DOE | MARKET RESEARCH STUDY BATTERY STORAGE

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1.0 Introduction

In recent years, power outages, driven primarily by extreme weather events, have increased markedly, exceeding 8 hours of interruption in 2020 and 7 hours in 2021.[1] Some data indicate that these outages disproportionately affect historically overburdened and underserved communities. For example, during a 2021 winter storm in Texas, low-income areas experienced more pipes bursting and made more calls for help per person than other areas.[2] In the coming years, more people are expected to become dependent on electricity for home dialysis or oxygen concentrators, and this group appears to be disproportionately lower-income.[3]

The impact of power outages on all business sectors can be severe.[4] Uptime's 8th annual Data Center Survey found that 31% of the 900 respondents experienced downtime in 2018.[5] Using an Activity-Based Cost Account Framework, the estimated cost of a U.S. data center outage in 2016 was $8,851 per minute.[6] This figure does not include the cost consequences for others. Supermarkets when impacted may have to dispose of tens of thousands of dollars worth of produce,[7] while hospitals may need to shut down completely. Measures that are sometimes taken in the face of out-of-control fires also have an impact on cellphone towers which are needed for vital communications. In 2019 when California shut-off power in order to reduce the risk of fire, it cut the power to many cellphone towers. "In Sonoma County, where a major fire led to the evacuation of 180,000 residents over the weekend, one quarter of the 436 cellphone towers were not functioning, the F.C.C. said."[8] According to an FCC report, in Marin County 49.6% of its cell sites were out of service during this same period.[9]

Many, but not all cell phone towers use generators or batteries to assure continued functionality.[10] During the fire in California in 2019, the cell phone providers commented on their back-up plans.

> "AT&T said all of its cell sites in California had some form of backup power. Verizon said most of its towers were equipped with batteries and generators. T-Mobile said it had built-in generators in its most critical sites, while others had batteries. Sprint said that some of its cell sites had built-in generators, and that it was deploying portable generators for others as quickly as possible."[11]

Extreme weather - manifest as cold spells, heat waves, hurricanes and/or floods results in more blackouts and makes life more tenuous for those who cannot afford back-up power. According to the Energy Information Administration, the U.S. electric utility customer lost power for nearly eight hours in 2021, more than twice as long as in 2013, when such data first became available.[12] These numbers are averages, and the range can be far greater. For example, the ice storms in Texas in February 2023, left hundreds of thousands of people without power for up to six days[13]. Flooding affects not only large cities, but also U.S. military installations in ways not previously imagined. "By 2050, sites such as the Naval Station Norfolk, the largest naval installation in the world, and the Kennedy Space Center in Merritt Island, Florida, where 12,000 employees work, are likely to face one major flood a year and minor floods every week, the projections show.[14]

Backup power to help the United States address the impact of weather on the ability of the U.S. citizenry to communicate, to keep families healthy and protected are required. This report explores the need for battery energy storage in three different sectors which require uninterrupted power supplies: (1) data centers and communication; (2) healthcare and (3) national defense. In each instance the intent is to provide a benchmark and begin the exploration of those factors that appear to facilitate adoption of long duration energy storage (LDES) as a replacement for generators, which are most commonly used for back-up power. Also explored is the type of investments being made in battery storage technologies by the private sector and utilities.

Data Centers & Communication

2.0 Energy Storage for Data Centers

A data center is defined as "[…] a physical room, building or facility that houses IT infrastructure for building, running, and delivering applications and services, and for storing and managing the data associated with those applications and services."[15] One (1%) to 1.5% of electricity used in the world is used by data centers[16] while in the U.S., data centers are responsible for 2% of total electricity use.[17]

Microsoft is planning on implementing the use of hydrogen powered back-up generators in all of its data centers in 2030 and has already tested this technology at one data center.

An example of one of these data centers is the Microsoft data center located in Quincy, Washington. Presently, 19,000 battery cells work in tandem with over 140 electric diesel fuel generators as backup power, if needed. In ten years, the plan is to replace these generators with either hydrogen powered generators or other advanced fuel cells. A number of European data centers such as NorthC began using hydrogen-powered back-up generators in 2022.[18, 19, 20, 21]

Figure 1: "Microsoft Reveals its Massive Data Center (Full Tour)"

Source: Click link to access video[22]

Generally, data center backup power has been provided by batteries, an uninterrupted power supply (UPS) system, and a diesel generator. That said, the aging electric grid and energy transition could spur the need for different backup power solutions in data centers.[23, 24] According to Uptime Institute's global survey of data center managers, 44% of outages at data centers were caused by power outages from the electric grid.[25]

2.1 Hydrogen Technology for Backup Power in Telecom and Data Centers

Hydrogen technologies are emerging as possible replacements for standard generators in data centers.[26] Hydrogen fuel cells have been an option for emergency backup power in telecommunications for a number of years.[27, 28] Fuel cells were identified for use in emergency backup power as a near-term market by the National Renewable Energy Laboratory (NREL) in 2007.[29] In 2009, NREL indicated that fuel cell backup power was used by some telecommunication sites.[30] A 2015 report published by NREL provides information on how hydrogen fuel cell backup power was operating in the U.S. after the deployment of fuel cell units (852 backup power units) primarily for telecommunications towers. These units were deployed in order to catalyze the "commercialization of early market technology." The data in this report contains operational data from 136 of the units.[31]

A 2021 paper, "Hydrogen-Based Energy Storage Systems for Large-Scale Data Center Applications," published by a team at the DOE explores "the current state of data centers and hydrogen-based technologies" as well as "a discussion of the hydrogen storage and infrastructure requirements needed for large-scale backup power applications at data centers." The paper indicates a restored interest for the use of hydrogen technology for "stationary applications," but the performance and cost of these technologies is important when considering them as replacements. In this vein, the DOE's Energy Earthshot Initiative is working toward reducing the cost of hydrogen production.[32]

2.2. Number of Global Data Centers

In May 2021, an Executive Briefing document prepared by the United States International Trade Commission noted the existence of 8,000 data centers across the world. At that time, 33% of these data centers were located in the U.S.[33] The information on the actual number of data centers by country varies widely. Statista for example, indicates that there are 5,375 data centers in the U.S.,[34] but most other 2023 publications indicate the following numbers of data centers for the top 15 countries world-wide.[35]

United States	2,701
Germany	487
United Kingdom	456
China	443
Canada	328
Australia	287
Netherlands	281
France	265
Japan	207
Russia	172
Mexico	153
Brazil	150
India	138
Poland	136
Italy	131

The following figure illustrates the projected U.S. growth of data center power consumption up to 2030 by enterprises and providers (co-location companies, enterprises, and hyperscalers). **Co-location companies** are "shared data centers"[36] while "**Hyperscalers** are large cloud service providers, that can provide services such as computing and storage at enterprise scale. While there is no universal standard for what should be classified as a hyperscaler, major cloud providers such as **Amazon Web Services, Google Cloud, Microsoft Azure, IBM Cloud and Alibaba Cloud fit the description**."[37]

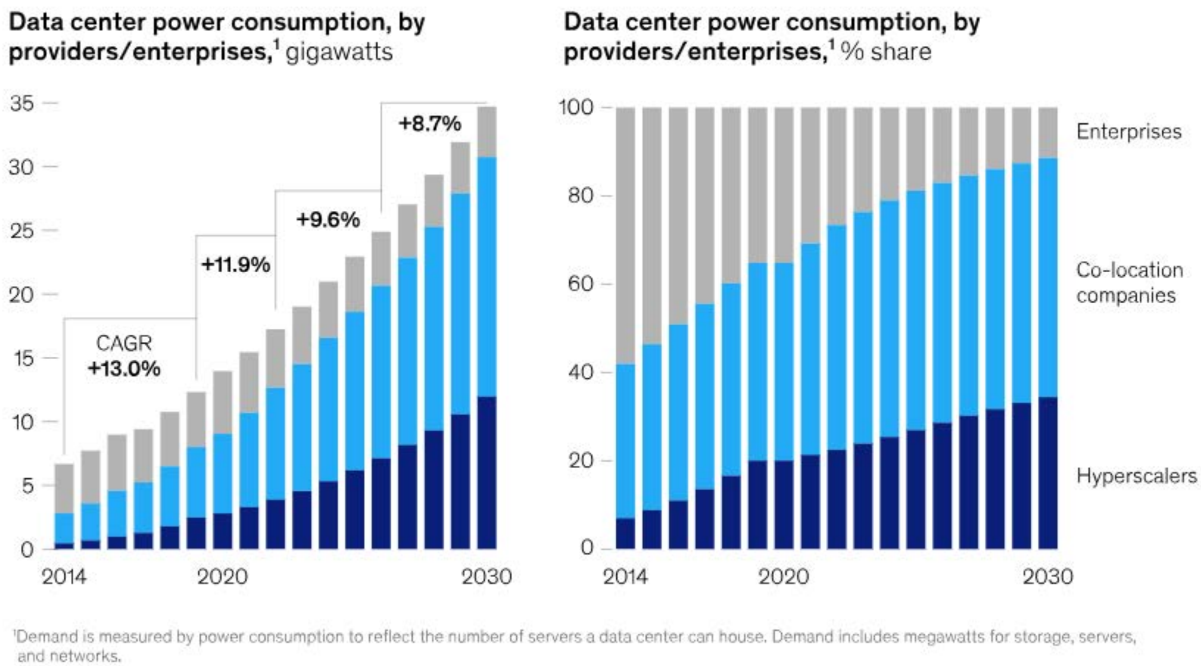


Figure 2: "US Data Center Demand is Forecast to Grow by some 10 Percent a Year Until 2030"
Source: McKinsey & Company[38]

2.3 Energy Storage Market for Data Centers

A 2020 Department of Energy (DOE) report forecasts the growing use of stationary energy storage solutions for industrial applications (which includes data centers). An 8% compound annual growth rate by 2030 was predicted for this application. The following table represents the forecast for the industrial application in GWhs (gigawatt hours). The Uninterrupted Power Supply (UPS) and Data Center segment are forecast to grow at a compound annual growth rate of 4%. Motive energy storage refers to batteries used for electric material handling and ground handling equipment. **This report also indicated an ongoing transition from lead-acid to lithium-ion batteries for data center energy storage technology.[39]**

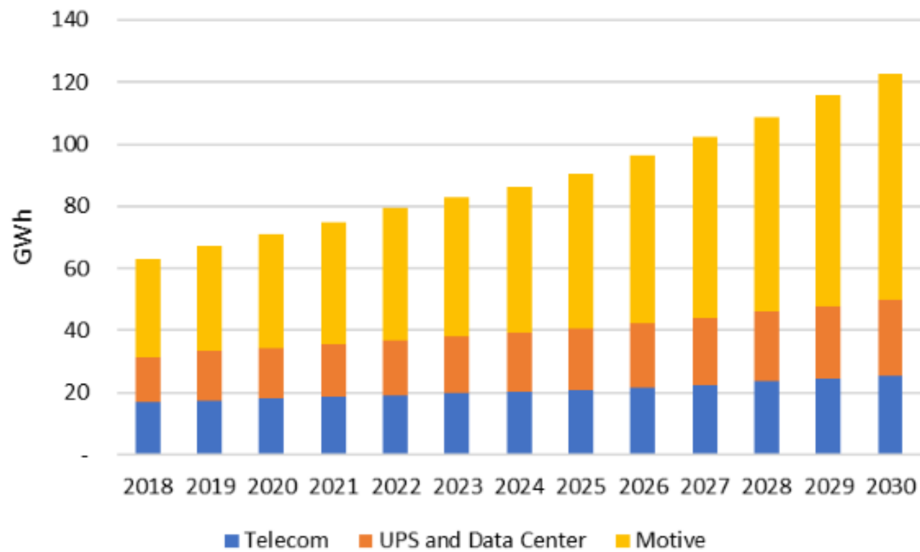


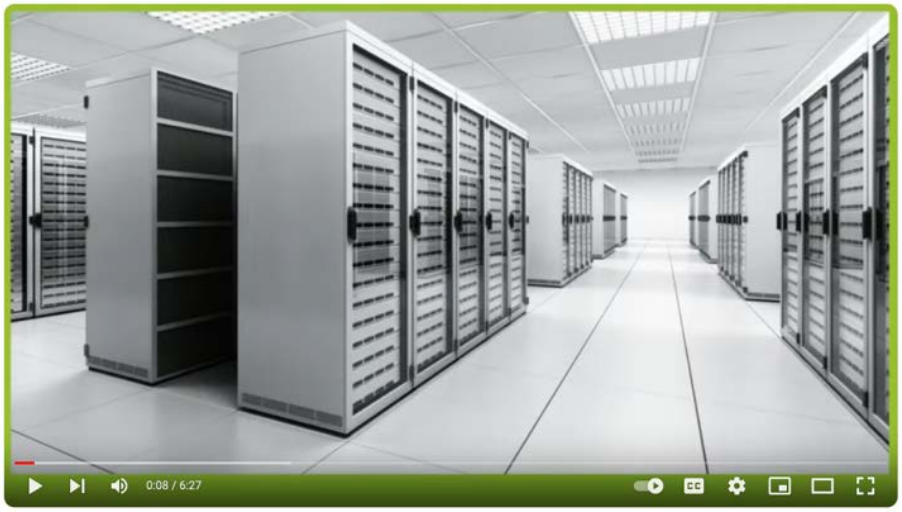
Figure 3: "Projected Global Industrial Energy Storage Deployments by Application"
Source: Department of Energy[40]

2.4 Power for Data Centers

Redundancy is vital for data centers. Therefore most use both battery systems and generators.

Data centers are not only vital for all data shared on the internet, but are at the heart of business in the U.S. Therefore, data centers must be online and available uninterruptedly with next to zero downtime. As noted previously, data centers use a huge amount of power for numerous functions including power for the servers, cooling for the electronics, monitoring equipment, lighting and security. "Data centers rely on the city's electrical grid for their power needs, but many data centers also have their systems for redundancy. So, if the city's electrical grid were to have an issue, the data center won't be affected. A backup battery system is vital for data center storage and power. Most data centers use two forms of backup power which include a battery system and generators that are powered by diesel."[41]

Data centers tend to use a valve-regulated lead-acid cell battery to power the uninterrupted power supply (UPS). These systems need to be replaced every 3-10 years.[42] These systems are readily available and reasonably priced, however lead-acid battery systems take up a lot of room and the cost of floor space in a data center is always a concern.[43] The lead acid batteries also need to be kept at around 20 degrees for optimal efficiency which increases the costs associated with air conditioning for the data center.[44] The following video provides an overview of the power chain in a typical data center, including an explanation of **uninterrupted power supply (UPS) systems**. These systems can be flywheel or battery systems and store energy for the time between an outage and when the generators begin operating, with a battery system providing a bit more time than a flywheel system.[45]



Click link to access video

Figure 4: "Data Center Power Chain – Animation"

Source: YouTube[46]

Due to concerns regarding the space required by lead batteries, the low temperature that must be maintained for optimal performance, as well as the frequency with which lead batteries need to be replaced, there has been a gradual shift to the use of lithium ion batteries, as a replacement. According to market analyst Frost and Sullivan, li-ion batteries accounted for 15 percent of the data center battery market in 2020 and is expected to grow to 39% by 2025.[47] Li – ion has a smaller footprint, has a longer life-cycle and requires less maintenance. However, the potential of fire when using lithium-ion battery remains a concern.

"While the rate of individual li-ion cell failures is typically quoted as rates of "1 in 1 million" to "1 in 10 million," data centers have become so large that one data center may contain millions of li-ion cells. Fire safety standards, building codes, and the safety of li-ion batteries are improving, but fire department responses to data center battery incidents are likely to increase in frequency until the hazards can be engineered out."[48] The Chief Technical Officer at Uptime suggests that data centers consideringthe use of lithium ion batteries should look at segregating them into their own battery room complete with fire rated walls and ceilings and installing a foam fire-suppression system.[49]

2.4.1. Data Center Outages

The number of data centers experiencing outages is an ongoing problem. According to Uptime Institute, during the last three years, "The single biggest cause of a power outage, by some distance, is a UPS failure (a grid failure is considered to be a backup or lower-cost power source, not a primary power source)."[50] Generator and transfer switch failures were experienced by just over a quarter of operators. Outages can also stem from human error, IT system glitches, and network failures.[51] Table 1 shows the results of the survey (n=393) conducted by Uptime Institute in 2023 regarding the causes of outages. Twenty-nine percent of the sample indicated that they had experienced a major power outage; while 65% indicated that they had not, and the balance (7%) didn't know.

Table 1: Causes of Major Power-related Outages (Uptime Institute, 2023)

Cause	Percentage
UPS failure	40%
Transfer switch (e.g., utility failure)	27%
Generator failure	27%
Controls failure	19%
Transfer switch between paths (A/B) failure	17%
Single-corded IT device(s) failure	15%
Power distribution unit failure	14%

With respect to major network-related outages caused by network/connectivity issues, 44% (N=174) of those interviewed (N=406) indicated the most common causes.

Table 2: Common Causes of Major Network-Related Outages (Uptime Institute, 2023)

Cause	Percentage
Configuration/change management failure	45%
Third-party network provider failure	39%
Hardware failure	37%
Line breakages	27%
Firmware/software error	23%
Cyberattack	14%
Network/congestion failure	12%
Weather-related incident	7%
Corrupted firewall/routing tables issues	6%

For more details regarding this study, please see the **Annual Outage Analyses 2023** by Uptime Intelligence.

Regulations are becoming more stringent for operators, with an increasing demand to use less energy.[52] Findings from Uptime Institute's 2022 Global Data Center Survey found:

> "Outages are becoming more expensive and are still far too frequent **–** The share of all outages costing operators over $1 million has reached 25%, a significant increase from 15% in 2021. In 2022, 60% of operators reported experiencing an outage (regardless of severity) in the past three years — down from 69% in 2021 and 78% in 2020. Although the data indicates a trend toward improved outage rates, the frequency of outages is still much too high and with more than two-thirds now costing operators upwards of $100,000, the consequences are getting worse."[53]

Uptime Institute's 2023 survey of the same name did report the "lowest number yet recorded" for operator reported outages: 55% of operators had an outage in the last three years which indicates a consistent advancement toward fewer outages.[54] Additional data identifies fire as the cause of 7% of outages in data centers while another 29% was from a variety of "connectivity problems", such as "issues with fiber, network software, and configuration."[55]

3.0 Telecommunications Power Plants

Adequate backup power is essential due to disruptions from natural and man-made factors like extreme weather and power shortages. As the industry expands, the increased use of cell phones, computers, and high-speed Internet necessitates an increase in towers and facilities. Backup power sources to ensure service reliability remains at the forefront for providers as the industry expands. Providers use redundancy and backup power sources to prevent power outages. When a tower or facility loses power, a backup power source must assume site load. Most telecommunications facilities have an eight-hour backup, but hurricane-prone areas require 24-72-hour backup capability. In 2020, as a response to the 2019 Californian wildfires, the California Public Utilities Commission (CPUC) mandated that wireless companies develop comprehensive resiliency plans and adopt a 72-hour backup power requirement to ensure that a minimum level of service and coverage is maintained during disasters or power outages.[56]

3.1 Telecommunications and Electric Power

There is a critical interdependence between the telecommunications and electric power sectors. Telecommunications networks depend on the availability of electric power. Both sectors can be severely impacted after a hurricane (see Figure 5 from GAO below). Generators can supply temporary power to damaged wireless towers, but they must be refueled.[57]

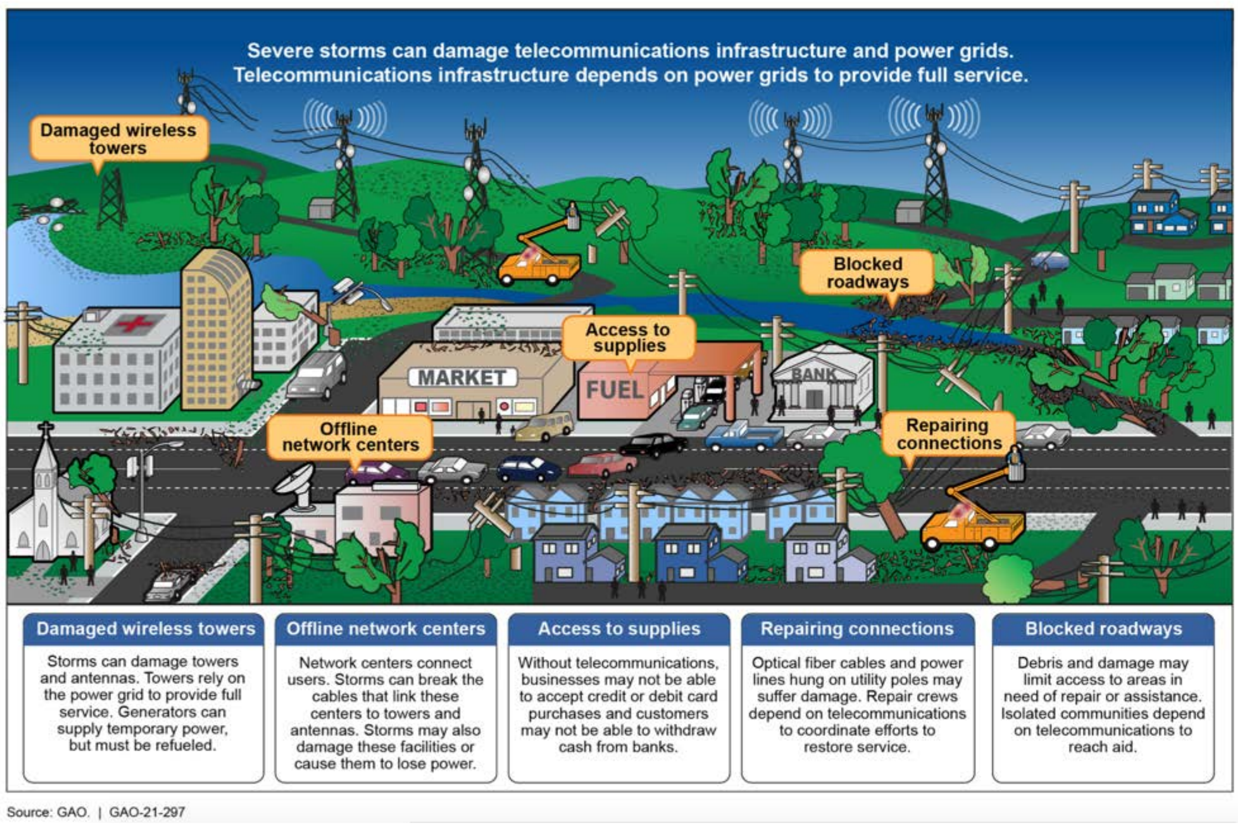


Figure 5: Interdependence Between Telecommunications and Electric Power Sectors

3.2 Data Centers and Telecom Plants

During a 2020 Capitol Hill briefing on batteries and energy storage, the director of network infrastructure systems for Ericsson, Richard Kluge, discussed data center UPS and telecom dc plants. According to Kluge, who spoke as an industry expert, both data center UPS and telecom dc plants are considered "standby power," where the batteries are used only when commercial power is lost, while energy storage systems (ESS) are used for cyclic applications that could put more stress on the system.[58] Kluge also provided comparisons between telecommunication plants and data centers.

> "Kluge explained how every city has several telecommunications plants. For example, in a large city like New York, there are about 20. Think of them as an older sort-of data center, constructed like a bunker. It's windowless and virtually indestructible and houses a labyrinth of wires, fiber optics, switching equipment, transmission equipment and batteries that support the millions of phone lines across the country.
>
> 'A telecom is a unique occupancy. It shares some similarities with data centers, but it's a little bit different.'
>
> For example, large telecom offices and cell sites with dedicated generators have three to four hours of battery reserve time. A large telecom office may have over 400 cells and 8,000 gallons of electrolyte. A smaller telecom facility without generators may have eight hours of battery reserve time.
>
> In contrast, a data center has an uninterruptible power supply (or UPS) that is typically much lower, with 10 to 20 minutes to allow a generator to start or a safe shutdown."[59]

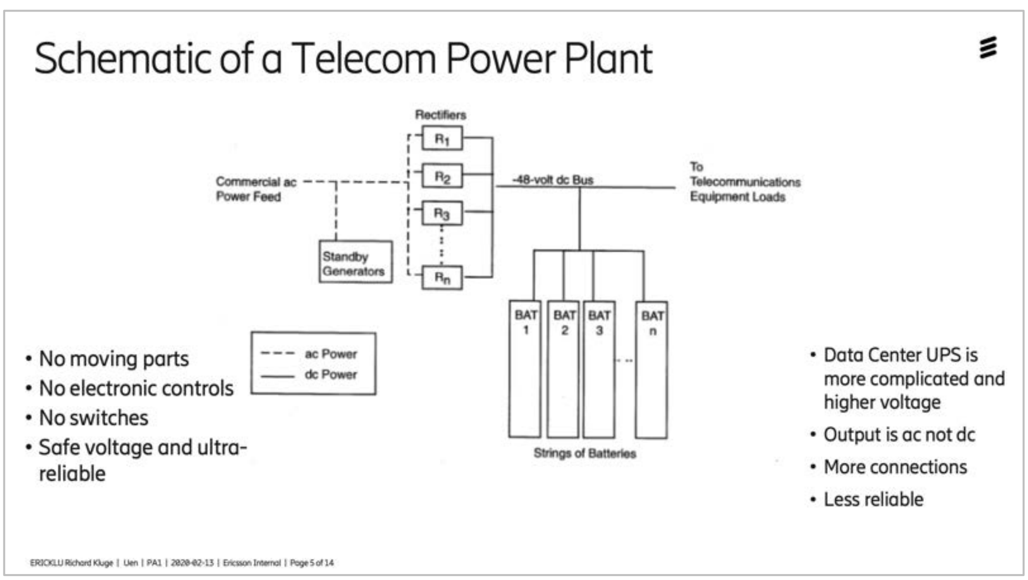


Figure 6: Schematic of a Telecom Power Plant

Source: Richard Kluge[60]

4.0 Cell Towers and the Need for Backup Power

Recent disasters, like Hurricane Ida and others, have highlighted the vulnerability of America's communications infrastructure during disasters, including wireline, wireless, cable, satellite, or broadcast facilities. These disruptions can delay 911 calls, first responder communications, and other potentially life-saving information. Interference with communications can also negatively impact the economy and critical infrastructures due to interdependencies among sectors, including the transportation, medical, and financial sectors. After Hurricane Katrina in 2007, the Commission implemented backup power obligations in limited contexts. One of which focused on requiring service providers to ensure reliable 911 service, including availability of central office backup power.[61] The following background pertains to resilient communication networks regarding the matter of backup power during disasters, specifically for public safety and 911.

> "Covered 911 service providers must certify their compliance with backup power standards of 24 hours for central offices that provide administrative lines for Public Safety Answering Points (PSAPs) and 72 hours for central offices that have a selective router that directs 911 calls. Further, the Commission has adopted rules requiring that providers of facilities-based, fixed voice service offered as a residential service provide their subscribers the options to purchase, at the point of sale, solutions that provide 8 and 24 hours of backup power for the service." [62]

In a 2021 publication, the FCC posed several questions to identify strategies that the Commission, communications providers, and power companies can implement to enhance coordination in the power and communications sectors during and after emergencies or disasters. Emphasis has been added to the questions to highlight some of the pressing matters as they relate to backup power.

> **"We seek comment on the current state of providers' backup power implementations. For example, how many hours of backup power do providers typically maintain, what technologies do they use to meet their requirements, and how readily deployable are those technologies when needed?** Does the amount or type of backup power solution differ depending upon the facility or type of infrastructure? What are the benefits and challenges of maintaining backup power onsite? If not maintained on-site, how could providers ensure that they can move backup power resources on-site with minimal delay when disaster strikes? **What steps do providers take to adequately mitigate the risk that a disaster event that**

disrupts primary power would also knock out any on-site backup power resources (e.g., fuel generators)? What types of backup power solutions are available for the various elements of infrastructure that may require it?

We seek comment on what steps service providers would need to take with respect to backup power deployment to significantly reduce the number of communications disruptions caused by power outages. **How many hours of on-site backup power would be appropriate at their facilities to significantly reduce the frequency of power-related service disruptions? Are there events or geographic areas in which more hours of backup power are needed than others?** To maximize the effectiveness of backup power solutions, should backup power be provisioned at certain critical points in communications infrastructure, and if so, at which points? In general, how should the Commission define or otherwise identify facilities and equipment that are critical to ensuring that emergency communications can be transmitted in the aftermath of a disaster? **Are there differences across different types of communications networks or geographies where they are located that are relevant to deployment of backup power solutions or performance during power outages more generally?** Is the deployment of on-site backup power sufficient to keep networks online in view of other potentially independent factors that may cause a network to fail during a disaster, e.g., lack of hardened and resilient network equipment? If it is not sufficient, what other steps should service providers take to avoid service disruptions? What are the associated costs and benefits?"[63]

4.1. Wireless Telecommunications Bureau

The Wireless Telecommunications Bureau (WTB) administers policies and procedures for licensing of wireless services and manages the tower registration process. They oversee nearly two million licenses, produce the Mobile Wireless Competition Report, and manage interactive web tools like the Spectrum Dashboard, that provides public key wireless service information in a transparent manner.[64] The Bureau is comprised of the Office of the Bureau Chief, Broadband Division, Mobility Division, Competition and Infrastructure Policy Division, and the Technologies, Systems and Innovation Division. Below is the organizational chart for the Wireless Telecommunications Bureau.

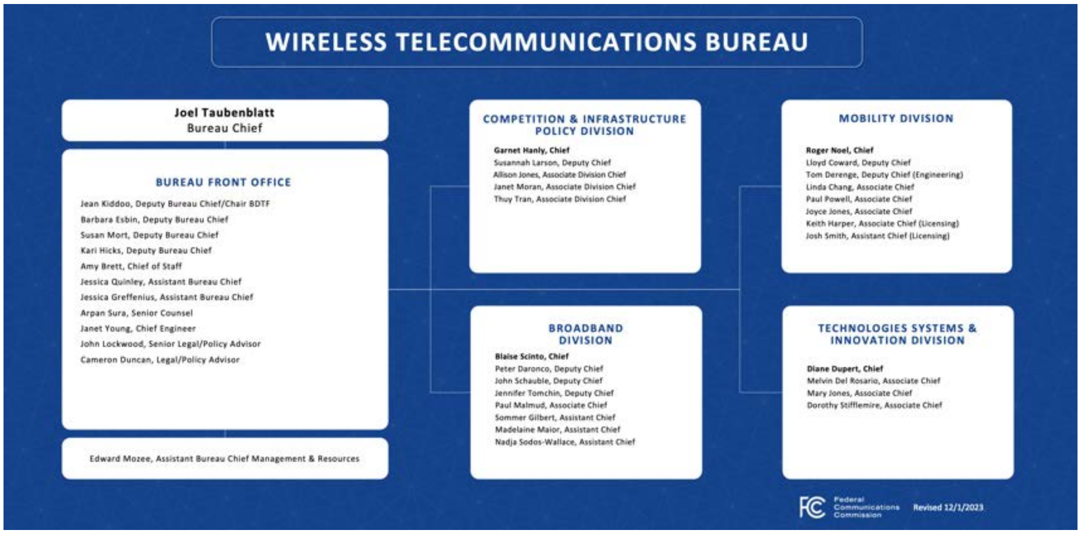


Figure 7: Organizational Chart for the Wireless Telecommunications Bureau

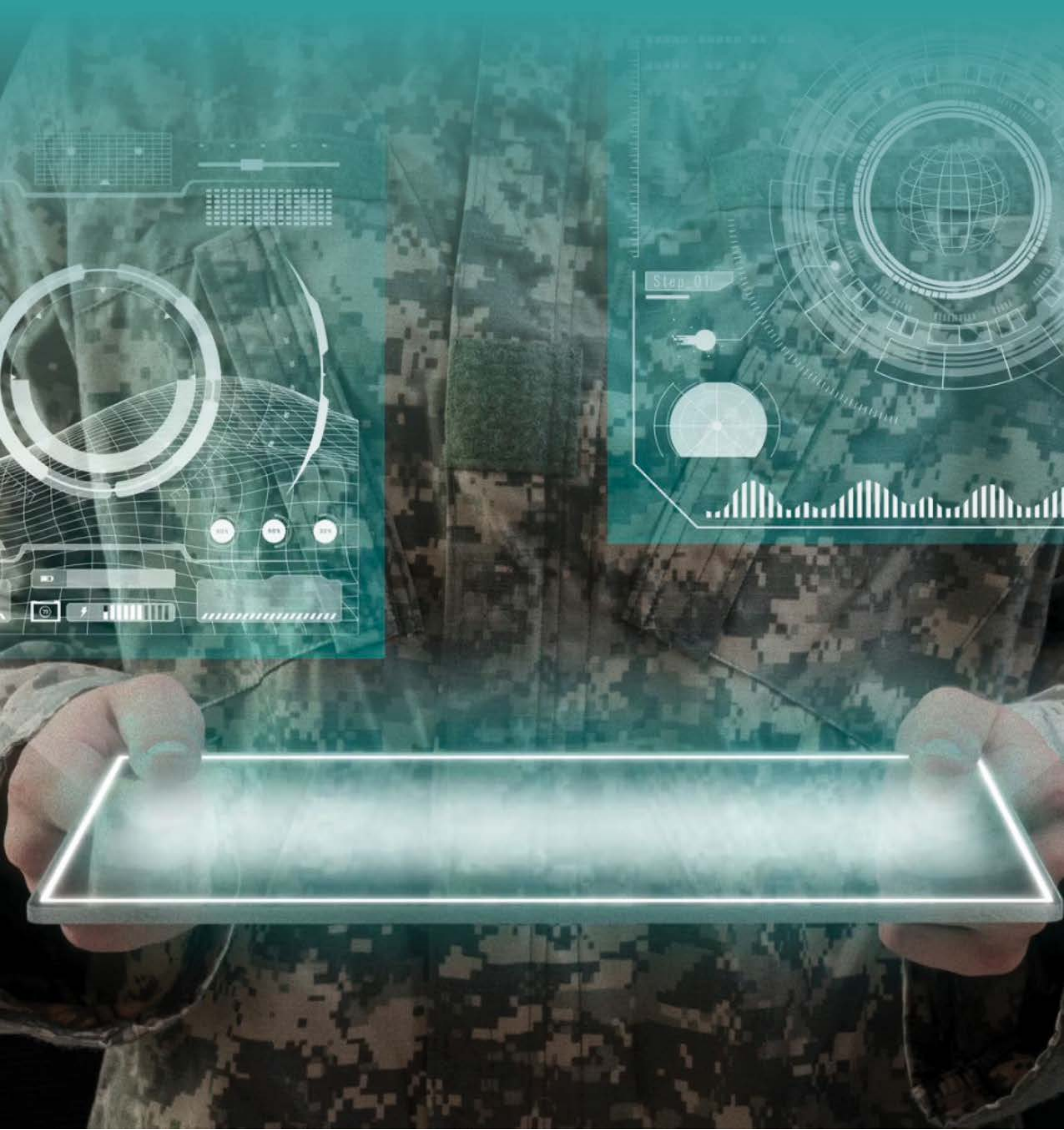
Source: FCC.gov[65]

Wireless carriers are tasked with managing high-profile disasters such as hurricanes and wildfires.[66] Several hurricanes in the last decade have caused extensive cellular outages in some areas. Outages caused by Hurricanes Matthew in 2016; Harvey, Irma and Maria in 2017; and Florence and Michael in 2018 all underscore the vulnerability of cellular networks when people are relying on cellphones for communication and emergency notifications. For example, Hurricane Irma caused significant cellular service outages in seven Florida counties, leaving the U.S. Virgin Islands and 3.7 million people without cellular service for two weeks. As a benchmark, AT&T has spent over $650 million on its NDR resources over the past three decades.[67] This is viewed as a tremendous burden.

In June 2022, the FCC adopted mandatory actions to improve the reliability and resiliency of wireless networks during emergencies. "The Mandatory Disaster Resilience Initiative requires wireless providers to:

1. Provide roaming to one another when a network is down, where technically feasible;
2. Establish mutual aid agreements to share physical assets and to consult with one another before and during emergencies;
3. Enhance municipal preparedness;
4. Increase consumer readiness;
5. and Improve public awareness and stakeholder communications regarding restoration times."[68]

Department of Defense



5.0 Department of Defense

Hurricanes, floods and other forms of extreme weather have an impact not only on civilians, but also on military facilities, especially those close to the coast. Like the communication sector, the Department of Defense also requires uninterrupted power in order to fulfill its mission. In this section the scope of the problem is introduced, and the methods used to provide backup power are highlighted.

Figure 8: Senate Armed Services Committee: Tillis on Camp LeJeuen's Recovery from Hurricane Florence

Source: Click here to see video

5.1. Climate Change and Corresponding Policy / Documentation

According to DoD's 2021 report, "DoD Installation Exposure to Climate Change at Home and Abroad," the 1,055 DoD installations vulnerable to "climate change hazards" are located in the contiguous United States (CONUS), Hawaii, and Alaska. There are also 336 additional vulnerable locations throughout the rest of the world (ROW).[69] The table below lists the U.S. Navy, Marine Corps, U.S. Army, and Air Force installations most likely to be negatively affected by climate change.

Table 3: Most Vulnerable U.S. Navy, Marine Corps, U.S. Army, and Air Force Installations

Marine Corps Installations	Navy Installations	Army	Air Force
Marine Corps Base Camp Pendleton, CA	Naval Air Station Key West, FL	Yuma Proving Ground, AZ	Vandenberg AFB, CA
Marine Corps Base Camp Lejeune, NC	Naval Submarine Base Kings Bay, GA	Fort Irwin, CA	Eglin AFB, FL
Marine Corps Base Camp Butler, Okinawa, Japan	Naval Base Guam, Guam	Fort Huachuca, AZ	Hurlburt Field, FL
Marine Corps Base Hawaii, HI	Joint Base Pearl Harbor Hickam, HI	Fort Bliss, TX	Patrick AFB, FL
Marine Corps Recruit Depot Parris Island, SC	Wahiawa Annex, HI	White Sands Missile Range, NM	Joint Base Charleston, SC
Marine Corps Support Facility Blount Island, FL	Naval Magazine Indian Island, WA	Camp Roberts, CA	Dover AFB, DE
Marine Corps Air Station Beaufort, SC	Naval Base Coronado, CA	Hawthorne Army Depot, NV	Homestead ARB, FL
Marine Corps Base Quantico, VA	Naval Base San Diego, CA	Tooele Army Depot, UT	MacDill AFB, FL
Marine Corps Reserve Forces, New Orleans, LA	Joint Base Anacostia Bolling, DC	Military Ocean Terminal Concord, CA	Tyndall AFB, FL
Marine Corps Recruit Depot San Diego, CA	Washington Navy Yard, DC	Pueblo Chemical Depot, CO	Joint Base Langley-Eustis, VA
	Andersen Air Force Base, Guam		
	Naval Support Facility Indian Head, MD		
	Naval Air Station Oceana, VA		
	Naval Air Station Norfolk, VA		
	Naval Support Activity Hampton Roads, VA		

	Naval Support Activity Hampton Roads – Northwest Annex, VA/NC		

Source: The Center for Climate & Security[70, 71, 72]

The DoD is actively pursuing climate change mitigation through various policies. A DoD Directive entitled "Climate Change Adaptation and Resilience" came into effect on January 14, 2016, with one additional change on August 31, 2018. The directive was implemented based on the guidance from Executive Order 13653 which created policy for DoD's role in climate change mitigation and its role in creating space for various sectors to make appropriate developments in this area. Protection of natural resources, infrastructure, environment, and economy are all important considerations. In addition, the DoD must have consistent programs, operations, and services throughout these changes.[73]

DoD's policy states that every element of the Department must adjust for climate change because the effects are unavoidable. This means that every operation within the Department must actively recognize climate change in its processes and makenany changes needed to coincide with the DoD's requirements for warfighting.[74]

The Department recently released the "Department of Defense Climate Adaptation Plan," which maps the DoD's goals for resilience against climate change. **The document encourages implementation of climate change mitigation technologies like power storage and microgrid implementation as they coincide with DoD mission requirements.**[75]

The Office of the Under Secretary of Defense for Acquisition and Sustainment's (OUSD(A&S)) 2020 Report to Congress entitled "Resilient Defense Infrastructure and Military Installations Resiliency," provides a summary of how the DoD is building installations in the face of climate and weather conditions. **Rising sea-levels and weather events like storm surges, hurricane-force winds, and massive rainfall are a few environmental factors that are driving the need for DoD installation resilience. The DoD is aware of the difficulties in preparing coastal installations for disaster and is committed to developing these locations for impending situations.**[76]

The DoD monitors installation energy because of the effect power outages incur on ongoing missions. They actively initiate improvements to mitigate risk in this area. It is of note that *"mission capability concerns override preferences toward specific technology implementation goals."*[77]

5.1.1. Utility Outages

Considerations for infrastructure improvement, local utility servicing endeavors, and "pursuing emergency or redundant power supplies such as backup generators and renewable energy technologies tied into microgrids or storage" are often implemented measures after utility outages. In the scope of Hawaiian, Alaskan, and CONUS locations, climate factors will impact energy demand the most in Northern Plains and Alaska locations according to information gleaned from the DoD Climate Assessment Tool (DCAT).[78]

There were 6,288 reports of unexpected utility outages from DoD Components in Fiscal Year (FY) 2021. This resulted in a roughly $128M financial impact (this number only reflects the financial impact of locations that reported monetary affects). The following figure illustrates the total cost, average cost each day, the length in days, and the total combined length in days of outages for this year. More than 1,000 hours of outages that year were caused by Winter Storm Uri which effected many installations in the Southwest.[79]

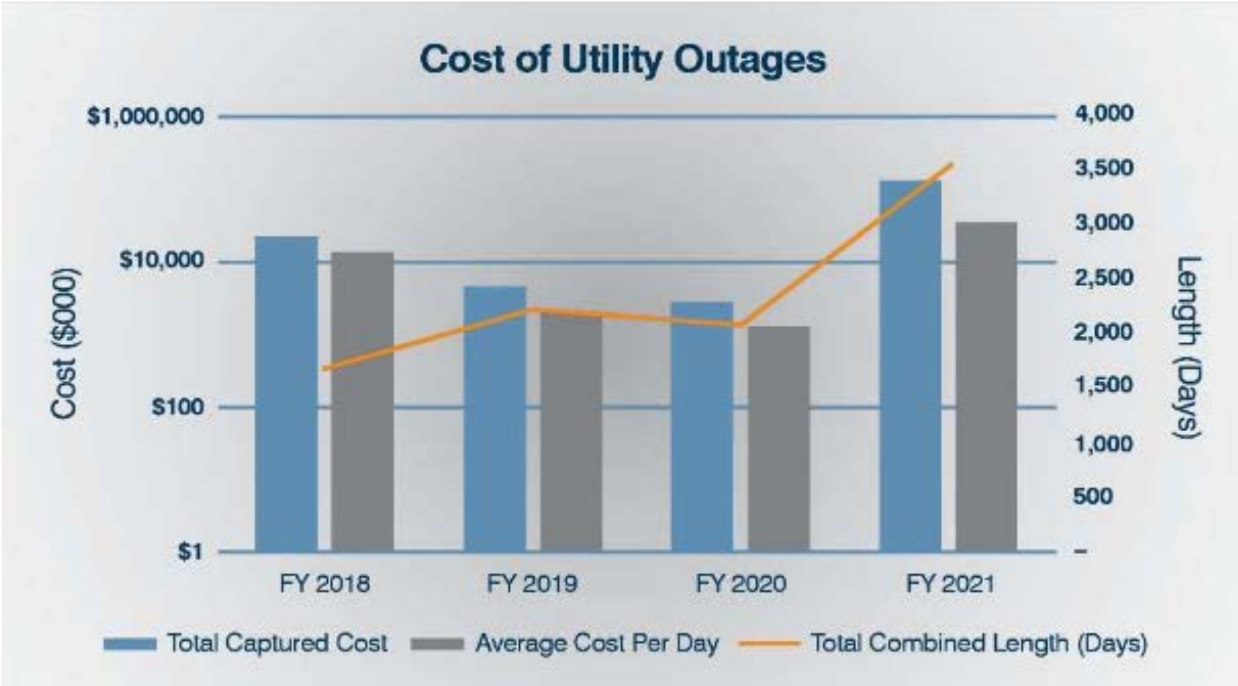


Figure 9: Utility Outage Costs and Duration
Source: Department of Defense[80]

The next figure shows the type of utility outages along with system types that occurred in FY 2021. Storms and weather are included in the scope of the acts of nature category.

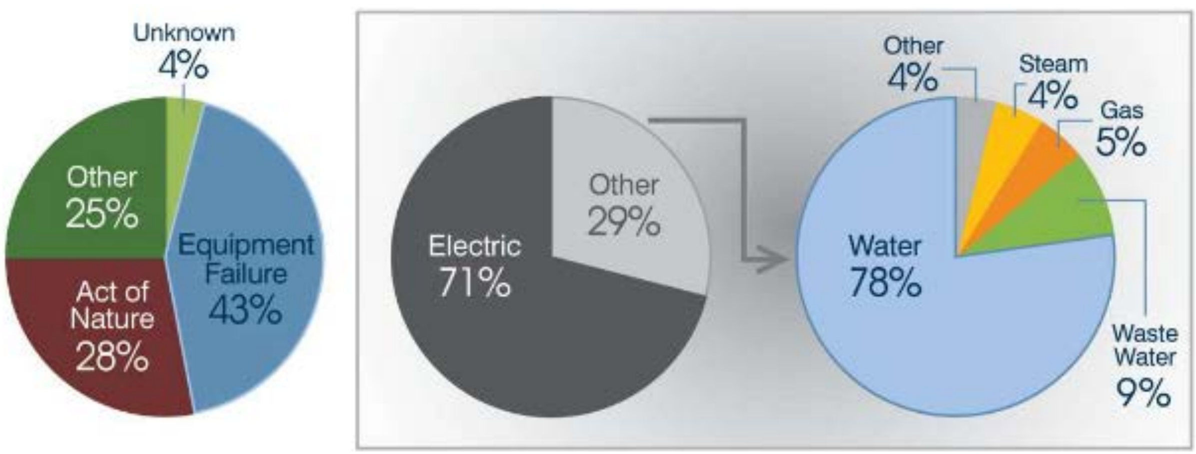


Figure 10: Utility Outage Costs and Duration
Source: Department of Defense[81]

In 2011, every southwest Marine Corps installation was impacted by the far-reaching blackout known as the "Great Blackout of 2011." This blackout spurred installation improvements after a regional After Action Report (AAR) combined the problems and knowledge gained from all effected installations. In the present, earthquakes and wildfires in the southwest area are a key concern when it comes to the need for installation resilience.[82]

As of May 2021, the U.S. Army, Navy, and Air Force are required to observe the following criterion when planning for installation energy resilience:

- "promote the use of multiple and diverse sources of energy, with an emphasis favoring energy resources originating on the installation such as modular generation
- promote the installation of cyber-resilient microgrids to ensure the energy security and energy resilience of critical missions
- **provide for a minimum of 14 days of energy disruption, unless otherwise prescribed by the military department or other departmental guidance**
- ensure the minimum level of energy availability standards within [the May 2021 memorandum] are applied to both steady state operations and for the purposes of energy resilience during a disruption to operations"[83]

Microgrids are an option for backup power that ensure resilience and elements of the Armed Forces are in the process of implementing this technology. For example, the U.S. Army is committed to matching battery storage with microgrids for contingency basing. According to the Army, they will "move to acquire, implement, and help advance [battery] technology." Backup renewable generation, large-scale battery storage, and microgrids will be invested in for all U.S. Army installations and the plan is for all Army installations to have a microgrid by year 2035.[84] In fact, in 2022, the U.S. Army awarded a contract to Lockheed Martin to build a long-duration energy storage system using a redox flow battery called GridStar® Flow at Fort Carson, Colorado. **The discharge duration is anticipated to be 10 hours and is the first long-duration energy storage system project at megawatt-scale for the DoD.**[85]

The Navy's accomplished microgrid program has initiated the Navy's efforts to create energy resilient microgrids or similar technologies to underpin critical missions. These implemented technologies will protect installations from power outages and grid unreliability with long-duration battery storage. The initiatives can be bolstered by Energy Resilience Readiness Exercises and "black start" tests that ensure installation readiness during power loss.[86]

5.2 Department of the Navy (DON) and Marine Corps

Natural hazards including drought, coastal erosion, and extreme rainfall are escalating along with climate change in Navy and Marine Corps installations.[87] The Department of the Navy (DON) has been involved in mitigating the effects of climate change for years. Most recently, the Navy has published "Department of the Navy Climate Action 2030" which reiterates their plan to shape climate action efforts around the five Lines of Effort (LOE) for climate action that were mapped out by the DoD. The DON has also partnered with the Army Corps of Engineers' Engineering With Nature (EWN) Program to facilitate installation assessments and workshops for eleven installations in the past two years. The Marine Corps Air Station Yuma and Naval Air Station Key West were among the installations visited due to their environmental stressors. Planners, engineers, landscape architects, and scientists were among the teams that visited these sites in an effort to plan resilience projects.[88]

Information about current or recent battery storage system projects at various Naval and Marine Corps installations is provided in this section. Navy and Marine Corps installations are of particular importance as they are often found in coastal areas with heightened exposure to climate change effects. According to a 2018 report which conducted a survey of DoD installations to assess climate risk,

> "Of the 761 Navy sites surveyed in SLVAS [Screening Level Vulnerability Assessment Survey], 73% of the sites indicated some sort of effect from past flooding, extreme temperatures, drought, wildfire, or wind events. The most prevalent factor was wind events, followed by non-storm surge flooding and flooding due to storm surge.
>
> Of the 292 Navy sites surveyed that are located within 2 km of the coastline, 45% of the sites indicated some sort of effect from storm surge and non-storm surge flooding in the past. **Navy plans to integrate the information into its planning and assessment processes**."[89]

The survey also indicated that a number of Marine Corps installations underwent repercussions from some of the same climate circumstances.[90]

5.2.1 Marine Corps Base Camp Lejeune's Lithium-ion Phosphate Platform

Marine Corps Base Camp Lejeune is in the process of developing an 11-megawatt energy storage system with a lithium iron phosphate platform (LFP). The base camp has an existing 13-MW solar facility in which the storage system can work with, although it can also work separately. Energy from these projects will flow into a Duke Energy grid that will not only provide power for Camp Lejeune, but every Duke Energy Progress customer. Duke Energy Progress is one of Duke Energy's six business units. This unit produces, sells, and administers electricity throughout parts of South Carolina and North Carolina. Their service area spans 32,000 square miles and serves around 1.5 million customers that use the electricity for commercial, industrial, and residential purposes.[91, 92, 93]

The Marine Corps Base Camp Lejeune is developing this project through an enhanced use lease and partnership with Duke Energy Progress.[94] In a document published by the Marine Corp, an enhanced use lease is defined as: "A method for funding construction or renovations on federal property by allowing a private developer to lease underutilized property, in exchange for cash or in-kind consideration. This authority enables the Navy to maximize the utility and value of installation real property and provide additional tools for managing the installation's real estate assets to achieve business efficiencies."[95]

Duke Energy also suggests potential that Camp Lejeune could be protected from grid power outages in the future by using the solar-plus-storage systems. This battery system is the biggest in North Carolina.[96, 97] This project was preceded by Hurricane Florence in 2018, when a section of the installation went without power for 11 days and caused an operation shut down. That 11-day span took almost a year to recuperate from and the installation faced an estimated million-dollar loss per day they went without power. There was also a ripple effect on Marine recruits, whose training schedules were skewed and resulted in a smaller number of deployments per enlistment period for some.[98] An image of the storage system at Camp Lejeune can be found in the following figure:

Figure 11: Energy Storage System at Camp Lejeune
Source: pv magazine[99]

5.2.2. Marine Corps Air Station Miramar's Microgrid

Marine Corps Air Station (MCAS) Miramar's microgrid installation completed in 2021. The microgrid uses solar and photovoltaic thermal energy, natural gas and diesel, and battery storage in tandem. These elements provide the installation with power outage protection that can last for as many as 21 days.[100] The microgrid was developed and installed by Schneider Electric and Black & Veatch after being contracted through the Naval Facilities Engineering Command, Southwest (NAVFAC Southwest).[101] 6.45 MW of diesel and natural gas generation augment additional distributed energy resources that contribute to the microgrid and act as backup energy. This setup ensures constant power that can handle a local power outage. Cost of fuel drove the plan for energy storage on the site and lithium-ion battery installation was planned for 2022.[102] In March of 2023, it was reported that a 1.5-MW energy storage system is in the works at this installation which will be implemented in upcoming years. This energy storage system will be funded by the California Energy Commission.[103]

The 2011 blackout in San Francisco stressed the urgency for an energy storage solution when MCAS Miramar endured an 8-hour span with no power.[104] Images of the MCAS Miramar power plant follow.

Figure 12: MCAS Miramar Microgrid Power Plant

Source: Black & Veatch[105]

Figure 13: MCAS Miramar Microgrid Power Plant 480v and 12kV Switchgear and Generators

Source: Black & Veatch[106]

5.2.3. Joint Base Pearl Harbor-Hickam Solar Project

The Kūpono Solar Project is a shared project between Ameresco and Bright Canyon Energy titled Kūpono Solar in Hawaii. Ameresco and Bright Canyon Energy provide the financial support for Kūpono Solar.[107] The project will lie on 131 acres of land leased from the Navy with a 37-year agreement.[108] The Navy has partnered with the Kūpono Solar Project as a means to meet their goal for mission resilience as well as energy resilience for the state of Hawaii and surrounding community. The project will be run by the Kūpono

Solar Project using a power purchase agreement with Hawaiian Electric that spans 20 years.[109]

This project includes a solar array (42-megawatt [MW]) and lithium-ion battery storage (42MW/168 MWh). Project construction is anticipated to be complete during the beginning of 2024 and span approximately 131 acres. The energy from this shared project between Ameresco and Bright Canyon Energy will provide power to 10,000 Oʻahu homes.[110]

Figure 14: Kūpono Solar Project

Source: Electrek[111]

5.2.4. Naval Weapons Station Seal Beach (NWSSB) Enhanced Use Leases

Presently, there are two ongoing enhanced use lease (EUL) projects at Naval Weapons Station Seal Beach (NWSSB) that are aimed toward building installation resilience efforts:

> "EUL #1 NAVWPNSTA-SB allows use of 59 acres of land for development of up to 10 MW of solar generation along with a battery energy storage system (BESS) and diesel generation backup. This will cover 14-day outage 24 hours a day.
>
> EUL #2 NAVWPNSTA-SB Detachment Norco allows use of 8.3 acres of land for development of 2.5 MW of solar generation, 2.5 MW of BESS and 2.1 MW of diesel generation. This will cover a 14-day outage 24 hours a day."[112]

A lease between Bright Canyon Energy (BCE) and Naval Facilities Engineering Command (NAVFAC) was signed in 2020 for the second EUL mentioned above. The renewable energy provided will not only be allocated to NWSSB Norco, but also to the local grid. The intent of the battery storage system and solar power is to strengthen the installation's resilience toward power outages that could result in the disappearance of data and defective equipment. The installation already manages a 1.25-MW backup diesel generator, which BCE will provide "maintenance and testing" for, in addition to the location's new microgrid. The project is slated to reach completion in December 2023.[113]

5.2.5. Pacific Missile Range Facility (PMRF)

The Navy's Pacific Missile Range Facility (PMRF) located in Kauai, Hawaii recently installed a battery energy storage system and solar facility. The battery energy storage system has 70 megawatt-hour (MWh) capabilities, while the solar facility has 14-megawatt (MW) capabilities.[114] Critical infrastructure at installations in Hawaii are in particular danger from natural hazards.[115]

This project was facilitated by an enhanced use lease and contributions from many parties such as the U.S. Navy, Kauai Island Utility Cooperative (KIUC), AES, and the National Renewable Energy Laboratory (NREL). Kauai Island Utility Cooperative was awarded the Navy's RFP (Request for Proposal) for the project. Thereafter, KIUC released their own RFP for project development which AES won. AES used NREL's facilities to ensure microgrid operations before installation. This project benefitted both parties: the Navy ensured installation resilience during outages while KIUC received land to build their solar and battery energy storage system.[116]

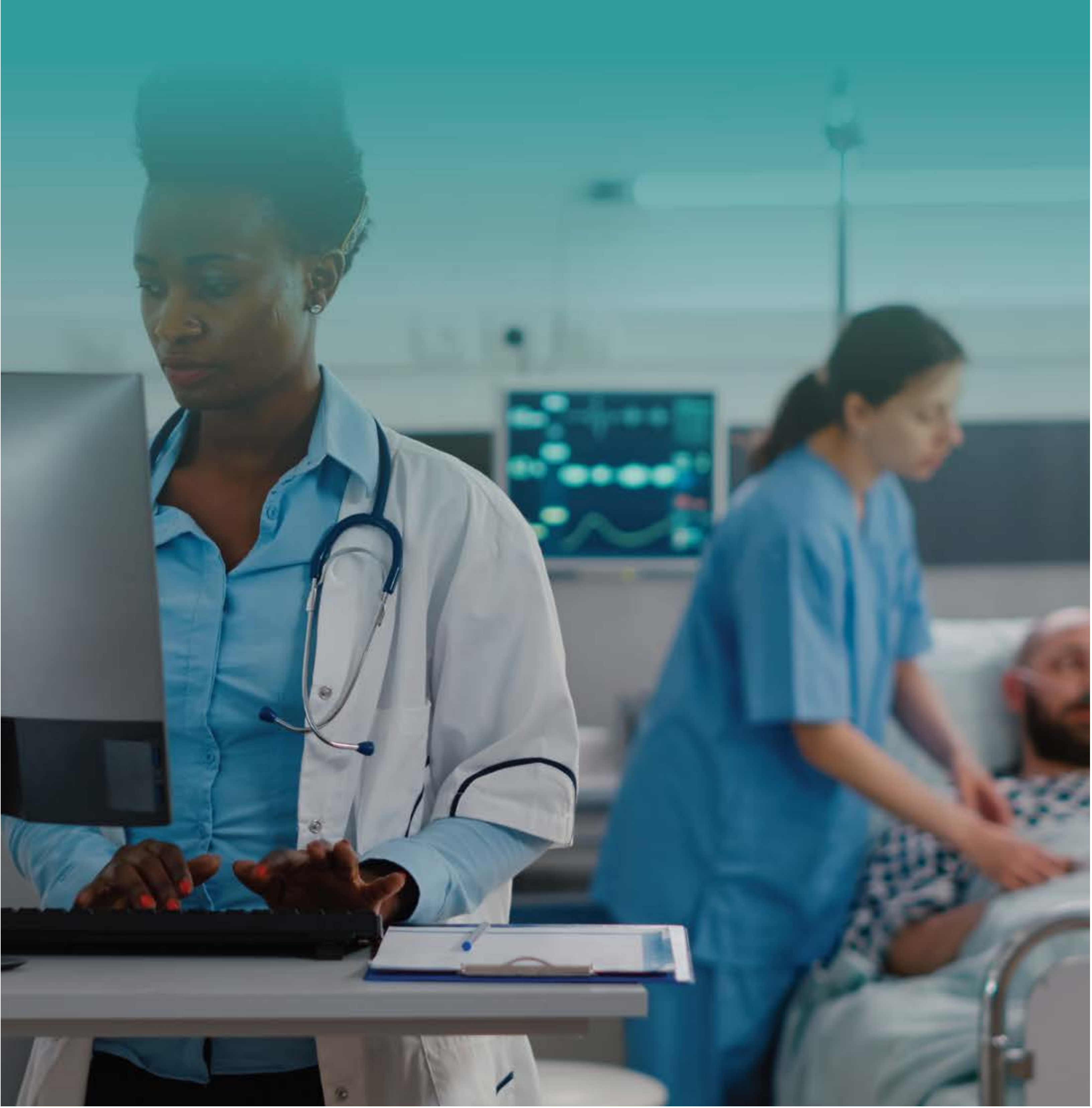
Figure 15: Cost-Effect Clean Energy Project on Kauai

Source: National Renewable Energy Laboratory, "U.S. Navy, KIUC, AES, and NREL Innovate and Collaborate for Resilience and Cost-Effective Clean Energy Project on Kauai," *nrel.gov*, November 16, 2021[1]

5.3. Concluding Statement

Climate change affects warfighter training, mission execution, tactical planning, acquisitions and sustainment of platforms and installations and national and global security. “The Navy and Marine Corps are targeting investments to enhance installation resilience, mitigating the vulnerabilities of energy, water, and facility control systems, while investing in energy storage and microgrids that can enable rapid recovery from severe weather or cyber threats. The Defense Department is making ships and tactical vehicles more efficient building better warfighters and investing in nature-based solutions to protect infrastructure and people.[117]

Healthcare & Public Health Sector



6.0 Healthcare & Public Health Sector

When the power goes off, not all facilities can continue to care for their residents. The elderly in assisted living facilities, or those living at home with chronic conditions that are dependent on the availability of power-hungry medical equipment are at risk. Healthcare facilities rely on power not only so that medical staff can provide medical procedures, but for lighting, environmental controls, access to patient records, food, and transportation. For this reason, the Public Health Sector also requires an uninterrupted power supply.[118]

Several regulations and codes from various bodies are used by hospitals and healthcare facilities to regulate backup power requirements. For example, the **National Fire Protection Association (NFPA), the Centers for Medicare & Medicaid Services (CMS), Federal Emergency Management Agency (FEMA),** and others cover preparedness and protection planning for healthcare facilities. Among the most frequently cited regulations are NFPA 99 and NFPA 110. NFPA 110 is the Standard for Emergency and Standby Power Systems that covers performance requirements for emergency and standby power systems providing an alternate source of electrical power in buildings and facilities in the event that the normal electrical power source fails. Systems include power sources, transfer equipment, controls, supervisory equipment, and accessory equipment needed to supply electrical power to the selected circuits. The table below introduces some of these codes, regulations, and recommendations.

Table 4: Codes for Healthcare Facilities

Code	Details
CMS-3178-F: Medicare and Medicaid Programs: Emergency Preparedness Requirements for Medicare and Medicaid Participating Providers and Suppliers	Establishes national emergency preparedness requirements for Medicare and Medicaid participating providers and suppliers to plan adequately for both natural and manmade disasters. It also requires providers and suppliers to coordinate with Federal, state, tribal, regional, and local emergency preparedness systems. (https://www.federalregister.gov/documents/2016/09/16/2016-21404/medicare-and-medicaid-programs-emergency-preparedness-requirements-for-medicare-and-medicaid)
CMS-3277-F: Medicare and Medicaid Programs: Fire Safety Requirements for Certain Healthcare Facilities	Amended the fire safety standards for Medicare and Medicaid participating hospitals, critical access hospitals, long-term care facilities, intermediate-care facilities for individuals with intellectual disabilities, ambulatory surgery centers, hospices which provide inpatient services, religious nonmedical

	healthcare institutions, and programs of all-inclusive care for the elderly facilities. (https://www.federalregister.gov/documents/2016/05/04/2016-10043/medicare-and-medicaid-programs-fire-safety-requirements-for-certain-health-care-facilities)
NFPA 99 – Health Care Facilities Code	Establishes criteria for levels of healthcare services or systems based on risk to the patients, staff, or visitors in healthcare facilities to minimize the hazards of fire, explosion, and electricity. (https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=99)
NFPA 101 – Life Safety Code	The most widely used source for strategies to protect people based on building construction, protection, and occupancy features that minimize the effects of fire and related hazards. (https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=101)
NFPA 110 – Standard for Emergency and Standby Power Systems	Covers performance requirements for emergency and standby power systems providing an alternate source of electrical power in buildings and facilities in the event that normal electrical power source fails. (https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=110)
International Building Code	The minimum requirements to safeguard the public health, safety, and general welfare of occupants of new and existing buildings. (https://www.iccsafe.org/codes-tech-support/codes/the-i-codes/)
FEMA P-1019: Emergency Power Systems for Critical Facilities	A Best Practices Approach to Improving Reliability: Guidance on the design and operation of emergency power systems in critical facilities so that they will be able to remain operational for extended periods, as needed. (https://www.fema.gov/media-library/assets/documents/101996)

Source: IAEI

Healthcare facilities tend to be among the first listed when discussing backup power supplies. These facilities must prove compliance with local authority regulations and codes. NFPA 110 defines two levels for Emergency Power Supply Systems (EPSS).

- **Level 1:** Where EPSS systems are engaged in the continuity of service for life support systems whose failure would result in the loss of human life.

- **Level 2:** Where EPSS systems are engaged in the continuity of service that are less critical to human life and safety.

The broad guidance categories for these areas cover the following topics:

- NFPA 110 Power Switching Time
- NFPA 110 Fuel Storage Requirements
- NFPA 110 Temperature Maintenance
- NFPA 110 Battery Capacity Requirements

Additionally, the August 2019 report from FEMA, *Healthcare Facilities and Power Outages Guidance for State, Local, Tribal, Territorial, and Private Sector Partners*, provides guidance and resources on improving healthcare facility resilience. In terms of funding and planning, the report notes that healthcare coalitions (HCCs) are permitted to use Hospital Preparedness Program (HPP) funding for the following:

- "Develop the staffing capacity and technical expertise to assist their members with the development of their emergency plans;
- Develop the staffing capacity and technical expertise to assist their members with the development of policies and procedures;
- Fund the costs associated with adding new providers and suppliers who are seeking to join coalitions to coordinate patient care across providers, public health departments, and emergency systems to their HCC;
- Assist members with the development of a communication plan that integrates with the HCC's communications policies and procedures; and
- Plan and conduct trainings and exercises at the regional or HCC level."[119]

The most common sources of backup power at healthcare facilities are diesel or gas generators. This is part of a fully integrated power system that includes an automatic transfer switch (ATS), uninterruptible power supply (UPS) and switchgear.

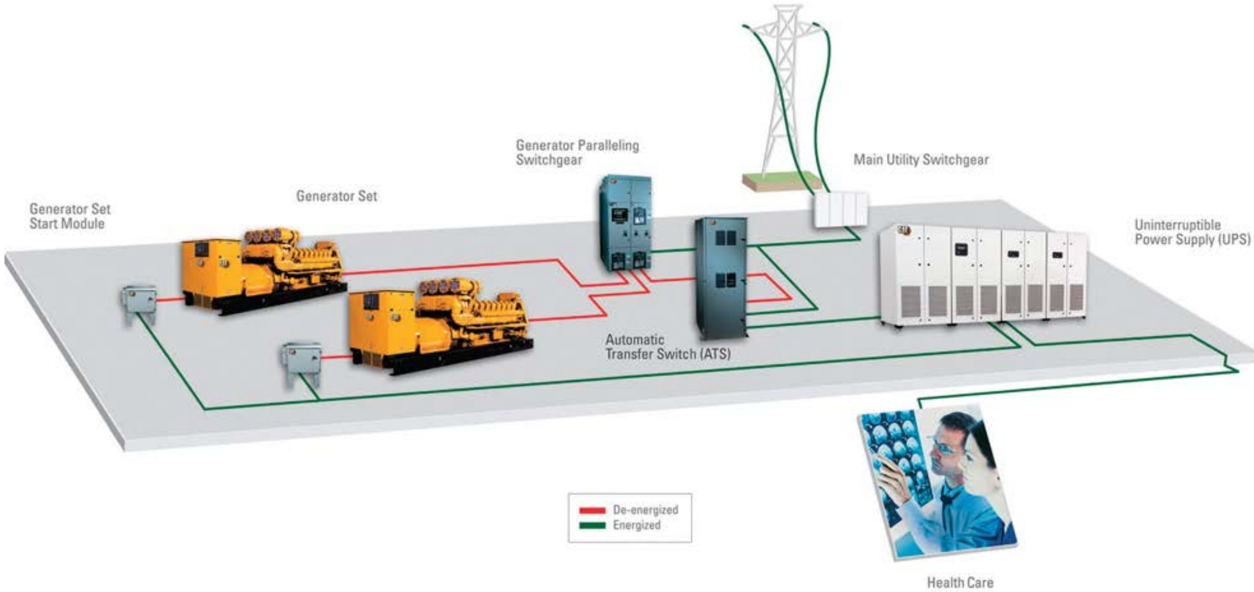


Figure 16: Healthcare Backup Power System
Source: Cat[120]

To meet the various codes and standards, hospital emergency power systems are typically required to be Class 96 meaning they must have at a minimum 96 hours of runtime or have an operational plan to supply 96 hours of fuel to the site. Additionally, they must be Type 10, which provides a maximum of 10 seconds to transfer, and Level 1 in terms of reliability given that a failure of the system could result in loss of human life or serious injuries. The two common fuel types for hospital generators are No. 2 diesel and natural gas. Typically, hospitals choose to install diesel generators for two primary reasons:

- "Hospitals are required to either have 96 hours of fuel stored on-site or an agreement to have the additional fuel delivered to maintain 96 hours of continuous runtime (see the Joint Commission's Emergency Management 96 Hour Plan for details). Natural gas is delivered to the hospital from the utility via underground distribution piping and cannot be stored on-site in the quantities required. Authorities having jurisdiction do not typically consider an off-site fuel source reliable enough to be the sole fuel source for generators (see NEC 700.12(D)(2)).
- Emergency generators and the EPSS for hospitals are required to be NFPA 110 Type 10 systems. This requires the system to restore power to the loads in less than 10 seconds. Most natural gas generators are not able to meet this requirement due to the time it takes the generator engine to start."[121]

Generators can be installed indoors or outdoors. Indoor installations are better protected from the weather and provide ease of maintenance. However, they typically have a higher first cost and require plans and space for airflow, cooling, and sound-mitigation. Outdoor installations typically have a lower first cost but are not as accessible and may be susceptible to degradation over time if not properly protected. Nonetheless outdoor generators are often preferred as the issues with ventilation and fuel oil delivery are made easier.[122]

Figure 17: Example of an Indoor (Left) and Outdoor (Right) Generator Installation
Source: CSE[123]

In terms of pricing for incumbent systems, the cost of a generator varies widely, as does the cost of installation. However, an average rate for both the unit and installation is around $400 per kilowatt with basic price ranges for just the generator listed below:

- A 50 kW, 120/200Vt diesel unit averages around $16,000.
- A 100 kW, 120/240V propane unit averages around $26,000.
- A 150 kW, 240V propane unit averages around $30,000.
- A 400 kW, 208V diesel unit averages around $85,000.[124]

Installation, warranties, and service agreements add to the total price, which contribute to the $400 per kW figure. Generator pricing by brand also covers a wide range. According to a 2023 pricing document, generator prices by brand (Generac, Kohler, Cummis, Caterpillar, or MTU Onsite Energy) can vary between a low of $20,000 and a high of $500,000.[125] Additionally, in December 2021 FEMA published a benefit-cost analysis (BCA) pre-calculated benefit for hospital generator projects under Federal Emergency

Management Agency (FEMA) Hazard Mitigation Assistance (HMA) programs and ultimately recommends hospitals estimate the benefits for generator hazard mitigation projects based on $6.95 per building gross square foot (BGSF) in urban areas and $12.62 in rural areas.[126]

6.1 Trends in Healthcare Backup Power & LDES Systems

In addition to the typical diesel or gas generator systems used for healthcare facilities backup power, there are many alternatives gaining traction in this space. This section introduces examples of alternatives to typical generators such as microgrids, community solar, and combined heat and power (CHP).

The National Governors Association (NGA) published, *Prioritizing Resilience: Best Practices On Energy Resilience For Healthcare Facilities*, in May 2023. This document introduced and segments healthcare backup power systems in two main categories: 1) stored energy devices that are intended for short duration emergency power (often 90 minutes or less) and are used to bridge the gap between an initial energy interruption and the resumption of energy via emergency generators, and 2) emergency generators. The report discusses the advantages and disadvantages of existing systems and focuses on the challenges of extreme weather, power system failure, and emerging mitigating options.[127]

The NGA report notes that in early 2023 Centers for Medicare & Medicaid Services (CMS) clarified through a categorical waiver that a *Health Care Microgrid System (HCMS)* can be substituted in place of traditional emergency generation in many healthcare facilities. It is important to note that the waiver "excludes long-term care facilities that provide life support because 42 CFR 483.90(c)(2) requires these facilities to have an emergency generator without exception."[128]

The September 2021 paper, *Microgrids for Healthcare Facilities*, was developed by the Hospital Building Safety Board Energy Conservation and Management Committee 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. While targeting California, the report provides a comprehensive look at options and developments related to microgrids in healthcare facilities. The document contains a detailed look at energy storage systems and their relationship with microgrids.

Microgrids in the United States are primarily concentrated in seven states: Alaska, California, Georgia, Maryland, New York, Oklahoma, and Texas. These microgrids currently provide less than 0.2 percent of U.S. electricity, but their capacity is expected to more than double in the next three years.[129] With the 2023 CMS decision, health care facilities will now be able to use solar, batteries, fuel cells, wind turbines and other renewable energy technologies. This capability has been seen already through several demonstration projects in the U.S. with approximately 70 healthcare or hospital sites operating microgrids as of December 31, 2022.[130]

Microgrids were installed at health care facilities in Ontario and Richmond, California, demonstrating the effectiveness of the technology. The Richmond project includes 2.2 MW of solar, a 1 MW fuel cell from Bloom Energy and a 9 MWh battery, which was funded in part by an $8 million grant from the California Energy Commission (CEC). The Ontario project is 10 times the capacity of the Richmond microgrid and can operate 10 hours or more in island mode with a more diverse array of assets and will be connected to a critical branch of power. The Ontario project was developed with a grant from the CEC and the microgrid from Faraday Microgrids (formerly Charge Bliss). The microgrids will allow the hospital to decrease its draw from the utility and also decrease peak loads and introduces the possibility for a hospital to provide grid services, demand response or exporting power and contributing to the power quality of the grid.[131]

Other states are also expanding the use of microgrids for healthcare facilities – Connecticut created a Microgrid Program to help support local distributed energy generation for critical facilities in January 2020, and projects in New York are also leveraging these options. The Buffalo Niagara Medical Campus (BNMC) in Buffalo, New York secured $1 million in funding from the New York Energy and Research Development Authority's (NYSERDA) NY Prize to deploy a microgrid project serving nine health care, life science research, and education facilities including New York's only freestanding pediatric health facility, the John R. Oishei Children's Hospital.[132] In Salisbury, Maryland, the Peninsula Regional Medical Center's (PRMC) coastal location makes it vulnerable to outages caused by hurricanes and other storms. However, PRMC was able to implement a microgrid based on a combined heat and power (CHP) system that consists of two 1,560 kW engines that can support the hospital's load during utility outages. Controls were added to the existing primary gear to allow the facility to easily load follow and enter island mode to operate as a microgrid hospital can continue to serve its patients with no interruption to its operations even if a storm cuts power.

Signature Healthcare entered into a 25-year power purchase agreement (PPA) solution with Siemens in November 2022 to help broaden its energy management efforts at Brockton Hospital in Massachusetts. As part of the agreement, Siemens will install and operate the renewable energy system that includes solar panels, totaling 1.9 MW fixed atop four carport canopies, microgrid controls that connect the panels to a 4MWh-BESS to help offset peak energy demands, and act as a supplemental onsite generation resource to bridge short-term grid disturbances. The hybrid renewable energy system is expected to be fully installed by late 2023 and is estimated to produce greater than 2,000 MWh of renewable energy in its first year of operation.

6.2 Combined Heat and Power (CHP)

Combined Heat and Power (CHP) is an on-site generation resource that can produce electricity and thermal energy around the clock that can also be designed to operate independently from the electric grid. When implemented with black start capability CHP can be a reliable and less costly option than installing backup generators. With respect to healthcare applications, the Texas Medical Center in Houston houses a 48 MW CHP system that operated without interruption during Hurricane Harvey in 2017. CHP also plays an important role in supporting the energy reliability and resiliency of many microgrids by providing baseload power and heat to connected buildings. The U.S. Department of Energy CHP Installation Database identifies 229 hospitals with CHP, totaling 745 MW of installed electric capacity. Reciprocating engines, with installations at 56% of sites are the most common CHP technology used in hospitals. Other sites use combustion turbines (21%), boiler/steam turbines (8%), microturbines (8%), and other prime mover technologies (7%). Over 83% of hospital CHP systems use natural gas, while the remainder use waste heat or other fuels, such as biomass, biogas, and oil.[133]

Table 5: Current CHP-Anchored Microgrid Installations - Primary Application by Technology as of December 31, 2022

	CHP		Solar		Wind		Hydro		Non-CHP Fuel Cell		Non-CHP Combustion		Storage		Unknown	
Primary Application	**Sites**	**MW**	**Sites**	**MW**	**Sites**	**MW**	**Sites**	**MW**	**Sites**	**MW**	**Sites**	**MW**	**Sites**	**MW**	**Sites**	**MW**
Agriculture	2	4.0	1	1.0	1	1.00	-	-	-	-	-	-	-	-	-	-
City/Community	13	385.2	2	0.6	-	-	-	-	-	-	1	0.3	3	0.7	-	-
College/University	64	1,200.3	12	35.5	1	0.02	1	1.2	-	-	15	67.3	6	17.1	2	14.0
Commercial	21	94.3	5	3.1	3	1.13	-	-	-	-	3	7.4	6	3.4	-	-
Hospitals / Healthcare	***59***	***464.1***	***3***	***0.5***	***-***	***-***	***-***	***-***	***-***	***-***	***3***	***7.5***	***1***	***0.6***	***-***	***-***
Military	9	74.1	4	31.2	-	-	-	-	-	-	9	191.7	4	6.3	-	-
Multi-Family Buildings	23	61.9	3	0.2	-	-	-	-	-	-	2	0.5	2	0.3	-	-
Public Institution	6	68.6	4	5.2	1	0.01	-	-	-	-	2	8.9	1	2.0	-	-
Research Facility	4	37.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Schools (K-12)	1	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water Treatment / Utility	3	9.0	3	4.5	1	1.0	-	-	-	-	3	6.7	2	5.7	-	-
Other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total*	**205**	**2,399**	**37**	**82**	**7**	**3**	**1**	**1**	**-**	**-**	**38**	**290**	**25**	**36**	**2**	**14**

**Totals may include duplicate sites (microgrids with more than one technology*

Source: U.S. Department of Energy Combined Heat and Power and Microgrid Installation Databases[134]

6.3. Community Solar

Community solar is another tool being used in healthcare and other settings to address backup power needs. For example, [Westerly Hospital in Rhode Island] is using electricity from a solar installation located an hour north of the hospital. Here a 28,000 ground-mounted solar panel farm is generating power for the hospital, resulting in annual savings of more than $400,000 through virtual net metering. The solar farm, operated by Kearsarge Energy, generates bill credits for every kilowatt-hour of energy produced. These credits are applied to Westerly Hospital's electricity accounts with Rhode Island Energy.

More recently, Lawrence Berkley National Laboratory (LBNL) published a report in September 2022 entitled, *Evaluating the Capabilities of Behind-the-Meter Solar-plus-Storage for Providing Backup Power during Long-Duration Power Interruptions*. This report examines and addresses the adoption of behind-the-meter (BTM) solar photovoltaic + energy storage systems (PVESS) and the backup power capabilities these systems offer. A better understanding of BTM PVESS is seen as critical to informing customer investments and early adoption as the industry scales up and other value streams develop – hospitals are among the use cases in the study.

Angel & Venture Capital Investment

7.0 Energy Storage Investment by Asset Management Firms

As projects scale, the amount of investment required continues to accelerate. Often such investment comes from asset management firms working in combination with other entities… such as utilities, state entities and other investors. This section includes examples of this type of collaboration and provides links to the projects under development.

7.1 AB Carval/Alliance Bernstein

AB Carval/Alliance Bernstein is a global asset management firm with its headquarters in Nashville, TN. According to a 2022 statement, the company has $646 billion assets under management. In June, 2022, Agilitas Energy which funds many battery storage projects announced a $350 million investment by CarVal Investors L.P.;[135] also known as AB Carval which was purchased by Alliance Bernstein in 2022.[136]

Agilitas Energy has been investing in many battery storage initiatives in combination with utilities in the Northeast U.S and positions itself as the "largest integrated developer, builder, owner and operator of distributed solar and energy storage systems in the North East."[137] The following are a few examples of their initiatives.

- Duke Energy, Agilitas Turn Utility-Scale BESS Projects Online in Florida and Rhode Island[138]
- Governor McKee, Pascoag Utility District Announce the Opening of Rhode Island's First Utility Scale Battery Storage System[139, 140]
- Energy Storage Project Aims to Stabilize Vermont's Electric Power Grid[141, 142]

7.2 Goldman Sachs Asset Management / Goldman Sachs Group, Inc.

Goldman Sachs Asset Management, L.P., headquartered in New York City, is a principal subsidiary and central investing area of the Goldman Sachs Group, Inc.[143, 144] Goldman Sachs Asset Management supervises over $2 trillion in assets and provides advisement and investment services for a variety of entities.[145] Hydrostor announced the investment of $250 million worth of preferred equity financing by the Private Equity and Sustainable Investing businesses within Goldman Sachs Asset Management in early 2022. The investment is intended to aid the advancement of Hydrostor projects in California and Australia.[146, 147] Hydrostor, out of Toronto, Canada, conducts business in utility-scale energy storage facility development and uses Compressed Air Energy Storage (CAES) technology for their protected Advanced Compressed Air Energy Storage (A-CAES) offering.[148] One of Hydrostor's active projects in development is the Willow Rock Energy Storage Center.[149] More information about the storage center can be found below.

- Willow Rock Energy Storage Center[150]
- Willow Rock Energy Storage Center[151]
- Engineering Study Begins for 500 MW Compressed Air Energy Storage Project[152]

Hydrostor has also received funding from their financing partner Meridiam, an asset management and Benefit Corporation (B Corp) company, based in Paris, France.[153, 154] According to Meridiam's 2023 impact report, which covers the 2022 financial year, the company had more than $20 billion in assets under management at that time.[155] Meridiam and Hydrostor's joint venture, with an estimated cost of $800 million, Pecho Energy Storage Center, is currently in development.[156, 157] More information about the shared project can be found below.

- Pecho Energy Storage Center[158, 159]

7.3 TPG Rise Climate / TPG

TPG is an alternative asset management firm and TPG Rise Climate is the company's "dedicated climate impact investing product," an entity that has $8.7 billion assets under management.[160, 161] TPG is led out of Fort Worth and San Francisco.[162] TPG Rise Climate centers their investments on negative emissions (carbon solutions), clean electrons (energy transition and green mobility), and clean molecules (sustainable fuels and sustainable molecules).[163]

Form Energy's recent financing round (Series E) was headed by TPG Rise Climate and ultimately resulted in a $450 million investment from their investor group.[164] Form Energy is responsible for an iron-air battery system that can store energy for 100 hours.[165, 166] Examples of Form Energy's current energy storage projects are listed below.

- Form Energy Partners with Xcel Energy on Two Multi-day Energy Storage Projects[167]
- Form Energy to Deploy 100-Hour Iron-Air Battery System in Georgia[168]

7.4 Prime Movers Lab

Prime Movers Lab has over $1.2 billion in assets under management after closing its most recent early-stage fund that raised $245 million. The venture capital firm is dedicated to investing in scientific start-ups across a number of sectors including energy.[169]

Energy Vault's Series C funding round was headed by Prime Movers Lab in 2021 and resulted in a $100 million in investment.[170, 171] Energy Vault provides utility-scale energy storage with solutions for long or short storage using protected green hydrogen, gravity, and battery technologies.[172] An example of a project the company is currently involved in, based in Napa Valley, California, is linked below.

- Energy Vault Partners with California Utility PG&E on Battery-Plus-Hydrogen LDES Microgrid Project[173, 174]

7.5 Blackstone Portfolio Company

Blackstone Portfolio Company, headquartered in New York City,[175] is an alternative asset manager. The company has $1 trillion worth of assets under management with 123 portfolio companies and $40 billion worth of available investment capital.[176, 177]

Aypa Power, a portfolio company of Blackstone Portfolio Company, focuses on energy projects that use hybrid renewable energy as well as owning and developing utility-scale energy storage projects.[178] Recent examples of energy storage systems Aypa Power has recently acquired are listed below.

- Aypa Power Acquires 'Williams' and 'Fletcher' Energy Storage Projects in Indiana[179]
- Aypa Power Acquires ‘Cald’ Energy Storage Project in Downtown Los Angeles[180]

7.6 Trafigura Group Pte Ltd.

Trafigura Group Pte Ltd. is a physical commodity trading group with $98.6 billion in total assets as of 2022.[181, 182] Trafigura Group Pte Ltd. invested in Malta Inc. (based out of Cambridge, Massachusetts[183]) in 2022. Malta Inc.'s technology facilitates long duration energy storage with a Pumped Heat Energy Storage (PHES) system.[184]

Long duration energy storage projects that Malta is involved in are listed below.

- Pumped Heat Energy Storage Seeks to Demonstrate Commercial Readiness[185]
- Malta Inc. and Orlando Utilities Commission Collaborate on Long-Duration Energy Storage[186]

8.0 State Investments in Energy Storage

Two examples of states that have recently decided to fund long duration energy storage projects are California and New York State. California has placed an ongoing emphasis on implementing energy storage to pair with their portfolio of renewable resources.[187] A representation of the state's battery storage capacity in the past, present, and projected capacity in the future, follows.

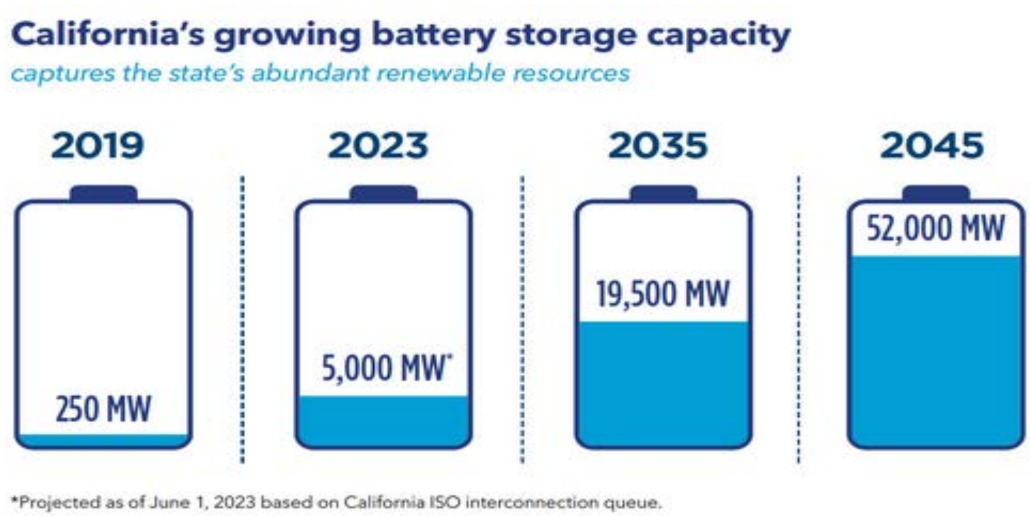


Figure 18: California's Battery Storage Capacity
Source: California Energy Commission[188]

8.1 California Energy Commission

The state of California has provided a budget for $380 million worth of funding for long duration energy storage projects that will be divvied out in fiscal years (FY) 2022-2023 ($140 million) and 2023-2024 ($240 million) through the California Energy Commission (CEC), a department of California Natural Resources Agency.[189, 190] The CEC "is committed to reducing energy costs and environmental impacts of energy use – such as greenhouse gas (GHG) emissions – while ensuring a safe, resilient, and reliable supply of energy."[191]

The California Energy Commission is granting $31 million to Indian Energy, the Viejas Tribe of Kumeyaay Indians.[192] The company provides "large-scale advanced energy resiliency solutions for the Department of Defense, Community Choice Aggregators and Tribal Utility Authorities."[193] Further information about this project can be found through the following link: Indian Energy Announces CEC-Funded Long Duration Energy Storage Project[194]

8.2. New York State Energy Research and Development Authority (NYSERDA)

New York State has identified energy storage as an essential part of reaching the state's renewable energy goals, which are to "generate 70 percent of its electricity from renewable sources by 2030 with a zero-emission grid by 2040." The state has the most aggressive target for energy storage installations in the country, with the goal of reaching 6 GW in 2030.[195]

The New York State Energy Research and Development Authority (NYSERDA), an agency within the New York State government, is funding a variety of long-duration energy storage projects through their Renewable Optimization and Energy Storage Innovation Program. In 2022, Governor Kathy Hochul made the announcement of $16.6 million worth of funding for five separate long-duration energy storage projects, as well as an additional $17 million in competitive funds "for projects advancing the development and demonstration of scalable LDES technologies."[196] Additional information about these five projects within the state's initial funding can be found by following the link listed below.

- Governor Hochul Announces $16.6 Million in Awards for Five Long Duration Energy Storage Projects[197, 198]

9.0 Summary and Conclusion

This report provides insight into the challenges faced by the communication, defense and medical sectors as the power grid continues to evolve and the climate continues to take its toll. In the communication industry, data centers require considerable redundancy as our society and economy depend so completely upon them. The uninterruptible power suppy (UPS) is the first line of defense and has historically been powered by lead acid batteries. However, a gradual shift to lithium-ion batteries is occurring, but with expressed concerns regarding the potential for thermal runaway. Generators are used as the second line of defense. Efforts are being made by companies such as Microsoft to shift from diesel to hydrogen powered generators by 2030. Wildfires and hurricanes have heightened the awareness of the problems that also occur when cell phone communication comes to a standstill. To address this, a new FCC ruling - “The Mandatory Disaster Resilience Initiative” will require that wireless providers collaborate more in times of crisis.

Many of the Department of Defense - Navy, Marine, Army, and Air Force bases are also located near the coast. This report highlights the damage that hurricanes have had on a number of bases and the methods that they have implemented to assure that in the future they have the power required to defend the nation. A number of large collaborative endeavors between the utilities and the Department of Defense have resulted in large installations of solar and with back-up battery technologies.

The public health sector also requires backup power. Historically this has been provided by large diesel generators. However, changes are occurring with noted shifts to the use of solar, often in collaboration with community power initiatives.

The shift to a new economy that can successfully face the myriad of challenges discussed in this report requires funding at multiple levels – funding for R&D, funding for scale up and funding for large scale implementation. This report introduced asset management firms. This sector is rarely discussed – but plays a significant role due to their financial assets and partnerships which enable them to implement on the large scales that need to occur rapidly.

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