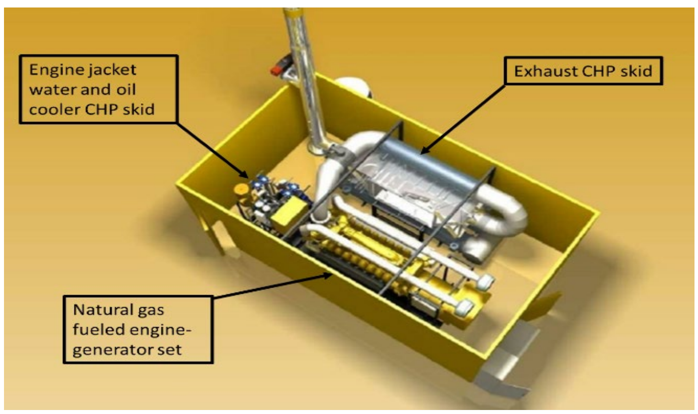


Figure 22: The Components of a CHP System

CHP extracted steam, hot water or exhaust can be combined with absorption chillers to produce cold water or cooled air. Absorption chillers use heat instead of electricity as the energy source. More complex heat recovery systems can be configured to deploy hot water and steam production to certain processes and the balance to the absorption chiller, in effect, producing space heat in the winter and air conditioning in the summer.

Customers should seek out an experienced partner with the expertise to help plan and implement CHP projects. Equipment suppliers, consultants or contractors should have a deep understanding of cogeneration project planning, design, construction, operation and maintenance and should also be able to model the financial benefits of the system.

Locally based service and technical support can help ensure the system is properly operated and maintained for maximum reliability and optimized return of investment. Service and maintenance contracts can provide contractual uptime guarantees and fixed, predictable costs. Numerous options are available for financial services that allow for $0 capital expenditures and purchase agreements for electricity and heat energy. CHP systems can be a key tool for hospitals to lower costs, reduce greenhouse gas emissions, and make progress toward their long-term sustainability goals.

Geothermal Energy in a Microgrid

Although many parts of the country experience seasonal temperature extremes - from scorching heat in the summer to sub-zero cold in the winter - a few feet below the earth's surface the ground remains at a relatively constant temperature. The U.S. Department of Energy reports that depending on latitude, ground temperatures range from 45°F to 75°F. Like a cave, this ground temperature is warmer than the air above it during the winter and cooler than the air in the summer. A geothermal heat pump (GHP) takes advantage of this by exchanging heat with the earth through a ground heat exchanger. These GHPs present the greatest opportunity for geothermal energy in local microgrids, as geothermal power generation remains a task best suited for utility scale operations.

Despite this GHP potential, geothermal opportunities rarely factor into microgrid discussions – particularly in the California healthcare market. First and foremost, a hospital must have the real estate to consider a GHP project. In an article from Becker's Hospital Review (2012) highlighting geothermal success at Sherman Hospital in Illinois, Ray Diehl remarks that the facility set aside 15 acres for its project. The article notes that comparable initiatives would require at least 10 acres. In addition, the Sherman Hospital project led to an increase in electricity use. Yet, with California electricity rates much higher than other parts of the country, the motivation to pursue these types of projects requires a niche set of conditions.

Thus, despite being a highly reliable and commended form of energy, its application in the California microgrid market is limited and any further discussion extends beyond the scope of this white paper.

Wind Energy in a Microgrid

According to the U.S. Wind Turbine Database, wind energy projects totaling at least 5,535 megawatts (MW) of capacity are operating in California today. In 2018, these projects generated 7.2% of all power in the state (California Wind Energy Association, 2020). In addition, the U.S. Energy Information Administration (EIA) suggests that from 2013 to 2018, costs for wind fell 27% while wind capacity additions increased 18% from 2017 to 2018 alone (Mey, 2020).

Despite these positive trends, wind energy is not a significant player in behind-the-meter California microgrids; a 2018 report from the California Energy Commission reviewing all microgrid capacity shows wind generation at only 5% (Asmus et al, 2018). This is due to a variety of factors, chief of which is the intermittency of supply; the more intermittent a technology is, the less reliable it becomes for critical infrastructure like healthcare facilities.

Consider the graphic from the U.S. Department of Energy in Figure 23, which shows the predicted mean annual wind speeds at a 30-meter height (small wind turbines are typically installed between 15 and 40 meters high). Ideal average wind speeds for this technology are at least four meters per second, which is not feasible for many regions of the state. As a result, most wind energy installations and microgrid integrations tend to occur at either a community or utility scale and in regions where prevailing wind speeds are suitable.

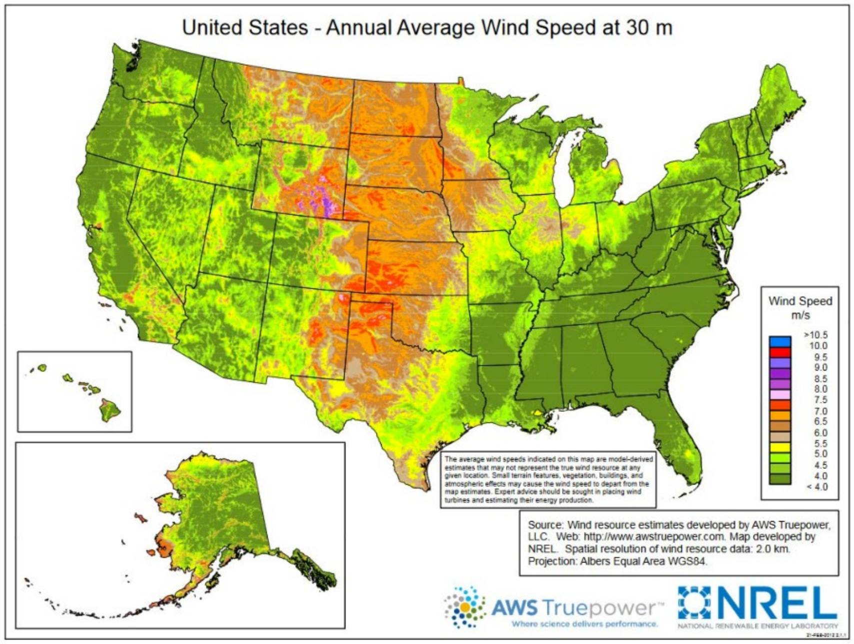


Figure 23. United States – Annual Average Wind Speed at 30m

In addition, the U.S. Department of Energy notes that, “Turbines should be located far enough from buildings to ensure noise control and safety.” It goes on to state that, “Mounting on buildings is discouraged due to vibration transmission and structural concerns.” (Taddonio, 2011). Thus, in densely populated areas of California, these spatial requirements are not feasible in a healthcare setting. Advances in the technology, such as vertical axis designs, are worth monitoring, but they do not have an immediate application for the broader healthcare microgrid arena in California.

Chapter 2 - Codes and Regulations

Code Compliant Microgrid for Healthcare Facilities

The use of microgrids at healthcare facilities provides a platform to utilize existing and emerging technologies to generate and utilize clean power onsite. This section of the white paper scrutinizes the codes and regulations that come into play when planning the implementation of a healthcare microgrid. A study of existing and projected codes shows that the term "microgrid" was first introduced in the 2019 CEC - Article 705 Interconnected Electric Power, and that this term is slated to be used for the first time in the upcoming 2021 NFPA 99, as an acceptable source for Emergency Power Systems (EPS).

Based on current codes, an engineered solution is required to implement microgrids for healthcare facilities in California to supplement the normal utility power service to the site. If all state, city and local codes are adhered to, and the system does not jeopardize the reliability of the healthcare facility, microgrids can be implemented with current code compliance, to work in tandem with the local electric utility company, to provide power for healthcare buildings. In this scenario emergency power would be separate from the microgrid. There are many benefits that can be garnered with this approach, including: higher reliability, lower environmental impacts, and less energy costs. All these advantages can be achieved, while meeting current codes, by connecting the microgrid to the building distribution system in a paralleled configuration with the electrical utility service. This can be evidenced by the dozens of facilities that currently employ this configuration of microgrids in service in California today. This approach utilizes the microgrid as a supplemental normal power source to the healthcare buildings.

What is more challenging is the implementation of microgrids as a code mandated Emergency Power Supply (EPS). The current "go-to" source for emergency power at healthcare facilities are diesel generators, which are currently installed and operational in virtually all hospitals in California. The challenge is how to install microgrids as an EPS in a code compliant manner and, most importantly, without reducing the reliability of emergency systems in the healthcare buildings. It should be noted that to receive reimbursements for Medicare and Medicaid programs the requirements of the older versions of the relevant codes will need to be met. (CMS currently adopts 2012 NFPA 101 and 2012 NFPA 99 which only permit emergency generators or batteries as EPSs). That is to say that while a design could be code compliant with current codes, the facility might not be able to get CMS reimbursements if the older codes are not complied with as well.

The codes are evolving and the soon to be released 2021 NFPA 99 states that microgrids can be used as EPS's if: "… designed with sufficient reliability to provide effective facility operation consistent with the facility's emergency operation plan". While this states that the microgrids will need to be reliable if used as an EPS, it does not present qualitative requirements. The general consensus is that if used as an EPS, microgrids would need to be at least as reliable as the current standard of care (diesel generators) to meet code.

Typically, a desired result in the codes today can be defined and enforced by requiring either a prescriptive approach or a performance approach (which is the case in the California Energy Code). At this point there is no criteria for defining or enforcing a performance approach for microgrids used as EPSs. It is recommended that when these criteria are developed in the national codes, that they should be considered for adoption in California. For now, the current code, with some prudent interpolations can be used to show compliance for designs that utilize microgrids as EPSs in a prescriptive manner.

The next section lists the relevant codes that would need to be adhered to for code compliant microgrid installations. This white paper highlights what exists in current code and identifies where changes could be made to facilitate the introduction of microgrids as EPSs at healthcare facilities. It was found in this process that the codes as currently developed list many requirements for EPSs in the context that the EPSs are diesel generators. The codes also are currently written with the requirement for ATSs and use the terms of normal power and alternate power, which at times appear to conflict with the concept of microgrids as EPSs. Recommendations to update the codes in these areas are made in this paper.

Evolution of Major Governing Codes for Implementation of Microgrid

Taking the prescriptive approach for compliance with current codes, it appears that the requirements currently imposed on the emergency generators can be revised to apply to microgrids which would result in interpolated code direction on how to implement microgrids as EP's for healthcare buildings. Conceptually, the use of green power producers connected to a healthcare microgrid as an EPS is achievable with current code compliance if all components of the microgrid meet the EPS requirements. Theoretically, the use of microgrids as the EPS could either reduce or eventually eliminate the need for emergency diesel generators at healthcare buildings in California. Since the EPS is a key life safety component, it is imperative that the implementation of microgrids as EPSs meet relevant code requirements and result in a highly reliable systems (as least as reliable as onsite diesel generators) that will withstand the test of time.

This study provides an in-depth analysis of **three codes** (CEC, NFPA 99 and NFPA 110), which appear to have the most requirements for the implementation of microgrids. Each have been evolving at different rates; however, all appear to be migrating to allow microgrids to be used in the healthcare environment as emergency sources. This paper includes matrices for each of these 3 codes with observations and recommendations on how changes could be made to support the implementation of microgrids (see appendixes A, B and C). Some instances are pointed out where discrepancies could develop interpreting the current code and recommendations have been offered for potential revisions which could be made to facilitate the use of microgrids as EPSs. This paper also makes recommendations that can be shared with vendors and Underwriters Laboratories (UL) to assist with the development of pre-certifications of equipment and listings that support the use of microgrids as the sole source of emergency power for healthcare buildings in the state of California.

While discussing potential code changes, it is important to explain the process and timing of how codes evolve for projects constructed in California. Code writing and maintenance is a year-round task that requires painstaking efforts and agreements between various champions of the construction industry. The national codes have committees that vet all requested changes from the general public and make revisions based on group consensus. New versions of existing codes are released every three years. Once the new national codes come out, the state authorities review and after making modifications adopt these national codes with amendments. While this process helps with the integrity of the code, it does not help with the speed of code changes geared to accept emerging technologies. The following matrix has been developed to show the past and projected schedule for the code updates as they apply to microgrids (see Figure 24).

TIME LINE FOR CODE REVISIONS

	Triennial Code Cycle			Triennial Code Cycle				Triennial Code Cycle				Triennial Code Cycle
1/1/2016	1/1/2017	1/1/2018	1/1/2019	1/1/2020	1/1/2021	7/1/2021 midcycle	1/1/2022	1/1/2023	1/1/2024	7/1/2024 midcycle	1/1/2025	1/1/2026
2013 CAC	2016 CAC	2016 CAC	2016 CAC	2019 CAC	2019 CAC		2019 CAC	2022 CAC	2022 CAC		2022 CAC	2025 CAC
2013 CBC	2016 CBC	2016 CBC	2016 CBC	2019 CBC	2019 CBC		2019 CBC	2022 CBC	2022 CBC		2022 CBC	2025 CBC
2012 NFPA 99	2015 NFPA 99	2015 NFPA 99	2015 NFPA 99	2018 NFPA 99	2018 NFPA 99		2018 NFPA 99	2021 NFPA 99	2021 NFPA 99		2021 NFPA 99	2024 NFPA 99
2010 NFPA 110	2013 NFPA 110	2013 NFPA 110	2013 NFPA 110	2016 NFPA 110	2016 NFPA 110		2016 NFPA 110	2019 NFPA 110	2019 NFPA 110		2019 NFPA 110	2022 NFPA 110
2013 CEC (NEC '11)	2016 CEC (NEC '14)	2016 CEC (NEC '14)	2016 CEC (NEC '14)	2019 CEC(NEC '17)	2019 CEC (NEC '17)		2019 CEC (NEC '17)	2022 CEC (NEC '20)	2022 CEC (NEC '20)		2022 CEC (NEC '20)	2025 CEC (NEC '23)
2013 CMC	2016 CMC	2016 CMC	2016 CMC	2019 CMC	2019 CMC		2019 CMC	2022 CMC	2022 CMC		2022 CMC	2025 CMC
2013 CPC	2016 CPC	2016 CPC	2016 CPC	2019 CPC	2019 CPC		2019 CPC	2022 CPC	2022 CPC		2022 CPC	2025 CPC
				2019 CeC	2019 CeC		2019 CeC	2022 CeC	2022 CeC		2022 CeC	2025 CeC
2013 CFC	2016 CFC	2016 CFC	2016 CFC	2019 CFC	2019 CFC		2019 CFC	2022 CFC	2022 CFC		2022 CFC	2025 CFC
				2019 CALGreen	2019 CALGreen		2019 CALGreen	2022 CALGreen	2022 CALGreen		2022 CALGreen	2025 CALGreen
				Todays codes							Targeted date for changes to support microgrids as EPS	

By law, Title 24 is adopted by the California Building Standards Commission during the Commission's Triennial Code Adoption Cycle and published in its entirety every three years.
Amendments and repeals to the triennial edition of the CBSC are adopted during the intervening code adoption cycle (mid cycle) that is offset 18 months from the triennial cycle.
- mid cycle code changes for CBC/CEC codes come into affect July 1, 2021 for 2019 Code and July 1, 2024 for 2022 Code, (18 months after each code cycle change)

2020	2019 CEC Incorporates 2018 NFPA 99	
	2019 CEC addopts and ammends 2017 NEC	
	2019 CEC Incorporates 2016 NFPA 110	The soonest we could get any changes in would be the 2020 midcycle (July1 2024)
	2022 CEC will addopt and ammend 2020 NEC (does not pick up changes in 2021 NFPA 99)	
2026	2025 CEC could include changes to list microgrids as EPP	The soonest we would see 2021 NFPA changes would be 2025 CEC (which will come out on Jan 1 2026)
	2025 CEC Incorporates 2024 NFPA 99	
	2025 CEC addopts and ammends 2023 NEC	
	2025 CEC Incorporates 2022 NFPA 110	

Figure 24. Timeline for California Code Updates

A schedule is included on the code update cycles to help conceptualize the current scenario and timing for codes to be revised to include needed information to permit microgrids to replace diesel generators as EPS for all DERs and healthcare building types. This could be used to track and monitor progress with the codes to fully support microgrids as an EPS. Based on the current schedule, any code changes that could be implemented based on input today would not come into effect until January 1, 2026.

Review of Codes

The upcoming 2021 NFPA 99 defines microgrids as, "A group of interconnected loads and distributed energy resources within clearly defined boundaries that acts as a single controllable entity with respect to the utility." This broad term covers many technologies, product types and concepts that incorporate known technologies and provides for the implementation of hereto unknown technologies.

This white paper attempts to list all codes that might come into play for the implementation of microgrids in the healthcare space. The codes/standards listed (see Figure 25) address: air quality requirements, Rule 21 requirements for utility interconnection, the requirements for local approval for siting of equipment in regards to aesthetics and accessibility, the California Building Code as it pertains to housing of equipment - seismic certification and restraint for equipment serving and located in OSHPD facilities, the California Fire Code for the various onsite power generators and fuel systems, the California Electrical Code which details requirements for electrical systems for healthcare buildings, addresses various onsite power generation systems and requirements for emergency power. Various NFPA Standards have been listed that provide requirements for fuel storage/delivery, healthcare facilities, emergency and standby power, stored electrical energy for emergency and standby use, hazardous materials code and the installation of stationary fuel cell power systems.

	Microgrid White Paper Codes/Regulations - Applicable Codes Matrix			Microgrid Power Source			
		Solar (PV's)	Wind	Fuel Cells	Cogen	Energy Storage	UPS
	Codes/Requirements						
1	CARB - California Air Resources Board - Air Quality Requirements				x		
2	CPUC - California Public Utility Comission (Rule 21)	maybe	maybe	x	x	maybe	no
3	OSHPD CAN 2-0 Local Approval	x	x	x	x	maybe	no
4	2019 CBC - California Building Code	Only if in OSHPD building and/or serving as alternate source					
5	2019 CFC - California Fire Code						
5a	1206 Electrical Energy Storage Systems					x	x
5b	1206.2 Stationary Storage Battery Systems					x	x
5c	1204 Photo Voltaics	x				x	
5d	1205 Fuel Cell (NFPA 53 addopted by reference)			x			
6	2019 CEC - Californial Electrical Code						
6a	517 Healthcare Facilities	Only if in OSHPD building and/or serving as alternate source					
6b	690 PV Systems	x				x	
6c	692 Fuel Cell Systems			x		x	
6d	694 Wind Electric Systems		x			x	
6e	700 Emergency power					x	x
6f	705 Interconnected Electric Power Production Sources	x	x	x	x	x	
7	2018 NFPA 30 - Flammable and Combustible Liquids Code			x	x		
8	2015 NFPA 37 - Stationary Combustion Engines and Gas Turbines			x	x		
9	2015 NFPA 54 - National Fuel Gas Code			x	x		
10	2017 NFPA 58 - Liquid Petroleum Gas Code			x	x		
11	2016 NFPA 59A - Production/Storage/Handling of Liquified Natural Gas LNG			x	x		
12	2018 NFPA 99 - Healthcare Facilities Code	x	x	x	x	x	
13	2016 NFPA 110 - Emergency and Standby Power	x	x	x	x	x	
14	2016 NFPA 111 - Stored Electrical Energy Emergency and Standby Power Systems					x	
15	2016 NFPA 400 - Hazardous Materials Code			x	x	x	
16	NFPA 853 - Installation of Stationary Fuel Cell Power Systems			x			
17	NFPA 855 -Standard for the Installation of Stationary Energy Storage Systems					x	
18	Centers for Medicare & Medicaid Services (CMS)	x	x	x	x	x	
18a	2012 NFPA 99 - Healthcare Facilities Code						
18b	2012 NFPA 101 - Life Safety Code						

Figure 25. Applicable Codes Matrix for Microgrid Implementation

The following subsections steps through these codes with brief descriptions and requirements that come into play for the installation of a healthcare microgrid.

CARB – California Air Resources Board (Air Quality Requirements)

CARB sets the standards for onsite power generation that is enforced by local Air Quality Management departments. In particular:

> Any person or organization proposing to construct, modify, or operate a facility or equipment that may emit pollutants from a stationary source into the atmosphere must first obtain an Authority to Construct from the county or regional air pollution control district (APCD) or air quality management district (AQMD). Air districts issue permits and monitor new and modified sources of air pollutants to ensure compliance with national, state, and local emission standards and to ensure that emissions from such sources will not interfere with the attainment and maintenance of ambient air quality standards adopted by the California Air Resources Board (CARB) and the U.S. Environmental Protection Agency. (California Air Resources Board website “Local Air Districts (APCD or AQMD) Authority to construct.

CPUC – California Public Utility Commission (Rule 21)

Electric Rule 21 is a tariff that describes the retail (vs. wholesale) interconnection, operating and metering requirements for generation facilities to be connected to a utility’s electrical system. The tariff provides customers wishing to install generating or storage facilities on their premises with access to the electric grid while protecting the safety and reliability of the distribution and transmission systems at the local and system levels.. The tariff provides customers wishing to install generating or storage facilities on their premises with access to the electric grid while protecting the safety and reliability of the distribution and transmission systems at the local and system levels.

California utility companies are responsible for maintaining the utility owned electrical systems throughout the state. To safely maintain these systems, they have developed requirements for clients who extend these systems to provide power to their site/building. There are also strict requirements for anyone who wishes to produce power onsite and interconnect with the public utility system. Two of the main functions of these requirements it to ensure safety and reliability for the utility company and all other customers connected to these systems. In order to ensure this safety, it is paramount that during a utility outage, the onsite power producers do not back-feed the utility system. This can involve protective relaying or other approved equipment.

Rule 21 is currently undergoing modification to help streamline the process of design/plan approval to make it easier for permitting of distributed power generation on customer sites. The modifications involve:

- Increased interconnection transparency though more detailed public reporting
- New tools to assess interconnection locations
- Streamlining some aspects of the PG&E technical review of projects
- Financial changes
- Other aspects of generator interconnection

OSHPD CAN 2-0 (OSHPD Jurisdiction)

OSHPD is responsible for the review of design and details of the architectural, structural, mechanical, plumbing, electrical, and fire and panic safety systems, under their jurisdiction (OSHPD-1, OSHPD-2 and OSHPD-5 buildings) including electric utilities as follows:

> Electrical service from the service point (utility vault, transformer or meter) to the point it enters a building or structure under OSHPD jurisdiction, and the essential electrical system (emergency power) including required onsite fuel system supply.

The local government retains *local jurisdiction* as the enforcing agency of other elements of the healthcare facility campus, including the location of structures on the property. OSHPD requires evidence of the following prior to issuing a plan approval or a building permit:

- Local authority's review of underground fuel storage tanks.
- Planning and zoning authority are retained by the local agency, including but not limited to: enforcement of setbacks, height restrictions, noise standards, equipment screening, non-building structures, California Environmental Quality Act (CEQA) compliance, entitlements, use permits and any conditions of approval.
- Other local agencies may include flood control districts including review of transformers, generator site security and local fire authority including access and public and private utilities.

2019 California Code of Regulations, Title 24 (California Building Standards Code)

In general, proposed microgrid systems will need to comply with all applicable Title 24 Code requirements, including but not limited to CBC, CEBC, CEC, CFCm, CMC, etc. and the amended sections thereof, and the system will need to comply with all applicable referenced standards. Specific codes with some analyses are listed below:

1. *2019 CBC – California Building Code*. Healthcare buildings under OSHPD jurisdiction and review are required to comply with the requirements in the California Building code. For microgrids the following conditions have been determined:
    - If the microgrid supplements the normal service and is not used as part of the EPSS then the only OSHPD requirement is to ensure that buildings/structures shall not feed buildings of lower acuity. This means that while the microgrid components would not be under OSHPD jurisdiction, they would need to comply with local ordinances.The feed shall be configured so that failure of the microgrid components cannot do harm to the hospital electrical distribution system.
    - If the microgrid is used for any part the EPS then it will need to comply with all of the requirements for OSHPD facilities including CEBC 307A.1.1.1.1 – "Services/systems and utilities that originate and pass through or under buildings and are necessary to the operation of the hospital buildings shall meet the structural requirements of this section," which includes:
        - Seismically certified and restrained.
        - Use of Listed products.
        - Seventy-two hours of fuel storage.

2. 2019 CFC - The California Fire Code. This code governs over the various sources that could be used for onsite power production. Chapter 1206 lays out requirements for Electrical Energy Storage Systems including stationary storage battery systems. Chapter 1204 provides requirement for photovoltaic installation. Chapter 1205 addresses fuel cells. Code for wind turbines and water powered generators are note addressed in this standard.

3. *2019 CEC – The California Electrical Code*. Section 517 entitled Healthcare Facilities states requirements for healthcare. A deep dive has been performed for this code section which lists relevant code sections with annotated comments and recommendations (see Appendix A). These recommendations include:
    - Manufacturers should address seismic certification of microgrid power sources.
    - UL should be approached to develop emergency power listing for microgrid controllers.
    - Definition of normal power and generators be included.
    - Consistency be developed for terms such as generator sets and generators to include all DERs.
    - Studies should be performed to develop demand loads for healthcare emergency power systems.
    - Temp generator provisions should be revised to include all essential power loads.

NFPA Codes for Fuel Systems

The following five NFPA codes address fuel systems that could be employed with a microgrid:

1. *2012 NFPA 30 – Flammable and Combustible Liquids Code*
2. *2015 NFPA 37 – Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*
3. *2015 NFPA 54 – National Fuel Gas Code*
4. *2014 NFPA 58 – Liquid Petroleum Gas Code*
5. *NFPA 59A – Standard for the Production, Storage and Handling of Liquefied Natural Gas (LNG)*

Additional NFPA Codes Relevant for Healthcare Facilities

Next to the NFPA codes that govern fuel systems, there are additional NFPA codes that can apply directly to microgrid systems installed at healthcare facilities. A list of identified NFPA codes is listed below.

1. *NFPA 99 – Healthcare Facilities Code*
   A deep dive for this code was performed which lists relevant code sections with annotated comments and recommendations (see Appendix B). These recommendations include:
   - Manufacturers should address seismic certification of microgrid power sources.
   - UL should be approached to develop emergency power listing for microgrid controllers.
   - Definition of normal power and generators be included.
   - Consistency be developed for terms such as generator sets, and generators to include all DERs.
   - Transfer switch/parasitic loads/alarm requirements should be reworked to include all DERs.
   - Temp generator provisions should be revised to include all essential power loads.
2. *2016 NFPA 110 – Standard for Emergency and Standby Power Systems*
   A deep dive has been performed for this section which lists relevant code sections with annotated comments and recommendations (see also Appendix C).
   - Definition of generator sets should be included.
   - Recommend that microgrids and DESs be added to definitions and in main body of the text.
   - Priority load add should be reworded to work with microgrids.
   - UL should be approached to develop emergency power listing for microgrid controllers.
   - Alarms/testing requirements should be reworked to work with microgrids
   - Temp generator provisions should be revised to include all essential power loads.
3. 2016 *NFPA 111 – Standard on Stored Electrical Energy Emergency and Standby Power Systems*
   This NFPA code is similar to NFPA 100 which provides requirements for generators to be used for emergency power. In addition, NFPA 111 provides requirements for Stored Electric Energy Systems (batteries) used for emergency systems.
4. *NFPA 400* – Hazardous Materials Code could come into play for batteries and fuels if quantities and type warrant.
5. *NFPA 853* – Standard for the Installation of Stationary Fuel Cell Power Systems. This standard governs over fuel cells but does not have any provisions for these fuel cell power systems to be used for emergency power. It would make sense if a code would be developed to mimic NFPA

110 and NFPA 111 for emergency use or if the requirements to use fuel cells as emergency power sources are added to NFPA 110 (see NFPA 110 deep dive).
6. *NFPA 855* – Standard for the installation of Stationary Energy Storage Systems (batteries) with uses other than emergency power.

Centers for Medicare & Medicaid Services

The Centers for Medicare & Medicaid Services (CMS) is the federal agency that oversees and manages the reimbursement process for Medicare and Medicaid programs across the country. CMS develops Conditions of Participation and Conditions for Coverage that healthcare organizations must meet to participate in the Medicare and Medicaid programs. One of those conditions has to do with the built environment.

CMS currently adopts the 2012 versions of the NFPA 101 and NFPA 99. These older versions of code have not introduced the healthcare microgrid as an acceptable EPS. 2012 NFPA 99 only allows onsite generators and battery storage systems as EPS sources. To allow healthcare providers to implement microgrids as an EPS and still participate in the CMS reimbursement programs, design teams will need to be careful to review the older version of these codes and comply. As can be evidenced by the versions currently accepted, the adoption of these codes lags behind the actual date of issuance. CMS has in the past issued memorandum(s) to partially adopt newer codes (specific items) when convinced that there is no risk. One recommendation to help with the acceptance of microgrids as an EPS for CMS facilities is to develop a task force that identifies desirable changes to these older codes to allow microgrids to be utilized as EPSs at qualifying healthcare facilities, and to work directly with CMS to develop memorandums to change the CMS requirements accordingly.

A Flow Chart for Healthcare Building Types

In the state of California healthcare facilities in general have been classified as one of the following:

- OSHPD 1 - Hospitals
- OSHPD 2 - Skilled Nursing Facilities
- OSHPD 3 – Clinics
- OSHPD 4 - Correctional Treatment Centers
- OSHPD 5 - Acute Psychiatric Hospitals

The Office of Statewide Health Planning and Development (OSHPD) is designated as the enforcing agency for these facilities, including plan checking and inspection of the design and details of the architectural, structural, mechanical, plumbing, electrical, and fire and panic safety systems, and the observation of construction.

While OSHPD is responsible for developing the building standards for the various healthcare facility types, they do not enforce these requirements for all healthcare facilities. For OSHPD 1, 2, and 5 facilities, OSHPD is responsible for plan review and approval and construction observation. For OSHPD 3 and OSHPD 4 facilities, plan check and construction inspections are the responsibility of local jurisdictions. It should be noted that at the building official's request, jurisdictions can assign OSHPD 3 projects to OSHPD for review if they do not have in-house expertise.

Microgrids for healthcare facilities may be governed by many codes and, moreover, the above-mentioned building types may come into play. To help with planning and design, a flow chart (see Figure 26) has been provided as a tool that can be used to evaluate the viability and assist with the implementation of microgrids for various healthcare building types. When combined with the code descriptions and deep dives of the CEC, NFPA 99 and NFPA 110, this flow chart will direct the design team on where to find applicable code requirements. The codes that come into play vary drastically depending on what power sources feed the microgrid, what type of building the microgrid will be implemented in and whether the microgrid will be used to back-up normal or essential power.

The flow chart in Figure 26 works as follows. At the top of the chart the designer will need to answer the question as to which building type the project will be. For instance, if looking to implement a microgrid in an OSHPD 3 facility, enter the chart at the "OSHPD 3 facility" box. Next, answer the question as to whether the OSHPD 3 facility has ORs "with surgery?" or not. If the facility has ORs, follow the codes listed on the right below this box. If the answer is no, follow the codes on the left below this decision box. Next, the designer should utilize the list of Codes/Requirements vs. Microgrid Power Source Matrix (Figure 2) to determine which codes are applicable for the project. The relevant codes that match the elements that make up the proposed microgrid should be reviewed and adhered to for each project.

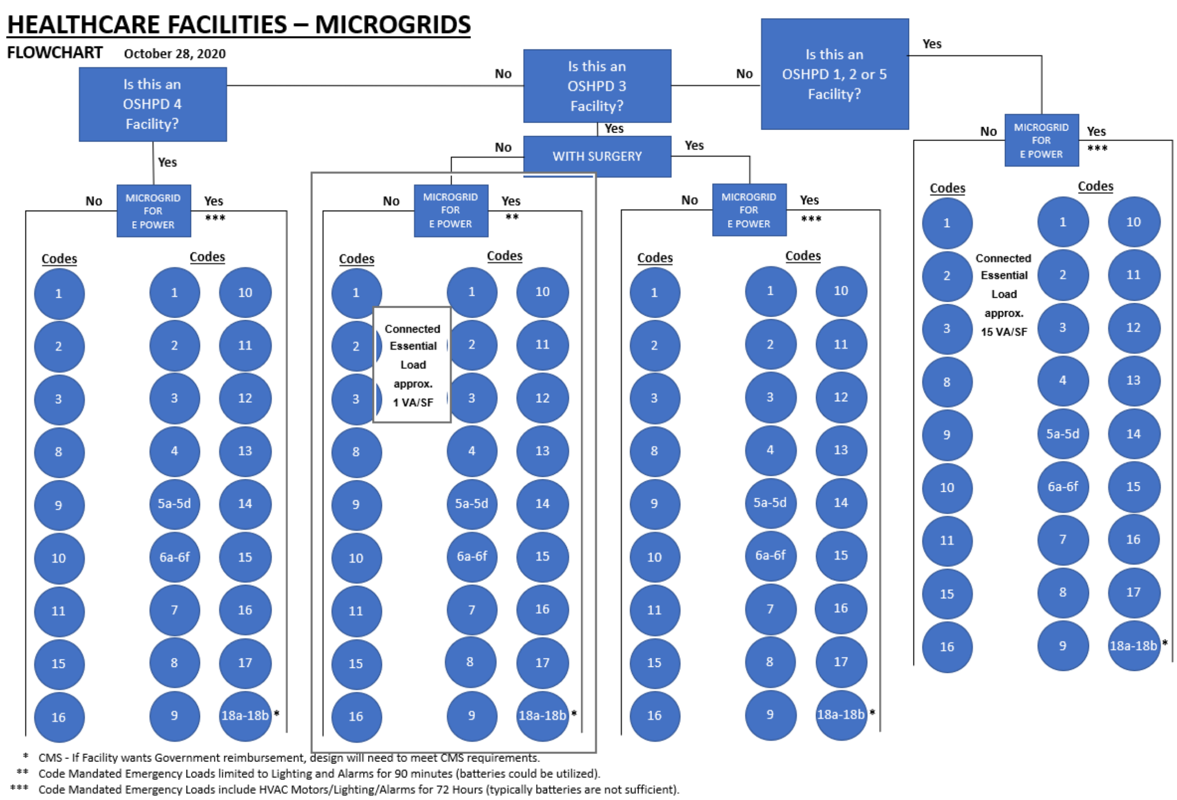


Figure 26. Healthcare Microgrids implementation flow chart

A few key concepts start to become evident when using the flow chart depicted in Figure 26:

1. Based on current codes it is straightforward to implement microgrids for healthcare facilities in California to supplement the utility “normal” power service. This can be accomplished by paralleling the microgrid with the electrical utility service. As can be seen in the flow chart, the codes/regulations that would need to be addressed are:
   - California Air Resources Board (CARB) – Air Quality Requirements– These requirements would only come into play for cogen facilities, where rotating equipment that burn fossil fuels and release toxins to the environment are utilized.
   - California Public Utility Commission Rule 21 – Will always come into play when paralleling with the utility.
   - When the microgrid is utilized for normal power and is located outside of OSHPD facilities, the plan review for the microgrid components will be by the local agencies. A feeder extended to the facility would be evaluated by OSHPD from the point where it enters the OSHPD facility. In general, the supplemental normal power source is required to be installed in such a manner as it can do no harm to the hospital if the microgrid fails. This will require a means to disconnect that will open and isolate the microgrid system from the healthcare facility it serves if any problems occur.
   - Next, select codes based on the proposed microgrid and fuel systems required. For example, for photovoltaics add CFC 1204 and CEC 690 to the list of codes that will need to be followed. If batteries are added to this system, consult CFC 1206, CFC 1206.2 and NFPA 855. Depending on the amount of hazardous materials associated with the batteries, NFPA 400 might come into play.
2. The design process for systems that utilize the microgrid as the sole source of essential power for healthcare facilities will have varying degrees of complexity based on the type of facility and electric power sources. Here are a few examples:
   - For OSHPD 3 facilities (clinics) without surgery that are going to incorporate the microgrid as the code mandated EPS emergency power, the requirements for these facilities are typically quite low. The only code-mandated emergency loads are egress lighting and alarms. Generally, this amounts to less than 0.2VA/sq. ft. connected. For a 100,000 sq. ft. clinic, this equates to 20kVA. For clinics, the duration that these emergency loads must be maintained is just 90 minutes. So, typically, batteries (standard storage products with UL listings for emergency sources) could be utilized to meet EPS requirements. See NFPA 111 for code implications.
   - For ambulatory surgery clinics the power density will ratchet up and the duration extends to four hours. Standard energy storage products with UL listings for emergency sources could be investigated and perhaps meet these requirements.
   - For correctional treatment centers, acute psychiatric hospitals and skilled nursing facilities with seven or more beds, the requirement is six hours of emergency power. The essential power density also increases, so study will be required to determine how these power requirements can be met and maintained for a duration of six hours.

- For acute care hospitals, the load density greatly increases up to 15 VA/sq. ft. connected and the duration is extended to 72 hours. Going back to the 100,000 sq. ft. model, a hospital would need 1.5 MW of emergency power with fuel storage onsite sufficient to operate for 72 hours. The design team will need to select appropriate onsite electric power generators to meet emergency power requirements. (Note: To get CMS reimbursements, emergency generators will be required.)

Some of the challenges to be overcome for larger hospital facilities include finding energy producers, microgrid controllers that are listed for emergency use, onsite fuel storage options to meet 72 hours runtime and seismic certification for all components of the microgrid. As stated in the deep dive code reviews, in order to align codes with the new green electric power producers, a number of things should happen, such as: 1) evolution of current code to coordinate with microgrid products, 2) manufactures to obtain OSPs for various components of the microgrid system and 3) UL to develop standards for microgrid controllers to operate as emergency power source operators.

Legislation and Future Standards to Achieve 100% Renewable Energy Generation

A modern microgrid would keep a facility in step with changes happening throughout California, like Senate Bill 100 (SB 100), and would ensure reliability for healthcare's future. Below is a sampling of legislation having ripple effects on California hospitals.

- Senate Bill 100 requires carbon neutrality by 2045. The bill mandates utility providers follow a strict schedule to achieve this goal. As they do, the cost of "cleaner" grid power gets passed on through rate increases to end users like healthcare facilities. Resilient microgrids help hospitals take control of their energy future.

- The 2022 Building Energy Efficiency Standards (Energy Code) will improve upon the 2019 Energy Code for new construction of, and additions and alterations to, residential and nonresidential buildings. Proposed standards will be adopted in 2021 with an effective date of January 1, 2023. The California Energy Commission (CEC) updates the standards every three years.

- Los Angeles' Green New Deal mandates that LADWP supply 55% renewable energy by 2025; 80% by 2036; and 100% by 2045.

Chapter 3 - Institutional and Financial

Healthcare Requires Reliable Electric Power

Healthcare facilities are dependent on reliable electric power for life support and medical treatment. On August 14, 2003, the United States and Canada experienced the largest power failure in history, affecting 13 million New York City (NYC) residents (Prezant, Belyaev, Alleyne, Banauch, Davitt, & Kalkut, 2005). Hospitals with emergency power experienced a significant surge of respiratory patients with failed mechanical ventilators, oxygen compressors, and positive pressure breathing assist devices. According to Prezant et al. (2005), the 2003 power outage followed two other NYC power outages, one in 1965 and 1977.

After the 1965 citywide power outage, the State of New York required backup emergency power systems for hospitals and long-term care facilities (Prezant et al. 2005); this marked the beginning of emergency preparedness for power outages in New York hospitals. In October 2012, Hurricane Sandy hit New York City, plunging the city into darkness once again; major streets were flooded in lower Manhattan, causing the failure of sublevel emergency generators (Tran, Heller, Berger, & Habboushe, 2014). Hurricane Sandy left 2.5 million New Jersey residents and 2.3 million New York City residents without electrical power. The blackout caused all hospitals in the lower half of Manhattan to evacuate except for the Mount Sinai Beth Israel Medical Center (Tran et al., 2014).

Maintaining healthcare services throughout the recovery efforts were not without challenges for the healthcare facilities team at Mount Sinai. The preparations between 2003 and 2012 proved inadequate as most of the emergency generators were sub-street level. The 2012 Hurricane Sandy revealed the vulnerability of backup power systems and the need to improve electrical power's resiliency. Understandably, New York City hospitals have learned they need a more reliable infrastructure (Tran et al., 2014). The U.S. Presidential study on the economic benefits of a resilient electrical grid stated that severe weather has contributed to 679 widespread power outages from 2003 to 2012 (House, 2013) as also summarized in Figure 27.

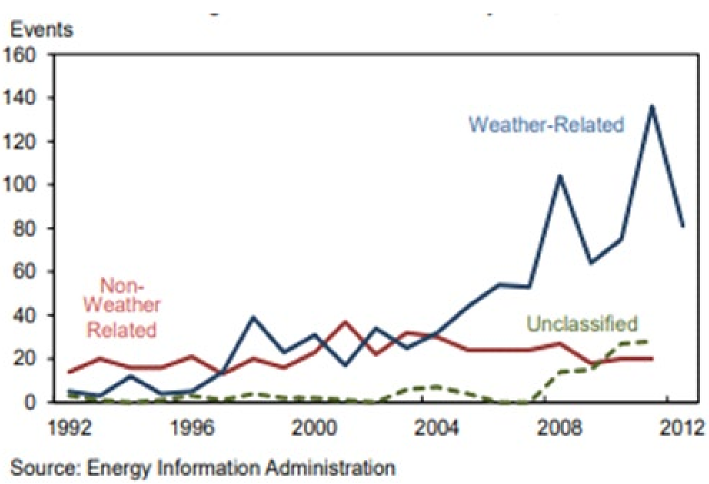


Figure 27. Observed outages in the bulk electric system, 1992-2012

The number one cause of power outages in the U.S. is severe weather; addressing severe weather vulnerability, President Obama created a policy framework to modernize the electric grid with smart technologies to lessen weather-related power outages (House, 2013). The estimated cost of severe weather-related power outages from 2003 to 2012 is from $18 billion to $33 billion annually, and the number of power outages related to severe weather has increased significantly since 1992. See the chart below from the Energy Information Administration (House, 2013).

Healthcare facilities face increasing weather-related power outages that require a reliable alternative to the national and local electrical power distribution grid. One such alternative to waiting for the rebuilding of the nation's power grid is the microgrid solution. The microgrid solution is a distributed energy resource (DER) with an interconnected load within a defined electrical power distribution boundary (Microgrids for Health Care Facilities, 2017). The microgrid can be a solution to provide clean, reliable, and sustainable electrical power during weather-related power outages in California.

Public Safety Power Shutoffs

The California utilities has implemented Public Safety Power Shutoffs (PSPS) to avoid wildfires caused by high winds that arc power lines supported upon an aging power distribution grid. California communities will continue to experience PSPS for years due in part to climate change, according to Wong-Parodi (2020). Although residents understand the need for PSPS to reduce the risk of wildfires, they grow weary of the mental stress PSPS events cause.

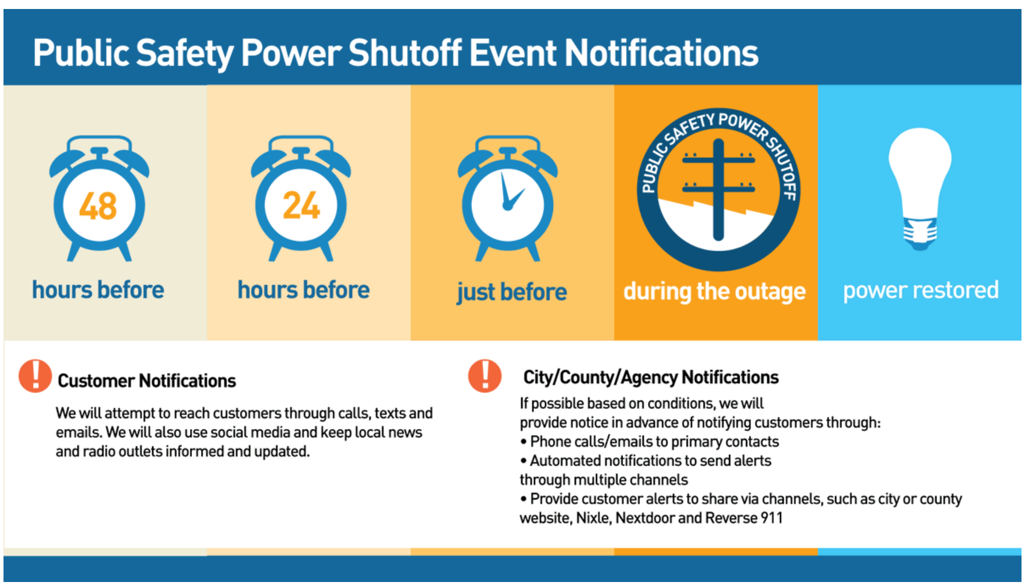


Figure 28. Example of event notifications for PG&E PSPS events.

PSPS events can last for days, forcing healthcare facilities to rely exclusively on emergency generator power. However, PSPS are often announced in advanced, as illustrated by Figure 28. As such, PSPS signals can be ingested by the microgrid controller to anticipate power loss by planning for charging of battery energy storage systems (BESS) and commission fuel for backup generation and fuel cells. The California Electric Code (CEC) requires emergency generators used for healthcare must have 72 hours of fuel, and The Joint Commission (TJC) requires a plan for power loss for 96 hours. Acute care hospital emergency power generators require monthly, annual, and triannual compliance testing; however, the most extended test duration is four hours. Some of the healthcare emergency generators, for the first time, run well beyond the four hours triennial test, with continuous loads testing the resilience of the healthcare facility emergency generator. Healthcare facilities need a creative way to purchase reliable power.

Corporate Sustainability Goals and Trends

Some healthcare systems in California have already embraced sustainability goals supporting energy use reduction and green power and are paving the way for others to join along. Below are examples from Kaiser Permanente and CommonSpirit Health.

Kaiser Permanente, the nation's largest nonprofit, integrated healthcare system, is becoming carbon neutral in 2020. Kaiser Permanente uses more than 1 million megawatt-hours of green power annually, which includes approximately 60,000 MWh of solar power generated at its facilities. Kaiser Permanente's 2020 commitment is to use green power for all the electricity it purchases, and carbon offsets to equal emissions from onsite equipment such as gas-fired boilers that heat its buildings.

Common Spirit Health, the parent company of Dignity Health and Catholic Health Initiatives, is driven by its five core values – Compassion, Inclusion, Integrity, Excellence, and Collaboration. It is these values that led their CEO, Lloyd H. Dean, to say that "We have always felt a special responsibility toward the communities we serve and the environment we are called to protect knowing that the decisions we make as an industry can either harm or benefit the safety and well-being of the families in our care." It is this fundamental belief that led CommonSpirit Health to announce their 2030 Sustainability Goals in 2020. These goals include reducing energy and water consumption by 25%, GHG emissions by 40%, and increasing the use of renewables by 20% based on a 2019 baseline. Lloyd H. Dean went on to say, "The magnitude of the changes and the challenges that the healthcare industry faces is abundantly clear; so are the opportunities. We will continue to value that which sustains life, including our environment. It is imperative that we measure, manage, and report our efforts on our interlocking environmental, social, and economic/governance (ESG) initiatives in a manner that allows all of us to see our true impacts on our world and our people."

Financing Microgrids for Healthcare Facilities

Microgrids are small independent utilities with a defined set of customers, an array of generating technologies that can be connected to the grid or operate as an island (Microgrids for Health Care Facilities, 2017). The cost of building a microgrid could be significant for some healthcare systems. Hospitals often have limited capital to devote to microgrid projects and often must compete for capital for projects that visibly improve patient care. Thus, being able to finance a microgrid through third-party financing – and repaying that cost through monthly energy or capacity payments (like a typical power purchase agreement) –offers a solution.

The industry already has much experience with power purchase agreements (PPAs) for onsite solar, fuel cells, and other forms of power-generating technologies. The vendor builds, owns, operates, and maintains the onsite generation asset and sells the power to the host. Ideally, the cost per kWh is less than the avoided cost that would otherwise pay to the utility, which can quickly happen in places with high electricity costs like California.

In recent years, battery companies have offered similar financing arrangements, but instead of charging for energy output like solar and fuel cells, they take a portion of demand (kW) savings. In some cases, these arrangements have not worked well, so battery companies have moved to leases or fixed monthly payments, which transfers some of the risks back onto the host. Adding microgrid controllers and other equipment needed to prevent back-feeding to the grid – thus enabling the facility to operate in island mode – often makes solar/fuel cell/battery storage projects non-viable financially. Microgrid controllers have become more affordable. The cost of microgrid controllers (one of the vital additional costs associated with microgrid projects) has come down dramatically in recent years, from the low millions of dollars to the hundreds of thousands of dollars.

These developments, including the continuing rise in power prices, are making financing microgrids easier. In some cases, even with the added cost of microgrid equipment, that capital cost can be built into a solar or fuel cell PPA, and the resulting price per kWh would still be less than the utility avoided cost (per kWh charge from the utility plus demand charges). These PPAs include onsite generation, storage, and resiliency, referred to as Energy as a Service (EaaS). EaaS is a relatively new development used to finance microgrids (Microgrid Knowledge, 2020).

According to Seth Baruch (2020), one of the reasons Kaiser Permanente (KP) utilizes third-party financing is due to their non-profit status. Third-party financing of microgrids can be attractive for non-profit healthcare organizations because non-profits cannot benefit from the Investment Tax Credit (ITC). For-profit healthcare organizations can benefit from the ITC for both solar and for batteries paired with solar. To maximize the ITC, healthcare organizations will need to act quickly as each year the ITC is reduced. In 2020, the ITC was 26% and is scheduled to drop to 22% in 2021. Each year the ITC is scheduled to reduce.

The Value of Resiliency

Microgrid financing is not always lower than the avoided utility cost. If the resiliency needs are modest, the microgrid can be modest. It is essential to balance resiliency versus cost.

Put another way, the value of resiliency is the cost of power outages. Several studies have looked at this question, and to the extent healthcare systems can quantify the costs of a power outage, look at the risks for outages, calculate an estimated economic cost per year, and add that to the business case. Figure 29, adopted from Microgrids for Health Care Facilities, 2017, illustrates the criteria for sizing the microgrid that could make more microgrid projects economically feasible.

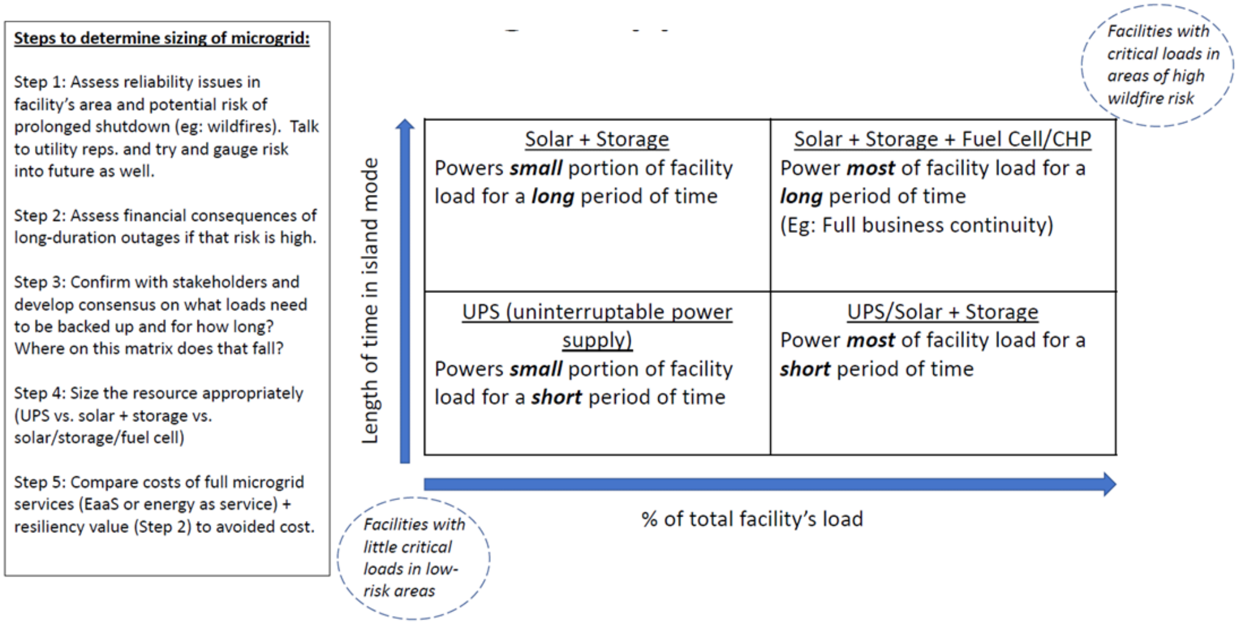


Figure 29. Selection criteria for sizing the microgrid for resiliency

In conclusion, there is a need for reliable electric power for healthcare organizations, both acute and non-acute medical office buildings. The existing electrical grid in California needs repairs to mitigate the risk of wildfires and long-term power outages. The long-term power outages that can last for days tax the existing onsite emergency generators, which typically run a maximum of four hours every three years during a compliance test. With climate change fueling high winds, drought conditions, and undergrowth with an electrical grid in need of repairs, a continuous threat of wildfires requiring PSPS to reduce wildfire risks have created an unreliable power grid. The microgrid provides sustainability and resiliency that meets the needs of healthcare in California. The means to acquire a microgrid system can be through capital purchase or a PPA. How ever the microgrid is acquired, it may be the best alternative.

References

A New Green Standard? How Hospitals Can Utilize Geothermal Energy to Save the Environment and Money. (2012). Retrieved from https://www.beckershospitalreview.com/hospital-management-administration/a-new-green-standard-how-hospitals-can-utilize-geothermal-energy-to-save-the-environment-and-money.html

AMERESCO, 2017. The Rise of Clean Energy Microgrids - why microgrids make sense for hospitals, higher education, military and government, and businesses, White Paper in Microgrid Knowledge, be Energy Efficiency Markets LLC.

American Fire Technologies (2018). Li-Ion Tamer Partners with American Fire Technologies. The Journal of Biological Chemistry. Retrieved from https://www.aft.net/news/li-ion-tamer-partners-with-american-fire-technologies-for-increasing-safety-of-li-ion-energy-storage-systems/

Asmus, Peter, Adam Forni, and Laura Vogel. Navigant Consulting, Inc. 2017. Microgrid Analysis and Case Study Report. California Energy Commission. Publication Number: CEC-500-2018-022.

Baruch, S.J. National Director Energy and Utilities, National Facilities Services, Kaiser Permanente (2020, November)

Bliss, D. (2019). A Novel, Renewable Energy Microgrid for a California Healthcare Facility. CEC Energy Research and Development Division Final Report CEC-500-2019-034.

California Building Standards Commission, and National Fire Protection Association. (2019). *2019 California electrical code: California code of regulations, title 24, part 3.*

California ISO. 2016. What the Duck Curve tells us about managing a Green Grid. Fast Facts 1–4. Retrieved from https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

Darling, D., & Hoff, S. (2020). U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=43915

Dishel, M. (2013). NFPA 110's Fuel requirements can help guide backup power plan for hospitals. Retrieved from https://www.facilitiesnet.com/healthcarefacilities/article/NFPA-110s-Fuel-Requirements-Can-Help-Guide-Backup-Power-Plan-For-Hospitals--14338

Emergency Generator 4-hour Load Test. (2020). Retrieved from https://www.jointcommission.org/standards/standard-faqs/home-care/environment-of-care-ec/000001267/

Fast Facts about California Wind Energy. (2020). Retrieved from https://www.calwea.org/fast-facts

Geothermal Heat Pumps. (2011, January 4). Retrieved from https://www.energy.gov/energysaver/heat-and-cool/heat-pump-systems/geothermal-heat-pumps

Goldie-Scot, Logan. (2019). A Behind the Scenes Take on Lithium-Ion Battery Prices. BloombergNEF. Retrieved from https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

House, W. (2013). Economic benefits of increasing electric grid resilience to weather outages. *Washington, DC: Executive Office of the President*.

Healthcare: An Overview of Energy Use and Energy Efficiency Opportunities [Pamphlet]. (n.d.). ENERGY STAR.

Hirschbold, M., & Haun, A. (2019). How new microgrid designs help hospitals increase resilience, cut costs, and improve sustainability (pp. 1-17, White Paper). Schneider Electric.

Hledik, Ryan, Peter Fox-Penner, Roger Lueken, Tony Lee, and Jesse Cohen. 2020. Decarbonized Resilience: Assessing Alternatives to Diesel Backup Power.

IEA. (2020). World Energy Outlook 2020.

Konakalla, S.A.R, Valibeygi, A. and de Callafon, R.A. (2020). Microgrid Dynamic Modeling and Islanding Control With Synchrophasor Data. IEEE Transactions on Smart Grid 11 (1), pp. 905-915, doi: 10.1109/TSG.2019.2948815.

Lasseter, R. H., & Paigi, P. (2004, June). Microgrid: A conceptual solution. In *2004 IEEE 35th Annual Power Electronics Specialists Conference (IEEE Cat. No. 04CH37551)* (Vol. 6, pp. 4285-4290). IEEE.

Lazard. (2017). Lazard's Levelized Cost of Storage Analysis – Version 3.0

Lazard. (2019). Lazard's Levelized Cost of Storage Analysis - Version 5.0.

Marqusee, J., Ericson, S., & Jenket, D. (2020). Emergency Diesel Generator Reliability and Installation Energy Security (pp. iv-36, Tech. No. NREL/TP-5C00- 76553). Golden, CO: National Renewable Energy Laboratory. Doi: https://www.nrel.gov/docs/fy20osti/76553.pdf

Mey, A. (2020). U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=45136

Microgrids for Health Care Facilities. (2017). *EC&M Electrical Construction and Maintenance (Online Exclusive)*.

National Fire Protection Association. (1900). *Standard for health care facilities: NFPA 99.* Quincy, MA, National Fire Protection Association.

National Fire Protection Association. (1989). *National fire codes: A compilation of NFPA codes, standards, recommended practices, manuals and guides*. Quincy, Mass: National Fire Protection Association.

Pamer, M., & Espinosa, E. (2017). We don't even call it fire season anymore ... it's year round: Cal Fire. Retrieved from https://ktla.com/news/local-news/we-dont-even-call-it-fire-season-anymore-its-year-round-cal-fire/

Prabakar, K., Valibeygi, A., Konakalla, S., Miller, B., de Callafon, R.A., Pratt, A., Symko-Davies, M., Bialek, T. (2020), Remote Hardware-in-the-Loop Approach for Microgrid Controller Evaluation. NREL Technical Report, NREL/CP-5D00-74887.

Prezant, D. J., Clair, J., Belyaev, S., Alleyne, D., Banauch, G. I., Davitt, M., and Kalkut, G. (2005). Effects of the August 2003 blackout on the New York City healthcare delivery system: a lesson for disaster preparedness. *Critical care medicine*, *33*(1), S96-S101.

RMI. (2017). BESS Used for Spinning Reserve.

U.S. average annual wind speed at 30 meters. (2012). Retrieved from https://windexchange.energy.gov/maps-data/325.

U.S. Energy Information Administration (2012). Electricity Storage Can Smooth out Moment-to-Moment Variations in Electricity Demand. The Journal of Biological Chemistry. Retrieved October 30, 2020 (https://www.eia.gov/todayinenergy/detail.php?id=6370).

van Zalk, John, and Paul Behrens (2018). The Spatial Extent of Renewable and Non-Renewable Power Generation: A Review and Meta-Analysis of Power Densities and Their Application in the U.S. Energy Policy 123:83–91. doi: 10.1016/j.enpol.2018.08.023.

Third Uniform California Earthquake Rupture Forecast (UCERF3). (n.d.). Retrieved from https://www.scec.org/ucerf

Tran, C. N. T., Heller, M., Berger, A., & Habboushe, J. (2014). Hurricane Sandy: how did we do? Assessing a Manhattan Hospital's response. *Frontiers in public health*, *2*, 90.

Valibeygi, A., de Callafon, R.A. Stanovich, M., Sloderbeck M. and Meeker, R. (2018). Microgrid Control Using Remote Controller Hardware-in-the-Loop Over the Internet. 2018 IEEE Power and Energy Society Innovative Smart Grid Technologies Conference (ISGT), Washington, DC, pp. 1-5, doi: 10.1109/ISGT.2018.8403345.

Valibeygi, A. and de Callafon, R.A. (2019) Cooperative Energy Scheduling for Microgrids under Peak Demand Energy Plans, 2019 IEEE 58th Conference on Decision and Control (CDC), Nice, France, 2019, pp. 3110-3115, doi: 10.1109/CDC40024.2019.9028866

Valibeygi, A., Konakalla, S.A.R., de Callafon, R.A. (2020). Predictive Hierarchical Control of Power Flow in Large-Scale PV Microgrids with Energy Storage, IEEE Transactions on Sustainable Energy, doi: 10.1109/TSTE.2020.3001260.

Winters, C. (2014). Is your hospital safe when disaster strikes? Retrieved from https://www.consumerreports.org/cro/news/2014/10/is-your-hospital-safe-when-disaster-strikes/index.htm

Wong-Parodi, G. (2020). When climate change adaptation becomes a "looming threat" to society: Exploring views and responses to California wildfires and public safety power shutoffs. *Energy Research and Social Science*, *70*, 101757.

Wu, X., Nethery, R. C., Sabath, M. B., Braun, D. and Dominici, F. (2020). Air pollution and COVID-19 mortality in the United States: Strengths and limitations of an ecological regression analysis. Science advances, 6(45).

Appendices

Appendix A CEC Matrix

2019 CEC 517

	CODE LANGUAGE	COMMENT	RECOMMENDATIONS
PART 1. GENERAL			
517.1	**Scope.** The provisions of this article shall apply to electrical construction and installation criteria in health care facilities that provide services to human beings.		
517.2	**Definitions** **Alternate Power Source.** One or more generator sets, or battery systems where permitted, intended to provide power during the interruption of the normal electrical service. Or The public utility electric service intended to provide power during interruption of service normally provided by the generating facilities on the premises.	The CEC limits the Alternate Power Source to on-site power sources with on- site fuel storage. The CEC limits the Alternate Power Source to on-site power sources with on- site fuel storage.	
	Essential Electrical System. A system compromised of alternate sources of power and all connected distribution systems and ancillary equipment, designed to ensure continuity of electrical power to designated areas and functions of a healthcare facility during disruption of normal power sources and also to minimize disruption within the internal wiring system.	Needs to meet code requirements for: 1) Seismic Certification (Per CBC 1705.13.3.1 required for life safety components for OSHPD 1 and 2 (if subacute) 4 and 5 facilities), 2) Listed Product CEC per 110.3(B) and 3) On-site fuel storage per CEC 700.12(B)(2)	Manufacturers should be approached to determine if they can address Seismic Certification of Microgrid Power sources and controllers. UL should be approached to develop a standard for microgrid controllers listed for emergency use (similar to ATS's & lighting inverters). CBC 1705A (seismic certification require-ments) should be modified to include CoGen, PV and fuel cells (if used as EPS) .
	Critical and Life Safety Branches. … are automatically connected to alternate power sources by one or more transfer switches during interruption of normal power source.		
	Normal Power Source. NO DEFINITION EXISTS in the CEC.	A definition for the normal power source should be added.	The following definition is proposed for the normal power source: "Source that has the capacity and distribution to normally feeds all non-essential loads (and typically essential load) unless an unscheduled outage of this source occurs."
	Equipment Branch - …arranged for delayed, automatic, or manual connection to the alternate power source…		
PART II. WIRING AND PROTECTION			
517.17(B)	**Ground Fault Protection.** Where ground-fault protection is provided for operation of the service disconnecting means or feeder disconnect means as specified by 230.95 or 215.10 (for 480Y/277V feeders 1000A and larger), an additional step of ground-fault protection shall be provided in all next level feeder disconnecting means...	Ground fault protection is required for normal power and ground fault protection or annunciation is required for emergency sources.	Code should provide definition of normal power. Plans will need to clearly identify if microgrid is normal power or essential power so proper ground fault protection and annunciation can be designed.
PART III. ESSENTIAL ELECTRICAL SYSTEM			
517.25	**Scope.** The essential electrical system for these facilities shall comprise a system capable of supplying a limited amount of lighting and power service, which is considered essential for life safety and orderly cessation of procedures during the time normal electric service is interrupted for any reason.	If Microgrid used for EPS and feeds to ATS's should be no different from current designs.	
517.30	**Sources of Power** **A) Two Independent Power Sources.** Essential electrical systems shall have a minimum of the following two independent sources of power: a normal power source generally supplying the entire electrical system and one or more alternate source(s) for use when the normal source is interrupted.	Microgrid can be used to parallel normal service or essential power. If the microgrid is used for essential power will need to be completely independent of normal power source.	Codes should state this clearly, i.e. if microgrid parallels with utility, there would need to be an additional utility service.

PART III. ESSENTIAL ELECTRICAL SYSTEM (cont'd)			
	CODE LANGUAGE	**COMMENT**	**RECOMMENDATIONS**
517.30	**(B) Types of Power Sources:** **(1.1) Generator Units.** The alternate source of power shall be one of the following: (A) Generator(s) driven by some form of prime mover(s) and located on the premises (B) Another generating unit(s) where the normal source consists of a generating unit(s) located on the premises		
	(C) Fuel Cell Systems	In order to allow microgrids to be uses as EPS would need to add other on-site generation sources to this list. i.e. Solar, Wind, CoGen, Battery storage, Water, etc.…	Recommend modifications to code to allow Microgrids as emergency source with all forms of on-site power generation (electromech-anical (combustion and fusion machines), wind, electrochemical (battery systems) photovoltaics Consideration for wind and geo-thermal sources? Add to article 700 as well. Note this would need to be separate from normal service.
	All on premises sources of power shall meet the on-premises fuel requirements specified in Article 700.12	1) Acute Care Hospitals -72 hrs. 2) Correctional treatment centers that provide optional services – 24 hrs. 3) Correctional treatment centers that provide only basics services – 6 hrs. 4) Acute psychiatric hospitals – 6 hrs. 5) Intermediate care facilities – 6 hrs. 6) Skilled nursing facilities – hrs. 7) Ambulatory surgical clinics – 4 hrs. 8) MOB's – 90 mins.	Code could be developed to identify means and methods for determining minimum requirements for microgrid to meet 72 hrs. of on-site fuel storage for actual essential loads, and testing commissioning requirements. Note, calculations could include contributions from multiple power sources with varying durations.
	(2) Fuel Cell Systems. Fuel Cell Systems shall be permitted to serve as the alternate source for all or part of an essential electrical system, provided the following conditions apply: (1) Installation of fuel cells shall comply with Article 692.		Recommend code changes to mimic Generators and Battery storage units. I.e. NFPA should develop fuel cells for emergency use code or revise NFPA 110 to include fuel cells (and other on-site power sources).
	(2) N+1 units shall be provided where N units have sufficient capacity to supply the demand loads of the portion of the system served.	As written, this would include a minimum of (2) fuel cells for all installations. Many fuel cells have redundancy built into them.	Investigation should be made to develop a definition of N+1 in regards to units with built-in redundancy.
	(3) System shall be able to assume loads within 10 seconds of loss of normal power source.	If microgrid is used for EPS, a listed smart inverter would be required so the transfer to alternate power source could be seamless.	UL should be approached to develop a standard for microgrid controllers listed for emergency use (similar to ATS's & lighting inverters).
	(4) System shall have a continuing source of fuel supply, together with sufficient on-site fuel storage for the essential system type.	Continuing source of fuel supply implies from utility. On-site storage would need to meet requirements of CEC 700.12	

PART III. ESSENTIAL ELECTRICAL SYSTEM (cont'd)			
	CODE LANGUAGE	**COMMENT**	**RECOMMENDATIONS**
517.30	(5) A connection shall be provided for a portable diesel generator to supply life safety and critical portions of the distribution system.	This code requirement partially mimics the requirements for temp hookups if a single generator on-site to allow back-up during maintenance. Why not temp hookup to supply life safety/ critical and equipment branches?	We would recommend that provisions for temp generator to back up entire essential power system (Life Safety, Critical and Equipment branches) to accom-modate for 10 yr life expectancy of fuel cells.
	(6) Fuel cell systems shall be listed for emergency use.	It would appear that the fuel cell and controls would need to be listed for emergency use, but might be a moot point as this requirement has been removed from 2020 NEC	Recommend that this be investigated further. Codes should be consistent for diesel generator sets and fuel cells if both could be used as EPS. Controllers should be UL listed for emergency use similar to ATS's.
	(D) Location of Essential Electrical System Components. Essential electrical system components shall be located to minimize interruptions caused by natural forces common to the area (storms, floods, earthquakes) installation of electrical services shall be located to reduce possible interruption of normal electrical services....	It will be important to identify normal source and emergency source so this can be complied with. All sources of microgrid (if used as EPS) would need to comply with this requirement.	
517.31	**Requirements for the Essential Electrical System.** **(A) Separate Branches.** Essential electrical systems shall be comprised of three separate branches capable of supplying a limited amount of lighting and power service that is considered essential for life safety and effective hospital operation during the time the normal service is interrupted for any reason (life safety , critical and equipment)	If Microgrid used for EPS and feeds to ATS's should be no different from current designs	Microgrid will need to be separate from normal source.
	(C)(1) Separation from other circuits. The life safety branch and the critical branch of the essential electrical system shall be kept entirely independent of all other wiring and equipment and shall not enter the same raceways, boxes, or cabinets with each other or other wiring	If Microgrid used for EPS and feeds ATS's should be no different from current designs.	
	(C)(3) Mechanical Protection of the Essential Electrical System. The wiring of the life safety and critical branches shall be mechanically protected.	It will be important to identify normal source and emergency source so this can be complied with. Feeders from all sources of microgrid (if used as EPS) would need to comply with this requirement.	
	(D.1) OSHPD - Capacity of Systems. The essential electrical system shall have the capacity and rating to meet the maximum actual demand likely to be produced by the connected load	No acceptable calculations other than measured demand (x 1.25) and connected per CEC. Current Standard of care is to size the emergency generators to meet connected load values.	Studies should be performed to gather historical data that could be used to develop demand factors for emergency power to help minimize on-site generation requirements.
	(G) Coordination. Overcurrent protection devices serving the essential electrical system shall be coordinated for the period of time that a fault's duration extends beyond 0.1 second.	If Microgrid is used for EPS then these requirements would apply for all components of the Microgrid and distribution system.	
517.32	**Branches Requiring Automatic Connection** (B) The life safety and critical branches shall be installed and connected to the alternate power source… automatically restored to operation within 10 seconds.		
517.33	**Life Safety Branch**	If Microgrid is used for EPS then these requirements would apply for all components of the Microgrid and distribution system.	
	(C) Alarm and Alerting Systems. Alarm and alerting systems including the following: (2) Alarm and alerting systems (other than fire alarm systems) shall be connected to the life safety branch or critical branch.		

PART III. ESSENTIAL ELECTRICAL SYSTEM (cont'd)			
	CODE LANGUAGE	**COMMENT**	**RECOMMENDATIONS**
517.33	(2) Alarm and alerting systems (other than fire alarm systems) shall be connected to the life safety branch or critical branch.		
	(E) Generator Set Locations. Generator set locations (circuited to life safety branch) as follows: (1) Task Illumination (2) Battery charger for emergency lighting (3) Select receptacles at the generator set location.		
	(F) Generator Set Accessories. … Loads dedicated to a specific generator, including the fuel transfer pump(s), .. controls, and other generator accessories essential for generator operation, shall be connected to the life safety branch or to the output terminals of the generator with overcurrent protective devices. The life safety and critical branches shall be installed and connected to the alternate power source… automatically restored to operation within 10 seconds.		
517.34	**Critical Branch.** (A) Task Illumination and Selected Receptacles. The critical branch of the essential electrical system shall supply power for task illumination, fixed equipment, selected receptacles… (8)(k) Electrical and mechanical rooms.	If Microgrid is used for EPS then these requirements would apply for all components of the Microgrid and distribution system.	
517.35	**Equipment Branch Connection to Alternate Power Source.** The equipment branch shall be installed and connected to the alternate power source such that the equipment described below is automatically restored to operation at appropriate time-lag intervals following the energizing of the essential electrical system. 1)Central Suction Systems, 2) Sump Pumps, 3) Compressed Air systems serving medical/surgical functions, 4) Smoke Control, 5) Kitchen Hoods, 6) Supply/return/exhaust for air born infectious/isolation rms.	If Microgrid is used for EPS then these requirements would apply for all components of the Microgrid and distribution system.	

Appendix B NFPA 99 Matrix

2018 NFPA 99 Health Care Facilities Code

	CODE LANGUAGE	COMMENT	RECOMMENDATIONS
3.3.4	**Alternate Power Source.** One or more generator sets, or battery systems where permitted, intended to provide power during the interruption of the normal electrical service; or the public utility electrical service intended to provide power during interruption of service normally provided by the generating facilities on the premises.	1) The terms "generator sets, or battery systems" is confusing. Does generator set just mean combustion engine/electric generator sets? 2) The CEC limits the Alternate Power Source to on-site power sources with on-site fuel storage.	Definition for "generator sets" should be added which could include: electromechanical (combustion and fusion machines), wind, electrochemical (battery systems) photo voltaics Consideration for wind and geothermal sources?
3.3.51	**Essential Electrical System.** A system comprised of alternate sources of power and all connected distribution systems and ancillary equipment, designed to ensure continuity of electrical power to designated areas and functions of a health care facility during disruption of normal power sources, and also to minimize disruption within the internal wiring system.	Needs to meet code requirements for: 1) Seismic Certification (Per CBC 1705.13.3.1 required for life safety components for OSHPD 1 and 2 (if subacute) 4 and 5 facilities, 2) Listed Product CEC per 110.3(B) and 3) On-site fuel storage per CEC 700.12(B)(2)	Manufacturers should be approached to determine if they can address Seismic Certification of Microgrid Power sources and controllers. UL should be approached to develop a standard for microgrid controllers listed for emergency use (similar to ATS's & lighting inverters). CBC 1705A (seismic certification requirements) should be modified to include Cogen, PV and fuel cells (if used as EPS) .
3.3.136.1	**Category 1 Space.** Space in which failure of equipment or system is likely to cause major injury or death of patients, staff or visitors.	Hospitals, SNF's with subacute patients and surgery centers.	
3.3.136.2	**Category 2 Space.** Space in which failure of equipment or system is likely to cause minor injury to patients, staff or visitors.	SNF's without subacute patients and MOB's	
Chapter 6	**Electrical Systems**		
6.2.4	**Location of Essential Electrical System Components**		
6.2.4.1	Essential electrical system components shall be located to minimize interruptions caused by natural forces common to the area (e.g., storms floods, earthquakes, or hazards created by adjoining structures or activities)	If the microgrid is used as EPS, this requirement would apply for all power sources and main distribution board.	Code language or revisions to include this requirement could be added to current code to clarify.
6.2.4.2	Installations of electrical services shall be located to reduce possible interruption of normal electrical services resulting from similar causes as well as possible disruption of normal electrical service due to internal wiring and equipment failures.		
6.2.4.3	Feeders shall be located to provide physical separation of the feeders of the alternate source and from the feeders of the normal electrical source to prevent possible simultaneous interruption.	If the microgrid is used as EPS, this requirement would apply for all power sources and main distribution board.	
6.3	**General**		
6.3.1	**Sources**		
6.3.1.1	**Power/Utility Company (Reserved)**	This could possibly be used to provide a definition for normal power.	
6.3.1.2	**On-Site Generator Set. (Reserved)**		
6.3.2.8	**Ground Fault Protection**		
6.3.2.8.2	Where ground-fault protection is provided for operation of the service or feeder disconnecting means an additional step of ground-fault protection shall be provided in the next level of feeder downstream toward the load.	If the microgrid is used as EPS, this requirement would apply for all microgrid power source feeders and main distribution board.	
6.4	**Category 1 spaces**		
6.4.1	Category 1 spaces shall be served by a type 1 Essential Electrical System (EES).	Based on this code the only type 1 EES power source are generators (see 6.7.1.2.4)	Code should add: electromechanical (combustion and fusion machines), wind, electrochemical (battery systems) photo voltaics Consideration for wind and geothermal sources?
6.5	**Category 2 spaces**		
6.5.1	Category 2 spaces shall be served by a Type 1 ESS or Type 2 ESS.		
6.7	**Essential Electrical Systems**		
6.7.1	**Sources**		

	CODE LANGUAGE	COMMENT	RECOMMENDATIONS
6.7.1.1	**Design Considerations.** Dual sources of normal power shall not constitute an alternate source of power as described in this chapter	In order for EPS to be considered as an alternate source, it would need to be completely separate from the normal source (typically utility)	
6.7.1.2	**On-Site Generator Set**		
6.7.1.2.2	Essential electrical systems shall have a minimum of the following two independent sources of power: a normal source generally supplying the entire electrical system and one or more alternate sources for use when the normal source is interrupted.	Normal source is partially defined here "generally supplying the entire electrical system". Two independent sources are required.	
6.7.1.2.3	Where the normal source consists of generating unit on the premises, the alternate source shall be either another generating set or an external utility service.	The CEC limits the Alternate Power Source to on-site power sources with on- site fuel storage.	
6.7.1.2.4.1	Type 1 and Type 2 essential electrical system power sources shall be classified as Type 10, class X, Level 1 generator sets per NFPA 110.	Code states that Type 1 power sources are generator set(s) - generator sets typically means combustion engine/generator sets, which could be confusing.	Code should add: electro-mechanical (combustion and fusion machines), wind, electrochemical (battery systems) photo voltaics Consideration for wind and geo-thermal sources? Or- new NFPA codes could be added for each of these sources and this text could change "generator sets" to generators.
6.7.1.2.5	**Use for Essential Electrical System.**		
6.7.1.2.5.1	The generating equipment used shall be either reserved exclusively for such service or normally used for other purposes of peak demand control, load relief for the external utility or Cogen. If normally used for such other purposes two or more sets shall be installed, such that the maximum actual demand likely to be produced by the connected load of the life safety and critical branches as well as medical air compressors, medical-surgical vacuum pumps, electrically operated fire pumps, fuel pumps etc.. shall be met by a multiple generator system with the largest generator set out of service.	The term "generating equipment" is not defined anywhere in the code.	Definition for "generator sets" should be added which could include: electromechanical (combustion and fusion machines), wind, electrochemical (battery systems) photo voltaics Con-sideration for wind and geothermal sources?
6.7.1.2.5.2	A single generator set that operates the Essential Electrical System shall be permitted to be part of the system supplying the other services…. such that any such use will not decrease the mean period between service overhauls to less than 3 years.	The term "generator set" is used here without a definition.	Definition for "generator sets" should be added which could include: electromechanical (combustion and fusion machines), wind, electrochemical (battery systems) photo voltaics Con-sideration for wind and geothermal sources?
6.7.1.2.5.3	Optional loads shall be permitted to be served by the Essential Electrical System generating equipment. Optional loads shall be served by their own transfer means, such that these loads shall not be transferred onto the generating equipment if the transfer will overload the generating equipment and shall shed upon a generating equipment overload. Use of the generating equipment to serve optional loads shall not constitute "other purposes" as described above.	1) Generating equipment seems appropriate if definition is updated. 2) It appears that this is making the distinction that the entire system is not backed up for peak demand control or load relief that an optional transfer switch could be used to add optional loads on the EPS with load shed capabilities.	
6.7.1.2.6	**Work Space or Room.**		
6.7.1.2.6.1	The EPS shall be installed in a separate room for Level 1 Installations	This requirement would apply for all source generators tied to the microgrid if used as EPS.	
6.7.1.2.6.1(B)	For indoor EPS installations, the EPS room shall be separated from the rest of the building by construction with a 2-hour fire resistance rating.	If the microgrid is used as EPS, this requirement would apply for all power sources and main dis-tribution board.	
6.7.1.2.6.1(C)	For outdoor EPS installations, the EPS shall be installed in a suitable enclosure located outside the building and capable of resisting the entrance of snow or rain at max wind velocities.	Will require Seismic Certification/ Restraint, Listed Product and 72 hrs. of fuel storage on-site.	

	CODE LANGUAGE	COMMENT	RECOMMENDATIONS
6.7.1.2.6.1(D)	The rooms, enclosures, or separate buildings housing level 1 or Level 2 EPSS equipment shall be designed and located to minimize damage from flooding, including that caused by the following 1) Firefighting, 2) Sewer water backup, 3) Other disasters or occurrences	If the microgrid is used as EPS, this requirement would apply for all power sources and main distribution board (required to be located above the 100 yr. flood plain)	
6.7.1.2.7	**Capacity and Rating.** The generator set(s) shall have the capacity and rating to meet the maximum actual demand likely to be produced by the connected load of the essential electrical system(s).	Would apply for microgrid (if used for EPS)	-Definition for "generator sets" should be added which could include: electromechanical (combustion and fusion machines), wind, electrochemical (battery systems) photo voltaics Consideration for wind and geothermal sources?
6.7.1.2.8	**Load Pickup.** The energy converters shall have the required capacity and response to pick-up and carry the load within the time specified in table 4.1(b) of NFPA 110 after loss of primary power.	Load pick-up of critical and life safety loads within 10 seconds	Will require seamless transfer for sources that parallel "other" services.
6.7.1.2.10.8	Design of the heating, cooling and ventilation system for the EPS equipment room shall include provision for factors including: 1) Heat 2) Cold 3) Dust 4) Humidity 5) Snow and Ice 6) Louvers 7) Remote radiator fans and 8) Prevailing winds	Would apply for microgrid (if used for EPS) for all parasitic loads associated with the on-site power sources.	Requirement should be added for design of parasitic loads to support all microgrid sources should be added to code.
6.7.1.2.1.13	**Fuel Supply.** The fuel supply for the generator set shall comply with Sections 5.5 - 7.9 of NFPA 110	1) Acute care hospitals-72 hrs. 2) Correctional treatment centers that provide optional services-24 hrs. 3) Correctional treatment centers that provide only basic services-6 hrs. 4) Acute psychiatric hospitals- 6 hrs. 5) Intermediate care facilities-6 hrs. 6) Skilled nursing facilities- 6 hrs. 7) Ambulatory surgical clinics-4 hrs. 8) MOBs-90 mins	Definition for "generator sets" should be added which could include: electromechanical (combustion and fusion machines), wind, electrochemical (battery systems) photo voltaics Consideration for wind and geothermal sources?
6.7.1.2.14.1	**Internal Combustion Engines.** Internal combustion engines serving generator sets shall be equipped with: water-jacket temperature sensors, high engine temp, low lubricating oil pressure, low water coolant level and auto shutdown for: over crank. Overspeed, low oil pressure, excessive engine temp		
6.7.1.2.15	**Alarm Annunciator.** A remote annunciator that is storage battery powered shall be provided to operate outside of the generating room in a location readily observed by operating personnel at a regular work station.	It makes sense that the same requirement would be required for all Microgrid sources and controllers.	Code will need to be developed to have requirements for similar sensors/alarms for Microgrid sources.
6.7.1.2.15.3	A remote common audible alarm shall be provided.	It makes sense that the same requirement would be required for all Microgrid sources and controllers.	Code will need to be developed to have requirements for similar audible alarm(s) for Microgrid sources.
6.7.1.2.14.1	**Internal combustion Engines.** Internal combustion engines serving generator sets shall be equipped with the following sensors/alarms : 1) Low water jacket temperature, High engine temps, low lubricating oil temperatures, Low water coolant level and Automatic engine shut down device for over crank, overspeed, low lubricating oil pressure, excessive engine temp.	Similar requirements related for parasitic loads would be required for Microgrid sources and controllers.	Code will need to be developed to have similar sensors/alarms/ controls for Microgrid sources.
6.7.1.2.15.4	For Level 1 EPS, at a minimum, local annunciation and facility remote annunciation, or local annunciation and network remote annunciation shall be provided.	Similar requirements related for parasitic loads would be required for Microgrid sources and controllers.	Code will need to be developed to have similar sensors/alarms/ controls for Microgrid sources.
6.7.1.3	**Battery.** Battery systems shall meet all requirements of NFPA 111.	This sentence seems to be out of place.	This could be clarified to state that Battery storage systems shall be permitted to serve as the alternate source for all or part of an essential electrical system provided that the meet all requirements of NFPA 111.

	CODE LANGUAGE	COMMENT	RECOMMENDATIONS
6.7.1.4	**Fuel Cell Systems.** Fuel cell systems shall be permitted to serve as the alternate source for all or part of an essential electrical system provided the condition of 6.7.1.4.1 through 6.7.1.4.6 apply	Along with 6.7.1 this allows that fuel cells and battery storage systems can be used for EES. The code does not list other green power sources such as wind power generators and/or Cogen facilities.	Add these sources to the code 6.7.1.5, 6.7.1.6…
6.7.1.4.1	Comply with NFPA 853		
6.7.1.4.2	N+1 Units provided	As written this would include a minimum of (2) fuel cells for all installations. Many fuel cells have redundancy built into them.	Investigation should be made to develop a definition of N+1 in regards to units with built-in redundancy.
6.7.1.4.3	Able to assume loads within 10 seconds	If fuel cell is utilized as source 24/7 will require a seamless transition from normal operation to emergency source.	
6.7.1.4.4	Systems shall have a continuing source of fuel supply, together with sufficient on-site fuel storage for the essential system type.	1) Acute care hospitals-72 hrs. 2) Correctional treatment centers that provide optional services-24 hrs. 3) Correctional treatment centers that provide only basic services-6 hrs. 4) Acute psychiatric hospitals- 6 hrs. 5) Intermediate care facilities-6 hrs. 6) Skilled nursing facilities- 6 hrs. 7) Ambulatory surgical clinics-4 hrs. 8) MOBs-90 mins	
6.7.1.4.5	Connection provisions for temp generator to back up life safety and critical branches	This code requirement partially mimics the requirements for temp hookups if a single generator on-site to allow back-up during maintenance. Why not temp hookup to supply life safety/critical and equipment branches?	Add provisions for temp generator to back up entire essential power system (Life Safety, Critical and Equipment branches) to accommodate for 10 yr. life expectancy of fuel cells.
6.7.1.4.6	Systems listed for emergency use.	Currently not available. Listing for Fuel Cells is IRGZ is required.	It is understood that this requirement will be dropped in next code update. This should be investigated further. Codes should be consistent for diesel generator sets and fuel cells if both could be used as EPS. Controllers should be UL listed for emergency use similar to ATS's.
6.7.2.2.2	**Coordination**		
6.7.2.2.2.1	Overcurrent protective devices serving the essential electrical system shall be coordinated for the period of time that a fault's duration extends beyond 0.1 second.	If Microgrid is used for EPS then these requirements would apply for all components of the Microgrid and distribution system.	
6.7.2.2.4	**Automatic Transfer Switch.** Transfer of all loads shall be accomplished using an automatic transfer switch(es)	ATS's required to be included in design.	
6.7.2.2.5	**Automatic Transfer Switch Features**		
6.7.2.2.5.1	**Source Monitoring**		
6.7.2.2.5.1(A)	Undervoltage-sensing devices shall be provided to monitor all ungrounded lines of the primary source of power as follows: (1) When the voltage on any phase falls below the minimum operating voltage of any load to be served, the transfer switch shall automatically initiate engine start and the process of transfer to the emergency power supply (EPS). (2) When the voltage on all phases of the primary source returns to within specified limits for a designated period of time, that process of transfer back to primary power shall be initiated.	Similar sensing would be required for all microgrid power sources. Does not appear to take microgrid into account. This requirement is not consistent with the concept of using the microgrid 24/7 and or for peak shaving and as EPS.	 Could be rewritten to address seamless transfer to microgrid source. Could be rewritten to address full time operation of microgrid and seamless transfer of essential loads to microgrid.

	CODE LANGUAGE	COMMENT	RECOMMENDATIONS
6.7.2.2.5.2	**Interlocking.** Mechanical interlocking or an approved alternate method shall prevent the inadvertent inter-connection of the primary power supply and the EPS…	This requirement is not consistent with the concept of using the microgrid 24/7 and or for peak shaving and as EPS.	Could be rewritten to address full time operation of microgrid and seamless transfer of essential loads to microgrid.
6.7.2.2.5.10	**Test Switch.** A test means shall be provided on each automatic transfer switch (ATS) that simulates failure of the primary power source and then transfers the load to the (EPS)	This requirement is not consistent with the concept of using the microgrid 24/7 and or for peak shaving and as EPS.	Could be rewritten to address full time operation of microgrid and seamless transfer of essential loads to microgrid.
6.7.2.3	**Branches.**		
6.7.2.3.1	The division between the branches shall occur at transfer switches where more than one transfer switch is required	Transferee switches required to be included in design.	
6.7.2.3.4	**Feeders from Alternate Source**		
6.7.2.3.4.1	A single feeder supplied by a local or remote alternate source shall be permitted to supply the essential electrical system to the point at which the life safety, critical, and equipment branches are separated.	If the microgrid is used as EPS, this requirement would seem to suggest a single distribution board with feeds from multiple green technology sources that in turn feeds all ATS's	
6.7.3	**Performance Criteria and Testing.**		
6.7.3.1	**Transfer Switches.** All ac-powered support and accessory equipment necessary to the operation of the EPS shall be supplied from the load side of the automatic transfer switch(es) or the output terminals of the EPS, ahead of the main EPS overcurrent protection to ensure continuity of the EPSS operation and performance.	Would apply for all microgrid sources.	
6.7.3.2	The essential electrical system shall be served by the normal power source, except when the normal power source is interrupted or drops below a predetermined voltage level.	This seems to be in conflict the concept of a microgrid that runs 24/7 and also is the onsite EPS source.	It would appear that some revisions to the current code would be required.
6.7.3.3	Failure of the normal source shall automatically start the alternate source generator after a short delay… the load shall be connected automatically to the alternate power source.	This seems to be in conflict the concept of a microgrid that runs 24/7 and also is the onsite EPS source.	It would appear that some revisions to the current code would be required.
6.7.3.4	Upon connection of the alternate power source, the loads comprising the life safety and critical branches shall be automatically re-energized... the equipment system shall be connected either automatically or after a time delay... In a sequential manner as not to overload the generator.		Appears to be addressed in code appropriately.
6.7.3.5	When the normal power is restored… connect the loads to the normal power source.	This seems to be in conflict the concept of a microgrid that runs 24/7 and also is the on-site EPS source	It would appear that some revisions to the current code would be required.
6.7.5	**Type 1 Essential Electrical System Requirements**		
6.7.5.1	**Branches**		
6.7.5.1.2	**Life Safety Branch**		
6.7.5.1.2.4	The life Safety branch shall supply power as follows:		
6.7.5.1.2.4(4)	Generator set locations as follows: a) Task Illumination b) Battery charger for emergency battery-powered lighting unit(s) c)Select receptacles at the generator set location and essential electrical system transfer switch locations.	Would apply to microgrid if EPS.	It would appear that some revisions to the current code to align with microgrid technology would be required.
6.7.5.1.2.5	Alarm and alerting systems (other than fire alarm) shall be connected to life safety or critical branch	Would apply to microgrid if EPS.	Appears to be addressed in code appropriately.
6.7.5.1.2.6	Loads dedicated to a specific generator Including fuel pump(s), ventilation fans, controls etc..	Would apply to microgrid if EPS.	It would appear that some revisions to the current code to align with microgrid technology would be required.

Appendix C NFPA 99 Matrix

2016 NFPA 110

	CODE LANGUAGE	COMMENT	RECOMMENDATIONS
	This standard contains requirements covering the performance of emergency and standby power systems providing an alternate source of electrical power to loads in buildings and facilities in the event that the primary power source fails.	1) The terms "generator sets, or battery systems" is confusing. Does generator set just mean com-bustion engine/electric generator sets? 2)The CEC limits the Alternate Power Source to on-site power sources with on-site fuel storage.	Definition for "generator sets" should be added which could include: electromechanical (combustion and fusion machines), wind, electrochemical (battery systems) photo voltaics Consideration for wind and geothermal sources?
3.2.3	**Labeled.** Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.		
3.2.4	**Listed.** Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.	UL IRGZ - Standard for Fuel Cells, UL 6200 - Standard for Power Controllers, UL 9540 - Standard for Energy Storage Systems, UL 1989 - Standard for Standby Batteries, UL 1741 - UL Standard for Grid Interactive Smart Inverters, UL 6200 - Power Production Controllers.	
3.3.3	**Emergency Power Supply (EPS).** The source of electric power of the required capacity and quality for an emergency power supply system (EPSS).	Microgrid is used in other codes, but not here.	Microgrid should be added to definitions and main body of text to list as an acceptable EPS.
3.3.4	**Emergency Power Supply System (EPSS).** A complete functioning EPS system coupled to a system of conductors, disconnecting means and overcurrent protective devices, transfer switches, and all control, supervisory, and support devices up to and including the load terminals of the transfer equipment needed for the system to operate as a safe and reliable source of electric power.		
Chapter 4	**Classification of Emergency Power Supply Systems (EPSS)**		
4.1	**General.** The EPSS shall provide a source of electrical power of required capacity, reliability, and quality to loads for a length of time as specified in Table 4.1(a) and within a specified time following loss or failure of the normal power supply …	Microgrid is used in other codes, but not here.	Microgrid should be added to definitions and main body of text to list as an acceptable EPS.
4.2	**Class.** The class defines the minimum time, in hours, for which the EPSS is designed to operate at its rated load without being refueled or recharged. [See Table 4.1(a).]	1) Acute care hospitals-72 hrs. 2) Correctional treatment centers that provide optional services-24 hrs. 3) Correctional treatment centers that provide only basic services-6 hrs. 4) Acute psychiatric hospitals- 6 hrs. 5) Intermediate care facilities-6 hrs. 6) Skilled nursing facilities- 6 hrs. 7) Ambulatory surgical clinics-4 hrs. 8) MOBs-90 mins	
4.3	**Type.** The type defines the maximum time, in seconds, that the EPSS will permit the load terminals of the transfer switch to be without acceptable electrical power. Table 4.1(b) provides the types defined by this standard.	1) Within 10 sec for life safety and critical branches. 2) Delayed auto-matic connections for equipment branch	
4.4	**Level.** This standard recognizes 2 levels of equipment installation, performance and maintenance.		
4.4.1	Level 1 systems shall be installed where failure of the equipment to perform could result in loss of human life or serious injuries.	Hospitals, SNF's with subacute patients and surgery centers.	
4.4.2	Level 2 systems shall be installed where failure of the EPSS to perform is less critical to human life and safety.	SNF's without subacute patients and MOB's	

	CODE LANGUAGE	COMMENT	RECOMMENDATIONS
4.4.3	All equipment shall be permanently installed.	Would apply to all microgrid sources	
Chapter 5	**Emergency Power Supply (EPS): Energy Sources, Converters, and Accessories**		
5.1	**Energy Sources**		
5.1.1	The following energy sources shall be permitted to be used for the emergency power supply (EPS): (1) Liquid petroleum products at atmospheric pressure as specified in the appropriate ASTM standards and as recommended by the engine manufacturer (2) Liquefied petroleum gas (liquid or vapor withdrawal) as specified in the appropriate ASTM standards and as recommended by the engine manufacturer (3) Natural or synthetic gas Exception: For Level 1 installations in locations where the probability of interruption of off-site fuel supplies is high, on-site storage of an alternate energy source sufficient to allow full output of the EPSS to be delivered for the class specified shall be required, with the provision for automatic transfer from the primary energy source to the alternate energy source.	This requirement allows on-site diesel generators and fuel cells for EPS's	Modifications to code should be made to allow Microgrids as emergency source with all forms of on-site power generation: electro-mechanical (combustion and fusion machines), wind, electro-chemical (battery systems) photo voltaics Consideration for wind and geothermal sources? Add to article 700 as well. Note this would need to be separate from normal service.
5.1.2	The energy sources listed in 5.1.1 shall be permitted to be used for the EPS where the primary source of power is by means of on-site energy conversion, provided that there is separately dedicated energy conversion equipment on-site with a capacity equal to the power needs of the EPSS.	The CEC limits the Alternate Power Source to on-site power sources with on- site fuel storage.	
5.1.3	A public electric utility that has a demonstrated reliability shall be permitted to be used as the EPS where the primary source is by means of on-site energy conversion.	The CEC limits the Alternate Power Source to on-site power sources with on- site fuel storage.	
5.2	**Energy Converters - General**		
5.2.1	Energy converters shall consist only of rotating equipment as indicated in 5.2.4	(1) Otto cycle (spark ignited) (2) Diesel cycle (3) Gas turbine cycle	Modifications should be made to allow Microgrids as emergency source with multiple forms of acceptable on-site power generation: electromechanical (combustion and fusion machines), water, wind, electro-chemical (battery systems) photo voltaics and geothermal sources be added to this requirement.
5.2.1.1	Level 1 energy converters shall be representative products built from components that have proven compatibility and reliability and are coordinated to operate as a unit.		
5.2.1.2	The capability of the energy converter, with its controls and accessories, to survive without damage from common and abnormal disturbances in actual load circuits shall be demonstrable by tests on separate prototype models, or by acceptable tests on the system components as performed by the component suppliers, or by tests performed in the listing process for the assembly.	Seismic Certifications and Restraint required.	
5.2.4.1	Other types of prime movers and their associated equipment meeting the applicable performance requirements of this standard shall be permitted, if acceptable to the authority having jurisdiction.	There is some mixed messages here, because many of the performance requirements are specific to diesel generator sets.	Other power sources should be identified such as: electromechanical (combustion and fusion machines), water, wind, electrochemical (battery systems) photo voltaics and geothermal sources be added to this requirement.
5.5.2	A low-fuel sensing switch shall be provided for the main fuel supply tank(s) using the energy sources listed in 5.1.1(1) and 5.1.1(2) to indicate when less than the minimum fuel necessary for full load running, as required by the specified class in Table 4.1(a), remains in the main fuel tank.	For a microgrids this could eventually be developed to a multifaceted calculation that would account for periods of run time for one or more sources.	Code could be developed to identify means and methods for determining minimum require-ments for Microgrid to meet 72 hr. of on-site fuel storage for actual essential loads, and testing commissioning requirements. Note calculations could include contributions from multiple power sources with varying durations.

	CODE LANGUAGE	COMMENT	RECOMMENDATIONS
5.5.3	The main fuel tank shall have a minimum capacity of at least 133 percent of either the low-fuel sensor quantity specified in 5.5.2 or the quantity required to support the duration of run specific in table 4.1.(a)		
5.6	**Rotating Equipment.**	It appears that other types of microgrid power producers should be added into this standard and/or new standards developed or reference made to other related standards such as NFPA 111 - Stored Electrical Energy Emergency and Standby Power Systems	Other power sources should be identified such as: electromechanical (combustion and fusion machines), water, wind, electrochemical (battery systems) photo voltaics and geothermal sources be added to this requirement.
5.6.1	**General.** Prime movers and accessories shall comply with NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines, except as modified in this standard.		
Chapter 6	**Transfer Switch Equipment**		
6.1.6	Where available, each switch shall be listed for emergency service as a completely factory- assembled and factory tested apparatus.	Should other components of the EPSS be listed for emergency service?	Microgrid controllers should be listed for emergency service to ensure reliability of system.
6.2.11	**Engine Generator Exercising Timer.** A program timing device shall be provided to exercise the EPS as described in Chapter 8. 6.2.11.1 Transfer switches shall transfer the connected load to the EPS and immediately return to primary power automatically in case of an EPS failure.	It would appear that this feature to controls would need to be customized for microgrids. (might want to run microgrid 24/7 with seamless transfer to emergency mode if normal power is lost).	
6.2.11.1	Transfer switches shall transfer the connected load to the EPS and immediately return to primary power automatically in case of an EPS failure.	It would appear that this feature to controls would need to be customized for microgrids. (might want to run microgrid 24/7 with seamless transfer to emergency mode if normal power is lost).	
6.3	**Load Switching (Load Shedding).** When two or more engine generator sets are paralleled for emergency power, the paralleled system shall be arranged to inhibit connection of EPS-damaging loads.	It would appear that this feature to controls would need to be customized for microgrids. (might want to run microgrid 24/7 with seamless transfer to emergency mode if normal power is lost).	
6.3.3	The transfer of loads to the EPS shall be sequenced as follows: (1) First-priority loads shall be switched to the emergency bus upon sensing the availability of emergency power on the bus. (2) Each time an additional engine generator set is connected to the bus, a remaining load shall be connected in order of priority until all emergency loads are connected to the bus. (3) The system shall be designed so that, upon failure of one or more engine generator sets, the load is automatically reduced, starting with the load of least priority and proceeding in ascending priority, so that the last load	It would appear that this feature to controls would need to be customized for microgrids. (might want to run microgrid 24/7 with seamless transfer to emergency mode if normal power is lost).	
7.1.5	When the normal power source is not available, the EPS shall be permitted to serve optional loads other than system loads, provided that the EPS has adequate capacity or automatic selective load pickup and load shedding are provided as needed to ensure adequate power to (1) the Level 1 loads, (2) the Level 2 loads, and (3) the optional loads, in that order of priority. When normal power is available, the EPS shall be permitted to be used for other purposes such as peak load shaving, internal voltage control, load relief for the utility providing normal power, or cogeneration.	It would appear that this feature to controls would need to be customized for microgrids. (might want to run microgrid 24/7 with seamless transfer to emergency mode if normal power is lost).	
7.2	**Location**		
7.2.1	**Indoor EPS Installations.** The EPS shall be installed in a separate room for Level 1 Installations	If the microgrid is used as EPS, this requirement would apply for all power sources and main distribution board.	
7.2.2	**Outdoor EPS Installations.**		

	CODE LANGUAGE	COMMENT	RECOMMENDATIONS
7.2.2.1	The EPS shall be installed in a suitable enclosure located outside the building and capable of resisting the entrance of snow or rain at max wind velocities.	Will require Seismic Certification/ Restraint, Listed Product and 72 hrs. of fuel storage on-site.	
7.2.4	The rooms, enclosures, or separate buildings housing level 1 or Level 2 EPSS equipment shall be designed and located to minimize damage from flooding, including that caused by the following: 1) Fire fighting, 2) Sewer water backup, 3) Other disasters or occurrences	If the microgrid is used as EPS, this requirement would apply for all power sources and main distribution board. (required to be located above the 100 yr. flood plain.	
7.3	**Lighting**		
7.3.1	The Level 1 or 2 EPS equipment locations(s) shall be provided with battery-powered emergency lighting. This requirement shall not apply to units located outdoors in enclosures that do not include walk-in access.	Would apply for microgrid (if used for EPS) for lighting and all parasitic loads associated with the on-site power sources.	
7.9	**Fuel System**		
7.9.1	Fuel tanks shall be sized to accommodate the specific EPS class.	1) Acute care hospitals-72 hrs. 2) Correctional treatment centers that provide optional services-24 hrs. 3) Correctional treatment centers that provide only basic services-6 hrs. 4) Acute psychiatric hospitals- 6 hrs. 5) Intermediate care facilities-6 hrs. 6) Skilled nursing facilities- 6 hrs. 7) Ambulatory surgical clinics-4 hrs. 8) MOBs-90 mins	This term could be changed to a more generic term to include fuel for either one or multiple sources of power for the microgrid electromechanical (combustion and fusion machines), water, wind, electrochemical (battery systems) photo voltaics and geothermal sources
7.11.5	In recognized seismic risk areas, EPS and EPSS components, such as electrical distribution lines, water distribution lines, fuel distribution lines, and other components that serve the EPS, shall be designed to minimize damage from earth- quakes and to facilitate repairs if an earthquake occurs. 7.11.6	The same requirement would be required for all Microgrid sources and controllers.	Code will need to be developed to have requirements for similar sensors/alarms for Microgrid sources.
7.11.5	For systems in seismic risk areas, the EPS, transfer switches, distribution panels, circuit breakers, and associated controls shall be capable of performing their intended function during and after being subjected to the anticipated seismic shock.		
7.11.6	A remote common audible alarm shall be provided.	The same requirement would be required for all Microgrid sources and controllers	Code will need to be developed to have requirements for similar audible alarm(s) for Microgrid sources.
7.12.5	All ac-powered support and accessory equipment necessary to the operation of the EPS shall be supplied from the load side of the ATSs, or the output terminals of the EPS, ahead of the main EPS overcurrent protection to ensure continuity of the EPSS operation and performance.		
7.13.4.1.3	When the EPSS consists of paralleled EPSs, the system control function for paralleling and load shedding shall be verified in accordance with system design documentation. 7.13.4.1.4 The tests conducted in accordance with 7.13.4.1.1 and 7.13.4.1.2 shall be performed in accordance with (1) through (12). (1) When the EPSS consists of paralleled EPSs, the quantity of EPSs intended to be operated simultaneously shall be tested simultaneously with building load ...	The same requirement would be required for all Microgrid sources and controllers.	Code will need to be developed to have requirements for testing, appropriate for microgrid functions.
7.13.4.1.4	The tests conducted in accordance with 7.13.4.1.1 and 7.13.4.1.2 shall be performed in accordance with (1) through (12). (1) When the EPSS consists of paralleled EPSs, the quantity of EPSs intended to be operated simultaneously shall be tested simultaneously with building load ...	The same requirement would be required for all Microgrid sources and controllers	Code will need to be developed to have requirements for testing, appropriate for microgrid functions.

	CODE LANGUAGE	COMMENT	RECOMMENDATIONS
Chapter 8	**Routine Maintenance and Operational Testing**		
8.1	**General.**	This sentence seems to be out of place.	This could be clarified to state that Battery storage systems shall be permitted to serve as the alternate source for all or part of an essential electrical system provided that the meet all requirements of NFPA 111.
8.1.1	The routine maintenance and operational testing program shall be based on all of the following: (1) Manufacturer's recommendations (2) Instruction manuals (3) Minimum requirements of this chapter (4) The authority having jurisdiction 8.1.2 Consideration shall be given to temporarily providing a portable or alternate source whenever the emergency genera- tor is out of service and the criteria set forth in Section 4.3 cannot be met. 8.2* Manuals, Special Tools, and Spare Parts. 8.2.1 At least two sets of instruction manuals for all major	Along with 6.7.1 this allows that fuel cells and battery storage systems can be used for EES. The code does not list other green power sources such as wind power generators and/or Cogen facilities.	Green power generators should be added to code such as: electromechanical (combustion and fusion machines), water, wind, electrochemical (battery systems) photo voltaics and geothermal sources
8.1.2	Consideration shall be given to temporarily providing a portable or alternate source whenever the emergency generator is out of service and the criteria set forth in Section 4.3 cannot be met.	This code requirement partially mimics the requirements for temp hookups if a single generator on-site to allow back-up during maintenance. Why not to supply life safety/critical and equipment branches	Should code be modified to require portable connections for code mandated life safety, critical and equipment loads if microgrid is utilized as EPSS.