RESILIENT SOLAR AND BATTERY STORAGE FOR COOLING CENTERS

Mitigating the Impacts of Extreme Heat on Vulnerable Populations

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ABOUT THIS REPORT

This report, prepared by Clean Energy Group (CEG) with American Microgrid Solutions (AMS), examines the opportunity for resilient power, solar PV paired with battery storage (solar+storage), to provide reliable backup power to cooling centers when times of extreme heat coincide with power outages. Health impacts of extreme heat, the implications of extreme heat on the electric grid, and future extreme heat trends are also discussed. The report includes seven case studies, a critical facility in each region of the country, each with a technoeconomic analysis for installing and operating solar+storage. The report concludes with a discussion of project economics and how utility programs, incentives, and determining a value of resilience can promote solar+storage adoption in underserved communities. The appendix includes more in-depth information related to solar+storage system design and configuration.

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Cover: © Dave Killen/The Oregonian

People made use of a cooling center at the Oregon Convention Center during Portland’s unprecedented heat wave on Monday, June 28, 2021. The building’s air conditioning provided relief from temperatures that rose to record levels.

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Overview

Extreme heat and power outages are increasingly problematic across the United States. When these disasters collide, the impact on public health can be severe. This report provides an overview on the trajectory of extreme heat and power outages and presents resilient power (solar PV combined with battery storage) as an invaluable resource for cooling centers. Solar paired with battery storage (solar+storage) enables a facility to continue operating in the event of an outage during times of extreme heat and can generate economic benefits during regular grid operations. This report can serve as a resource to provide municipalities and critical community facilities with the information necessary to take steps towards developing resilient power for cooling centers in their communities.

The report is divided into six parts and an appendix.

Parts 1 and 2 provide background on the trends for power outages and extreme heat in the United States. Health impacts are explored, as well as disparities in the how extreme heat and power outages harm vulnerable populations, including low-income communities, communities of color, and medically vulnerable individuals

Part 3 introduces the concept of a cooling center. This section also includes an overview of the inequitable distribution of cooling technologies (such as central air and window air conditioners).

Part 4 overviews the components of a solar+storage system, including details about the technologies and system configurations that should be considered when designing a resilient power system that can support cooling equipment—primarily, heating, ventilation, and air conditioning (HVAC). This includes an understanding of how to select necessary electrical equipment that will be connected to the system, how long the battery will need to support the critical loads of a facility, and how to manage the system to optimize performance of the battery.

Part 5 focuses on applications of resilient solar+storage at a variety of critical community facilities in each region of the country. Seven case studies are presented, one facility for each region of the country. These case studies present the technoeconomic feasibility of solar and battery storage at each facility, as well as potential obstacles to resilient power development. The section ends with a list of key takeaways based on the analysis of each case study presented in the report and standardized results for the entire group of buildings that were assessed.

Part 6 concludes the report with a set of recommendations that would improve solar+storage economics, thereby improving access and ensuring more facilities can support cooling operations through resilient, reliable, and renewable energy technologies. Emphasis is placed on state and federal policy, as well as how to determine a monetary value of resilience that can support system economics.

Appendices A–D provide more in-depth details about the technology and economic considerations that facility owners should contemplate when pursuing resilient power development for their cooling center—including types of HVAC equipment and system operation options.

Photo: CHAI CGN/Bigstock.com

Background

Extreme heat is responsible for more weather-related deaths than any other weather event. Community service providers and emergency preparedness leaders scramble each summer to ensure those at high risk—including electricity-dependent, medically vulnerable, and elderly individuals, as well as those without access to in-home air conditioning—have access to cooling centers, which are air-conditioned locations that have been designated as sites to provide relief and safety during extreme heat, when temperatures skyrocket.

The health impacts of extreme heat become more dire in the event of a power outage because air conditioning systems and fans cannot run without electricity. When high temperatures coincide with a power outage, hospitalizations and fatalities rise. Low-income communities, communities of color, and medically vulnerable individuals face disproportionate health impacts. As the number of high temperature days and occurrence of extreme weather events continue to climb, this deadly combination will continue to wreak havoc on public health in almost every state in the United States.

Cooling centers, air-conditioned buildings that are open to the public on extreme heat days, are key to community preparedness and providing relief during high temperatures. But these centers must also be prepared for power outages and have access to reliable backup power. It is often the case that demand for electricity drastically rises on extreme heat days. As more people turn on air conditioners, more stress is placed on the grid to provide power to homes and businesses. Too much demand can also increase the likelihood of planned power shut offs or unavoidable power outages.

Resilient power (solar paired with battery storage) can support cooling center operations in the event of an outage, without the climate, air quality, and reliability issues that come from using traditional diesel generators. Deploying more resilient power systems at cooling centers will improve public health, resulting in fewer fatalities and hospitalizations in the event of extreme heat during power outages, and allowing first responders and critical community service providers to better support vulnerable populations during extreme heat events.

Part 1
The New Normal: Extreme Heat And Power Outages

Rising Temperatures Across the Country

Defined as at least two consecutive days of high heat and humidity (typically, temperatures above 90 degrees), extreme heat is becoming the new normal for large swaths of the United States. This is especially true during the summer months. In August 2022, over one-third of the U.S. population was under an extreme heat warning.[1] Extreme heat in 2022 was not an anomaly; 2021 was the fourth-hottest year in the United States to date, behind only 2013, 2016, and 2017.[2]

While the South has traditionally been viewed as the warmest region of the United States, temperature trends are suggesting that more and more states will see continued extreme heat in the summer months and beyond. One 2022 study envisions large portions of the Midwest linking with southern states to create an "extreme heat belt" that stretches across the center of the country. The study, conducted by First Street Foundation, a nonprofit organization that assesses future climate risk, predicted that one-quarter of the country would eventually be in the "extreme heat belt" by 2053.[3] In this scenario, over 100 million people would be experiencing the catastrophic consequences of living in locations with temperatures exceeding 125 degrees. While 2053 may seem like the distant future, the study also predicts that at least 8 million residents in the heat belt would see temperatures over 125 degrees as soon as next year (in 2023).

Future predications aside, 2022 was record setting for heat. Multiple cities in California and Texas, as well as Boston, Massachusetts; Providence, Rhode Island; and Newark, New Jersey, broke previous daily high temperatures. In Newark, residents had their longest heatwave to date—five days of 100-degree temperatures.[4]

HEAT EXPOSURE DISPARITIES

Extreme heat disproportionately impacts low-income communities and communities of color. Predominantly Black, Latinx, and Asian neighborhoods suffer hotter temperatures

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1 National Integrated Heat Health Information System (NIHHIS), *heat.gov*, https://www.heat.gov (accessed September 29, 2022).

2 Dolce, Chris, "2021 Was Fourth-Warmest Year on Record for Contiguous U.S., NOAA Says," *weather.com*, January 10, 2022, https://weather.com/news/climate/news/2022-01-10-2021-united-states-fourth-warmest-year-noaa-report (accessed September 29, 2022).

3 The 6th National Climate Risk Assessment: Hazardous Heat, *firststreet.org*, August 15, 2022, https://report.firststreet.org/heat (accessed September 29, 2022).

4 Shapero, Julia, "Hundreds of Temperature Records Broken as Heat Wave Scorches the U.S.," *Axios.com*, July 25, 2022, https://www.axios.com/2022/07/24/heat-wave-temperature-records (accessed September 29, 2022).

than nearby neighborhoods with wealthier and white residents, which usually have more trees and are less compact. Over 60 percent of Black people in the United States experience dangerous heat waves, compared to approximately 40 percent of white people. By 2053, that figure will increase to 79 percent for Black communities, as opposed to 50 percent for their white counterparts.[5]

The difference in temperature between these communities can be attributed to decades of disinvestment in infrastructure, as well as environmental degradation: communities of color typically have denser populations, are more packed with buildings, and contain less vegetation.[6] The temperature disparities between geographically similar locations has been named the "urban heat island effect." In addition to experiencing hotter temperatures, residents in urban heat islands are also more likely to have higher energy burdens, live in inadequate housing conditions without sufficient insulation or efficient air conditioning, and must rely on fossil-fuel dependent and outdated energy infrastructure.

More Frequent Power Outages

The frequency of major power outages has also been trending upward. While the percentage of power outages due to non-weather-related events has remained relatively

Photo: Lance Cheung, USDA

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[5] Muyskens, John, Andrew Ba Tran, et al., "More Dangerous Heat Waves Are on the Way," *WashingtonPost.com*, August 15, 2022, https://www.washingtonpost.com/climate-environment/interactive/2022/extreme-heat-risk-map-us/?itid=hp-top-table-main-t-3 (accessed September 29, 2022).

[6] Benz, Susanne Amelie, and Jennifer Anne Burney, "Widespread Race and Class Disparities in Surface Urban Heat Extremes across the United States," *Earth's Future*, vol. 9, no. 7, 13 July 2021, *agupubs.onlinelibrary.wiley.com*, https://doi.org/10.1029/2021ef002016, (accessed September 29, 2022).

Intentional utility shutoffs, or "public safety power shutoffs" (PSPS), are increasingly to blame for power disruptions in parts of the country prone to wildfire.

MARION COUNTY, Ore. (Sept. 18, 2020)—Crews work to clear the road and restore power along U.S. Highway 22.
Photo: FEMA

unchanged since 2013, power outages caused by extreme weather events have steadily increased. In 2020, each household in the United States experienced, on average, a combined total of eight hours of power outages.[7] Power outages are also of longer duration, with outages that last over an hour increasing by 60 percent since 2015.[8,9] The percentage of these outages occurring during the summer months has steadily climbed.

The electricity grid is particularly vulnerable in the summer. Hurricane season and wildfire season both coincide with summer months. The weather associated with these natural

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[7] Calma, Justine, "2020 Was the Worst Year Yet for Power Outages in the US," *theverge.com*, 10 Nov. 2021, https://www.theverge.com/2021/11/10/22774266/power-outages-worse-united-states-electricity-grid-climate-change (accessed September 30, 2022).

[8] Statistic applies to outages affecting at least 50,000 utility customers.

[9] Stone, Brian, and Evan Mallen, et al., "Compound Climate and Infrastructure Events: How Electrical Grid Failure Alters Heat Wave Risk," *Environmental Science & Technology*, vol. 55, no. 10, 2021, pp. 6957–6964, *pubs.acs.org*, April 30, 2021, https://doi.org/10.1021/acs.est.1c00024 (accessed September 30, 2022).

disasters—such as high winds and torrential rains—can cause grid failure and widespread power outages. However, extreme heat can also result in grid instability. When temperatures are high, more people remain indoors with air conditioning on full blast. The volume of energy required to maintain the demand for air conditioning, in addition to "regular" electric loads (lights, refrigeration, outlets), can lead to a tremendous strain on the grid. When there is not enough energy to meet these periods of peak energy demand, power outages (blackouts and brownouts) will result.

The frequency of major power outages has also been trending upward. While the percentage of power outages due to non-weather-related events has remained relatively unchanged since 2013, power outages caused by extreme weather events have steadily increased.

Intentional utility shutoffs, or "public safety power shutoffs" (PSPS), are increasingly to blame for power disruptions in parts of the country prone to wildfire. PSPS occur when a utility de-energizes the grid as a preventative measure to avoid utility equipment sparking a wildfire. In California, for instance, 20 PSPS events in 2020 resulted in over 850,000 customers losing power for an average of 32 hours per outage (with some outages exceeding five days).[10] This year, PSPS events resulted in outages for 40,000 customers in the Portland, Oregon area.[11] Since wildfire season runs from June through August, PSPS outages oftentimes overlap with high temperatures.

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[10] Murphy, Patrick, "Preventing Wildfires with Power Outages: The Growing Impacts of California's Public Safety Power Shutoffs." *psehealthyenergy.org*, March 19, 2021, https://www.psehealthyenergy.org/news/blog/preventing-wildfires-with-power-outages-2 (accessed September 30, 2022).

[11] Dooris, Pat, and David Mann, "What Led PGE and Pacific Power to Cut Power to Thousands of Customers in Oregon?" *Kgw.com*, 10 Sept. 2022, https://www.kgw.com/article/news/local/wildfire/oregon-planned-power-outages-explained/283-39875804-19d3-4821-aedc-9a89c5eb21d5 (accessed September 29, 2022).

Part 2
Consequences of Extreme Heat and Power Outages

Effects on Public Health

The Centers for Disease Control and Prevention (CDC) estimates that approximately 700 people die each year due to complications from heat exposure.[12] Other studies suggest that figure is massively undercounted and estimate that annual heat-related deaths are closer to 12,000.[13] Furthermore, some states, which had not experienced frequent and long-duration heatwaves in the past, are now having to contend with massive heat-related public health crises. In 2021, 800 people died in Oregon, Washington, and British Columbia after a heat wave produced temperatures exceeding 115 degrees.[14] Most households in these regions are not equipped with cooling systems to handle temperatures under such extreme conditions.

There is a direct correlation between extreme heat, power outages, and health outcomes.

There is a direct correlation between extreme heat, power outages, and health outcomes. A doctor in Los Angeles reported an increase of 1,500 patients and approximately 16 deaths for each day of extreme heat.[15] In New Orleans, a public health crisis unfolded after Hurricane Ida resulted in widespread outages in 2020. Residents were trapped in over 100-degree heat without access to air conditioning. At least ten people died, all of whom were over the age of 60.[16] One study predicted that between 68 percent and 100 percent of the population of three major cities (Atlanta, Georgia; Detroit, Michigan; and Phoenix, Arizona) would be at risk of heat exhaustion or heat stroke due to dual blackout and heatwave events.[17]

[12] Vaidyanathan, Ambarish, et al., "Heat-Related Deaths - United States, 2004–2018," *cdc.gov*, June 19, 2020, https://www.cdc.gov/mmwr/volumes/69/wr/mm6924a1.htm#T2_down (accessed September 30, 2022).

[13] Shindell, Drew, and Yuqiang Zhang, et al., "The Effects of Heat Exposure on Human Mortality throughout the United States," *agupubs.onlinelibrary.wiley.com*, August 7, 2021, https://doi.org/10.1029/2019gh000234 (accessed September 30, 2022).

[14] Guilfoil, Kyla, "4 Dead in Oregon as Heat Wave Bakes Pacific Northwest," *abcnews.go.com*, July 29 2022, https://abcnews.go.com/US/dead-oregon-heat-wave-bakes-pacific-northwest/story?id=87547792 (accessed September 29, 2022).

[15] Chow, Denise, et al., "Heat Waves and High Energy Costs Are Hitting Some Communities Hard," *nbcnews.com*, June 19, 2022, https://www.nbcnews.com/science/environment/heat-waves-high-energy-costs-are-hitting-communities-hard-rcna33978 (accessed September 30, 2022.)

[16] Bogel-Burroughs, Nicholas, and Katy Reckdahl, "The Greatest Killer in New Orleans Wasn't the Hurricane. It Was the Heat," *nytimes.com*, Sept. 15, 2021, https://www.nytimes.com/2021/09/15/us/new-orleans-hurricane-ida-heat.html (accessed September 30, 2022).

[17] Alters Heat Wave Risk," *Environmental Science & Technology*, vol. 55, no. 10, 2021, pp. 6957–6964., *pubs.acs.org*, August 30, 2021, https://doi.org/10.1021/acs.est.1c00024 (accessed September 30, 2022).

Robert Franks (right) has spent his entire life in Florida and has survived countless hurricanes on his own. At 84 years old, he knew to seek help from the Red Cross for Hurricane Ian because he's on oxygen and can't be without electricity.
Photo: FEMA

Medically vulnerable individuals—such as individuals reliant on electricity-dependent medical equipment and the chronically ill—are especially at risk. Heat exacerbates existing medical conditions, such as cardiovascular and respiratory diseases. Without access to air conditioning or outlets to power medical equipment, even short durations of extreme heat can leave medically vulnerable individuals in a life-threatening situation. After Hurricane Irma in 2017, 14 nursing home residents in Florida died when their facility lost power, leaving residents without access to air conditioning.[18] In addition to senior citizens, children are also prone to severe heat-related medical issues. Almost half of those diagnosed with heat-related illnesses are children.[19]

> *Without access to air conditioning or outlets to power medical equipment, even short durations of extreme heat can leave medically vulnerable individuals in a life-threatening situation during a power outage.*

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[18] Nedelman, Michael, "Husband and Wife among 14 Dead after Florida Nursing Home Lost A/C," *cnn.com*, October 9, 2017, https://www.cnn.com/2017/10/09/health/florida-irma-nursing-home-deaths-wife (accessed September 30, 2022).

[19] Huetteman, Emmarie, "Extreme Heat Can Be Dangerous for Kids, Experts Warn," *cbsnew.com*, August 3, 2022, https://www.cbsnews.com/news/extreme-heat-dangerous-for-kids-health-experts-warn (accessed September 30, 2022).

There exist major health inequities related to heat exposure health impacts. Of the 700 deaths attributed to heat, as reported by the CDC, those that identify as American Indian/ Alaska Native are at greatest risk, followed by Black individuals.[20] People of color are also significantly more likely to visit the emergency department due to heat-related illnesses; 67 percent of visits are attributed to Black individuals, versus 27 percent for white individuals.[21] In Los Angeles, Black and Latinx communities experience 18 percent more deaths during extreme heat than white people who live in communities a few miles away.[22]

Effects on Mental Health

While much of the literature available is specific to the physical impacts of heat, there is growing evidence indicating that mental health can also be negatively impacted by extreme heat. Heat can alter risk perception, exacerbate existing mental health conditions (including depression and anxiety disorders), and impact cognitive ability.

The CDC reported that of the death records that included mental and behavioral disorders as the underlying cause of death, many also included references to heat as a contributing cause.[23] Another study found that there were approximately 8 percent more emergency department visits for mental health concerns on the hottest days of the summer. On these days, emergency visits also rose among individuals reporting mood disorders.[24]

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[20] Vaidyanathan, Ambarish, et al., “Heat-Related Deaths - United States, 2004–2018,” *cdc.gov*, June 18, 2020, https://www.cdc.gov/mmwr/volumes/69/wr/mm6924a1.htm#T2_down (accessed September 30, 2022).

[21] Ndugga, Nambi, and Samantha Artiga, “Extreme Heat and Racial Health Equity,” *KFF.org*, September 8, 2021, https://www.kff.org/policy-watch/extreme-heat-racial-health-equity (accessed September 30, 2022).

[22] Chow, Denise, et al., “Heat Waves and High Energy Costs Are Hitting Some Communities Hard,” *nbcnews.com*, June 19, 2022, https://www.nbcnews.com/science/environment/heat-waves-high-energy-costs-are-hitting-communities-hard-rcna33978 (accessed September 30, 2022).

[23] Vaidyanathan, Ambarish, and Josephine Malilay, et al., “Heat-Related Deaths – United States, 2004–2018,” MMWR Morb Mortal Wkly Rep 2020;69:729–734, *cdc.gov*, June 19, 2020, http://dx.doi.org/10.15585/mmwr.mm6924a1 (accessed September 30, 2022).

[24] Nori-Sarma, Amruta, Shengzhi Sun, et al., “Association between Ambient Heat and Risk of Emergency Department Visits for Mental Health Among Us Adults, 2010 to 2019,” *JAMA Psychiatry*, vol. 79, no. 4, 23 Feb. 2022, p. 341., *jamanetwork.com*, February 23, 2022, https://doi.org/10.1001/jamapsychiatry.2021.4369 (accessed September 30, 2022).

Part 3

Ensuring Access to Reliable Cooling

What is a Cooling Center?

A cooling center is a facility with air-conditioning that has been designated as a site to provide relief and safety for the public during extreme heat events. Cooling centers are typically not constructed for this sole purpose; most facilities that become designated cooling centers are pre-existing community facilities, such as libraries, schools, and community centers. For organizations that are developing Resilience Hubs—community-serving facilities that support residents and coordinate resource distribution and services before, during, or after a natural hazard event—including a robust cooling system may be a key community deliverable.[25]

Accessibility of cooling centers is essential for ensuring that vulnerable residents can escape extreme temperatures, especially during a power outage. Many of the most vulnerable community members do not drive or are unable to drive, and therefore require transportation. Proximity is also key. Cooling center locations should be hyper-local enough so that people in the surrounding area know where the centers are located and can get to them easily. Yet, most cities are grossly underequipped with cooling centers. One study found that only 2 percent of residents could be accommodated in existing cooling centers in cities with high risk of extreme heat coinciding with power outages.[26]

In most parts of the country, only hospitals are required to be equipped with emergency backup power. Some states that have experienced recent heat-related tragedies, such as Florida, have extended the mandate to include facilities like nursing homes. However, despite the impacts of extreme heat on health, cooling centers are not typically required to have backup power. Without access to reliable backup power, critical community facilities like cooling centers are forced to close in the event of a power outage.

Technical Considerations for Resilient Power

To learn more about the technical considerations for installing resilient power at a cooling center, such as the design and energy needs of the facility's heating, ventilation, and air conditioning (HVAC) system, see Appendix A for more information.

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[25] This definition of Resilience Hubs is defined by the Urban Sustainability Directors Network and can be found here: https://www.usdn.org/resilience-hubs.html.

[26] Flavelle, Christopher, "A New, Deadly Risk for Cities in Summer: Power Failures during Heat Waves," *nytimes.com*, July 2, 2021, https://www.nytimes.com/2021/05/03/climate/heat-climate-health-risks.html (accessed September 30, 2022).

Those facilities with backup power capabilities likely rely on a diesel generator. For instance, in California, almost 90 percent of backup generators are diesel.[27] Diesel generators are often unreliable during extended outages, emit hazardous pollutants, and are at the mercy of fuel availability (a major hinderance when considering the likelihood and history of fuel shortages following a disaster). Furthermore, when operated improperly, diesel generators can be dangerous. In fact, carbon monoxide poisonings are a leading cause of death after power outages as people improperly operate diesel generators inside their homes or other poorly ventilated spaces. One study found that 83 percent of fatal disaster-related carbon monoxide poisonings in the United States were attributed to improper generator use.[28]

Inequitable Access to Cooling

In the event of a heatwave, oftentimes emergency preparedness alerts will encourage people to stay cool by staying indoors. In low-income communities and communities of color, the multi-level housing infrastructure can actually make for even more dangerous heat-related conditions because the temperature inside the building increases with each additional apartment floor, and air conditioning can be limited (if available at all). Apartments are the least likely of all housing types to have air conditioning. Only 80 percent of 1-to-5-unit buildings and 85 percent of over-5-unit buildings use air conditioning. Comparatively, 90 percent of single-family households have air conditioning; although, renters of single-family homes are less likely to have air conditioning.[29]

Coast Guard shallow-water response team personnel assist 142 residents at Panama City Health and Rehabilitation Center in Panama City, Florida, Oct. 11, 2018, following Hurricane Michael. The Center needed food, water, and portable oxygen for their patients.

Photo: US Coast Guard

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[27] M. Cubed and Bloom Energy, "New Study Shows a Rapid Increase of Diesel-Fueled Backup Generators across California," *businesswire.com*, October 6, 2021, https://www.businesswire.com/news/home/20211006005088/en/New-Study-Shows-a-Rapid-Increase-of-Diesel-Fueled-Backup-Generators-Across-California (accessed September 30, 2022).

[28] Iqbal, Shahed, and Jacquelyn H. Clower, et al., "A Review of Disaster Related Carbon Monoxide Poisoning: Surveillance, Epidemiology, and Opportunities for Prevention," AM J Public Health, 2012 October; 102(10): 1957–1963, *ncbi.nlm.nih.gov*, October 2012, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3490658 (accessed September 30, 2022).

[29] Beall, Ross, and Bill McNary, "Nearly 90% of U.S. Households Used Air Conditioning in 2020." *eia.gov*, May 31, 2022, https://www.eia.gov/todayinenergy/detail.php?id=52558 (accessed September 30, 2022).

As power outages become more commonplace, many individuals with mobility challenges fear that if they stay in their apartment building during an extreme weather event, they could be trapped when the power goes out and elevators no longer function. For more than a week after Hurricane Sandy hit in 2012, New York City public housing residents, many elderly and frail, were still stuck in their apartments without power and without functioning elevators.[30]

Carbon monoxide poisonings are a leading cause of death after power outages as people improperly operate diesel generators inside their homes or other poorly ventilated spaces.

There's also the issue of cost of air conditioning. Inflation and sky-high fuel prices have forced most Americans to re-evaluate their budgets. Utility expenses are not immune. As heatwaves linger, lower-income households using air conditioners can struggle to pay their electricity bills. One California resident stated it clearly, "I can't afford to live." She couldn't afford to run both her electricity-dependent oxygen concentrator and the air conditioner. The technologies were co-dependent: the oxygen concentrator would overheat and shut off for periods of time without air conditioning keeping the unit cool.[31] In Georgia, a Salvation Army facility operating as a cooling center was overwhelmed with people retreating from over 100-degree temperatures. Many newcomers to the cooling center had air conditioners at home, but for some, the cost of running an AC was too high and for others their AC wasn't enough to combat the extreme temperatures inside.[32]

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[30] Smith, Greg B., "A Living Hell in NYCHA Houses: Agency Ignores Blackout Victims Trapped since Hurricane Sandy," *nydailynews.com*, November 7, 2012, https://www.nydailynews.com/new-york/living-hell-nycha-houses-article-1.1197748 (accessed September 30, 2022).

[31] Anguiano, Dani, "'Can't Afford to Live': California Heatwave Leaves Older Adults Teetering on Edge," *theguardian.com*, September 10, 2022, https://www.theguardian.com/us-news/2022/sep/10/california-heatwave-older-adults-public-health (accessed September 30, 2022).

[32] Chow, Denise, et al., "Heat Waves and High Energy Costs Are Hitting Some Communities Hard," *nbcnews.com*, June 19, 2022, https,//www.nbcnews.com/science/environment/heat-waves-high-energy-costs-are-hitting-communities-hard-rcna33978 (accessed September 30, 2022).

Part 4
Resilient Power for Cooling Centers

What is Resilient Power?

Resilient power is the ability to provide a facility with continuous, reliable power even when the electric grid goes down. Truly resilient power should be clean, renewable, and have the ability to provide benefits throughout the year, not just during natural disasters and other power emergencies.[33]

Resilient power—solar PV paired with battery storage (solar+storage)—can provide life-saving backup power in the event of an outage and provide economic benefits during times of regular grid operations. Resilient solar+storage systems offer automatic, reliable, and uninterrupted backup power when the grid goes down. This automatic transition from grid-tied power to grid-independent power is facilitated by a transfer switch, which allows the solar+storage system and interconnected loads to disconnect (or "island") from the grid, and power the facility as a self-contained microgrid. As long as the sun is shining, a well-designed solar PV system can continue to recharge a battery throughout an outage.

Resilient power—solar PV paired with battery storage (solar+storage)—can provide life-saving backup power in the event of an outage and provide economic benefits during times of regular grid operations.

The battery provides backup power to a facility's designated critical loads (such as HVAC for cooling and outlets for charging). Although a battery can be charged from the grid, without onsite solar connected to the battery, it has limited capacity to provide power during an extended outage. Furthermore, pairing battery storage with solar reduces emissions and generates more financial benefits than a battery alone could provide. Solar and battery storage can provide utility bill savings by offsetting grid electricity consumption and by reducing demand for electricity during times of peak grid demand. In some parts of the country, incentive programs have been developed for batteries to help support the grid during times of high demand.[34]

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[33] To learn more about resilient power, see: Mango, Marriele and Seth Mullendore, "Understanding Solar+Storage: Answers to Commonly Asked Questions about Solar PV and Battery Storage," *cleanegroup.org*, October 2020, https://www.cleanegroup.org/wp-content/uploads/Understanding-Solar-Storage.pdf (accessed September 30, 2022).

[34] To learn more about battery storage incentive programs, see: Olinsky-Paul, Todd, "Energy Storage Policy Best Practices from New England: Ten Lessons from Six States," *cleanegroup.org*, August 5, 2021, https://www.cleanegroup.org/ceg-resources/resource/energy-storage-policy-best-practices-from-new-england (accessed September 30, 2022).

Solar+storage system at Boulder Housing Partners (BHP) headquarters in Boulder, CO. The resilient solar+storage system is paired with a backup generator.
Photo: Clean Energy Group

Designing a Resilient Power System: Goals, Constraints, and Managing Expectations

When considering a resilient power system, each facility must first define 1) the intended purpose of the system, 2) potential constraints when designing the system, and 3) expectations for actual system performance.

GOALS

Facilities often have targets for which parts of the building and what critical electricity loads should be supported during an outage, and for how long. Most organizations seek systems that can provide backup power for at least eight hours. Certain parts of the country—such as regions of California that experience wildfires and the hurricane-prone Gulf region—typically request durations of a minimum of 24 hours. Decisions about the duration of power needed from the batteries will need to be made by evaluating the relative importance of cost savings, reliability, and sustainability that a resilient power system can provide. The balance of these three factors will help the resilient power developer deliver a solar+storage system that provides the most value to the site. For cooling centers, reliability is likely the primary goal, and a high degree of performance during hot weather will be paramount.

Resilient Power Components

Resilient power is the combination of solar and battery storage technologies that will provide electricity to facilities during grid power outages.

Solar photovoltaic (PV) panels convert sunlight into electrical energy. However, in the event of a grid outage, solar PV cannot—on its own—provide continued electricity to a facility if it is not designed to island from the grid. This is because most PV systems are connected directly into the utility electric grid. Due to safety concerns, solar systems installed without a battery and transfer switch must therefore automatically shut down during a grid outage.[35]

Battery storage is a rechargeable battery that stores energy from other sources, such as solar arrays or the electric grid, to be discharged and used at a later time. The reserved energy can be used for many purposes, including shifting when solar energy is consumed onsite, powering homes or businesses in the event of an outage, and generating revenue for the system owner by providing grid services. Batteries can charge from any source—such as solar arrays, generators, and/or the grid—so when the grid goes down, they have hours of backup energy stored that can release to continue providing power to the facility.

Hybrid resilient power systems pair solar+storage with conventional fossil-fuel powered generators for additional redundancy in the event of an outage. Generators can be integrated with solar+storage systems to recharge the batteries during periods of low solar production, or they can provide additional power during demand spikes when high-power devices are being operated. The extent to which the systems complement each other depends on the overall system design. To learn more about how fossil-fuel generators can be paired with solar+storage, see Appendix B.

To learn more about general solar+storage system performance, such as factors that determine battery performance and how critical loads factor into a system design and system sizing, see Appendix C.

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[35] For an introductory overview of solar basics, see: Richardson, Luke, "How do solar panels work?" *energysage.com*, April 3, 2022, https://news.energysage.com/solar-panels-work (accessed September 30, 2022).

CONSTRAINTS

Multiple constraint can impact the design of a resilient power system. Every facility will have one or more financial constraints, whether it be a budget cap or a maximum annual outlay of funds. Usually, there are also physical constraints to consider, as the layout of the facility and space available for each of the components may be limited, such as available roof space for the solar panels. Regulatory constraints could be common challenges that affect the design of the solar+storage system if there are specific requirements for utility interconnection or limitations to maximum solar sizing. Electrical constraints are also common and typically not known to the facility staff. These may include required code upgrades to existing electrical panels or utility upgrades required to accommodate a resilient power installation. The same is true for roof condition for the installation of solar panels.

EXPECTATIONS

In some cases, the constraints noted above may limit the achievability of resilient power goals. Solar+storage performance varies widely for any individual building and cannot be assessed without analysis. Through a solar+storage feasibility assessment process, the facility owner will have the technical and economic information needed about each component of solar+storage system design and how the system can be operated. This pre-development process is essential as it sets expectations for what critical services the system can support and for how long.

Through a solar+storage feasibility assessment process, the facility owner will have the technical and economic information needed about each component of solar+storage system design and how the system can be operated.

Factors that Determine Solar+Storage Performance

Four interrelated factors will determine the overall performance of a resilient power system: 1) electrical load needs during an outage, 2) battery energy capacity, 3) solar power availability, and 4) how long the system must continue to operate. Every facility has a different combination of these factors, and a careful evaluation of the system's possible configurations and their respective ability to achieve the site's goals is critical to achieving a satisfactory design.

Resilient load. Also known by other names such as critical load or backup load, resilient load represents the amount of electricity required by the facility to operate during an outage. Some facilities choose to operate at a dramatically reduced capacity during an outage and only seek to support a modest number of essential systems with resilient power solutions. Others may find that their energy requirement during an outage meets or exceeds that of normal operation. Increasing resilient load can decrease the duration that can be supported by batteries during a grid failure, and/or increase the size of battery that is required for the resilient power system to perform to specification.

Battery capacity. The capacity of the battery, measured in kilowatt-hours (kWh), is the primary reservoir of power available during an outage. When all the stored electricity in the battery is discharged, the system is exhausted and will shut down. Increasing battery

Photo: Via Mobility Services

capacity increases the amount of time that it can support the resilient load and increases the system's duration—but it also increases the cost of the resilient power system proportionally. One advantage of a solar+battery storage system over conventional fossil-fuel generation is that it can be re-charged without the need to re-fuel with oil or gas resources. Because the sun is the battery's "fuel," even if the battery becomes exhausted, the solar+storage system can be designed so that the sun and the solar panels are able to sufficiently recharge the battery.

Solar availability. Solar power, if available, replenishes or preserves the battery's stored energy. The extent to which the solar system is capable of completely recharging the battery determines whether the solar-battery combination can provide extended resilience and continuous power. If the solar system can produce 100 percent of the resilient load and the battery is large enough to store excess electricity during the day for use at night, the system will operate indefinitely. Increasing the size of the solar array results in a higher likelihood of fully charging the battery each day, and therefore allowing extended operations.

Endurance (or duration of backup power). Because both resilient load and solar availability will change on daily and seasonal cycles, there is no single factor that determines system endurance. Instead, system owners must understand that the potential results are distributed across a range of probabilities. Many owners are interested in the minimum, or worst-case, scenario for the proposed system; meaning, what is the minimal amount of backup power the battery storage can provide. This worst-case scenario typically occurs when a facility is at peak load and assumes there is no solar available.[36] It is also possible to calculate a typical endurance—the median endurance in any particular window of time throughout the year. For cooling centers, this window of interest is normally the hottest summer months, and the limiting case is often a point of time in August when the weather is still quite warm but solar production has begun to wane due to shorter daylight hours. To learn more about the factors that impact endurance, including seasonal variability, see Appendix D.

Resilient Load Planning

Identifying the loads that will be necessary for the facility's continued operation during an outage is a vital step in the design and planning processes. The operational plan for a building and the resulting power requirements are the foundation for most of the decisions that follow and are related to planning for how to manage and control backup loads during an outage. In some cases, individual loads are scattered across multiple electrical panels throughout a building; if so, the entire building will have to be powered, and some means of shutting off noncritical loads may be necessary. In other buildings, the essential loads are consolidated onto just one panel (i.e., a "critical load panel" or "resilient load panel") that is electrically isolated from the rest of the building during an outage. If that configuration of the system is possible, the amount of load supported as well as the size and cost of the system can be minimized.

Identifying the loads that will be necessary for the facility's continued operation during an outage is a vital step in the design and planning processes.

The ability to adjust the resilient load ("load flexibility") can be a valuable tool for a cooling center. On a bright midsummer day, it's possible to run more loads and still replenish the battery than during a cloudy late-summer outage. The ability to adjust the load based on the performance condition of the solar+storage system may allow for a less expensive system overall, because the highest energy load requirement need not be satisfied 100 percent of the time.

To learn more about load control and flexibility, see Appendix C.

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[36] Peak load is the maximum amount of energy that a consumer draws from the grid (or a resilient power system) during a period of time.

Part 5
Solar+Storage for Cooling Centers

Case Studies by Region

In this section, several case studies are presented that represent actual facilities in seven geographic regions. Each of the facilities is interested in installing solar+storage to support cooling capabilities as part of their resilient power operational plan. All the facilities analyzed received one-on-one technical support and small grant funding through Clean Energy Group's Technical Assistance Fund (TAF) to conduct resilient solar+storage assessments.[37] The names and details of each property have been withheld to maintain participant privacy.

For the purpose of these case studies, the economic analyses *did not include* state or federal incentives. An overview of potential incentives, including the updated federal Investment Tax Credit, and how incentives impact project economics is detailed in the following section, "Economic Opportunities and Obstacles."

Cooling Center Case Studies: Solar+Storage Assessments of Seven Facilities

Each of the cooling centers in the case studies below has received a solar and battery storage feasibility assessment prepared by American Microgrid Solutions (AMS).[38] A solar+storage assessment is the first step in the resilient power development process and provides in a comprehensive summary of technoeconomic considerations for solar+storage for a specific facility. The assessment includes how much a solar PV and battery storage system would cost, where it would be located, potential obstacles (such as electrical or roof concerns), economic benefits (such as utility bill savings), and the amount of time the battery could provide reliable backup power to power specific loads.

Facilities have been chosen based on geographic diversity so as to convey the obstacles and opportunities specific to each region of the country.

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[37] To learn more about Clean Energy Group's Technical Assistance Fund, visit: "Resilient Power Project Technical Assistance Fund," *cleanegroup.org*, https://www.cleanegroup.org/ceg-projects/resilient-power-project/technical-assistance-fund (accessed September 30, 2022).

[38] From concept to commission, AMS delivers hybrid power systems that improve security, savings, and sustainability for a wide range of facilities. To learn more about American Microgrid Solutions, see American Microgrid Solutions, "Home," *americanmicrogridsolutions.com*, 2020, https://www.americanmicrogridsolutions.com/ (accessed September 30, 2022).

Clean Energy Group's Technical Assistance Fund

As part of its Resilient Power Project, Clean Energy Group manages the Technical Assistance Fund (TAF), which supports resilient power development in low-income, environmental justice, and communities of color. The TAF provides funding to qualifying organizations to support the first step in the solar+storage development process: completing a feasibility assessment. This assessment provides critical insights into the project economics and components for developing solar+storage at a specific facility. Once completed, the organization can utilize the results of the assessment to help with obtaining financing, grant support, or to engage a developer.

Organizations that receive TAF funding provide essential services to vulnerable communities in the event of a power outage. Past recipients have included municipal facilities, affordable housing providers, health clinics, and community facilities, such as community centers, food pantries, and cooling centers. To date, the TAF has provided over $1 million in funding for feasibility assessments to over 100 affordable housing and nonprofit community organizations, representing resilient solar+storage projects across 22 states, the District of Columbia, and Puerto Rico.

To learn more about the TAF, or to apply, visit www.cleanegroup.org/ceg-projects/resilient-power-project/technical-assistance-fund.

View of the 20-kW Sunverge battery storage system at the Clinica Profamilia in San Juan, Puerto Rico. This community medical clinic was the recipient of technical and financial support from CEG's Technical Assistance Fund, enabling the installation of a resilient solar+storage system.

Photo: Clean Energy Group

SITE 1

Library in the Southeast

Facility Description: A library in a major metropolitan area that is located in a low- and middle-income community and is subject to very hot days. The facility already had a solar array, therefore the analysis focused on installing battery storage and connecting it with the existing solar system.

Resilience Goal: The facility completed its own load analysis and found that the solar+storage system must support a 56-kW peak load, with 700 kWh of load per day in the summer.

HVAC system: Single large central A/C unit

Considerations: This site did not have an existing backup generator or plans to install a generator. Because of this and the size of the facility's cooling system, power control was a paramount consideration. The large central HVAC unit, if allowed to draw an uncontrolled starting surge, could require nearly 170 kW on its own and therefore requires a hard-start or soft-start kit.[39] The peak load of the site is more than double the peak load of resilient operations, which means a battery sized for the resilient load will not be able to power all the loads during a black start; some loads must be shut off before the system attempts to restart.[40]

Site 1: Library	
Region: Southeast	
Annual electricity consumption (kWh)	488,000
Ratio of backup load consumption to annual consumption (percent)	41%
Solar installation size (kWdc)	115
Annual solar production (kWh)	151,000
Ratio of solar production to backup load consumption (percent)	75%
Battery power (kW)	100
Battery capacity (kWh)	198
Duration of backup power (Minimum) (hours)	3
Duration of backup power (Typical) (hours)*	12
Total solar+storage system cost	$182,000
Year 1 utility savings	$6,600
Annual operations and maintenance cost	$2,700
Net Present Value of installation (20-year at 6% discount rate)	($152,000)

* All typical results greater than 72 hours are capped at 72

Constraints: This site had a challenging budget to be able to purchase a large battery system. Therefore, rather than the battery being sized to fit the resilient loads, it was sized to fit the budget (resulting in a much smaller battery). With these limitations, extended resilience durations are not possible during the hottest summer months because the solar system cannot produce enough to replenish the load in use, and because the battery cannot store enough energy to routinely get through the night.

Duration of Backup Power: Three hours minimum, 12 hours typical.

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[39] To learn more about HVAC start scenarios, see Appendix A.

[40] Black start is restoring power an electric power generator, building, or grid, after a power outage/grid failure, without having to call on external power lines.

SITE 2

Community Center in the Mid-Atlantic

Facility Description: A large community center with multiple temperature zones that can be independently operated. This facility had personnel dedicated to building operations.

Resilience Goal: A cooling center to be established in a portion of the building. The building is 60,000 square feet, but the entire facility would not be used for a cooling center.

HVAC system: Multiple zoned rooftop units of varying sizes.

Considerations: This facility had an existing fossil-fuel-powered generator that was already set up to provide backup for a portion of the building. The generator would remain separate and support separate loads from the new solar+storage system. A major consideration was the reduction in resilient load because full building backup would have resulted in a prohibitively expensive system.

Constraints: The square footage to be used for the cooling center was identified, along with the HVAC units that serviced it, to minimize the amount of the building that needed support. The resilient load forecast was adjusted to reflect the reduced installation footprint, and an operational plan was put into place where the staff would monitor the indoor temperature, adjusting it to a higher minimum temperature before the battery started to run low to preserve as much power as possible.

Site 2: Community Center

Region: Mid-Atlantic	
Annual electricity consumption (kWh)	1,070,000
Ratio of backup load consumption to annual consumption (percent)	37%
Solar installation size (kWdc)	237
Annual solar production (kWh)	323,000
Ratio of solar production to backup load consumption (percent)	83%
Battery power (kW)	250
Battery capacity (kWh)	2000
Duration of backup power (Minimum) (hours)	27
Duration of backup power (Typical) (hours)*	72
Total solar+storage system cost	$2,160,000
Year 1 utility savings	$41,000
Annual operations and maintenance cost	$36,000
Net Present Value of installation (20-year at 6% discount rate)	($835,000)

* All typical results greater than 72 hours are capped at 72

Duration of Backup Power: 27 hours minimum, 72 hours typical. The objective, a minimum of 24 hours backup power, was met with a relatively large battery. The solar installation was enough to provide long-duration backup power throughout the year.

SITE 3

Community Center in the Northeast

Facility Description: A community center that serves a low-income community intended to use a large gymnasium as a cooling center as part of a Resilience Hub.

Resilience Goal: A cooling center to be established in the gymnasium portion of the building.

HVAC system: Hydronic gas-fired heat, end-of-life air conditioning units (packaged and window units mixed).

Considerations: This facility had an existing 30-kW bio-diesel generator. The site has a sustainability goal that requires a net-zero electrical installation.[41] As is common for most net-zero applications, the summer solar production significantly exceeds the historical monthly electricity usage.

Constraints: Extensive renovations are planned at this property, which made it challenging to predict future loads. While the cooling need is relatively low when averaged over a summer month, New England does experience some very hot days, which leads to a worst-case scenario that is much more challenging than the average energy requirement. The bio-diesel generator provides supplemental power in this case and extends resilience significantly.

Site 3: Community Center

Region: Northeast	
Annual electricity consumption (kWh)	50,000
Ratio of backup load consumption to annual consumption (percent)	82%
Solar installation size (kWdc)	43
Annual solar production (kWh)	51,000
Ratio of solar production to backup load consumption (percent)	124%
Battery power (kW)	30
Battery capacity (kWh)	60
Duration of backup power (Minimum) (hours)	3
Duration of backup power (Typical) (hours)*	51
Total solar+storage system cost	$194,000
Year 1 utility savings	$10,700
Annual operations and maintenance cost	$1,700
Net Present Value of installation (20-year at 6% discount rate)	($11,000)

* All typical results greater than 72 hours are capped at 72

Duration of Backup Power: Three hours minimum, 51 hours typical; over one week typical with backup generator. The variance between the three hours minimum and 51 hours typical is due to the occurrence of some very hot days. When temperatures spike that much above average, it greatly reduces the ability of the solar+storage system to keep up with cooling demand, which is why the generator was incorporated as a redundancy measure.

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[41] A net-zero solar system is designed to produce the same amount of electricity the building consumes in one year.

SITE 4

Municipal Facility in the Southwest

Facility Description: A municipal facility intended to be used as a Resilience Hub in an urban desert environment.

Resilience Goal: A cooling center and resilience hub space to be establish in the gathering spaces of the facility. Only part of the building was included in determining resilient load.

HVAC system: Multiple zoned rooftop units of varying sizes.

Considerations: In the Southwest, the increase in solar production from summer to winter is not as dramatic as in other parts of the country, but the cooling need increases proportionally more. Sites in the Southwest are more likely to have the uncommon result where the minimum, or worst-case, scenario for solar+storage occurs in the summer when cooling need is greatest.

Constraints: The roof space available for solar was very limited, making a net-zero electrical installation not possible. No fossil-fuel generator was allowed. The resilience goals had to be modified so that only part of the building was supported by solar+storage in the event of an outage.

Site 4: Municipal Building

Region: Southwest	
Annual electricity consumption (kWh)	146,000
Ratio of backup load consumption to annual consumption (percent)	37%
Solar installation size (kWdc)	40
Annual solar production (kWh)	67,000
Ratio of solar production to backup load consumption (percent)	124%
Battery power (kW)	125
Battery capacity (kWh)	250
Duration of backup power (Minimum) (hours)	28
Duration of backup power (Typical) (hours)*	72
Total solar+storage system cost	$268,000
Year 1 utility savings	$9,500
Annual operations and maintenance cost	$3,300
Net Present Value of installation (20-year at 6% discount rate)	($200,000)

* All typical results greater than 72 hours are capped at 72

Duration of Backup Power: 28 hours minimum, over 72 hours typical. The significant difference between the 28 hours minimum and 72 hours typical is due to the fact that the Southwest has a higher average temperature year-round than other regions and therefore, on days of extreme heat, the ability of the solar+storage system to keep up with cooling demand is limited.

SITE 5

Museum and Community Center on the West Coast

Facility Description: The museum and community center, which is located at the edge of a wildfire zone in Northern California, intended to include a cooling center as part of the site's development as a Resilience Hub.

Resilience Goal: Full building operations.

HVAC system: Multiple zoned rooftop units of varying sizes.

Considerations: The site's two-week resilience goal resulted in a very large solar installation, which allows for excellent performance during the summer. The battery design is large enough that it can reliably carry the building through the night, and the large solar system can recharge the battery even on cloudy days. The addition of a generator in phase 2 would provide backup power in the event of sustained cloudy but hot days.

Constraints: Summer usage is normally low when school is not in session; cooling center operations would require more than the normal load profile. State disaster planning requirements target two weeks of resilience.

Site 5: Museum and Community Center

Region: West Coast	
Annual electricity consumption (kWh)	74,000
Ratio of backup load consumption to annual consumption (percent)	66%
Solar installation size (kWdc)	77
Annual solar production (kWh)	94,000
Ratio of solar production to backup load consumption (percent)	192%
Battery power (kW)	125
Battery capacity (kWh)	220
Duration of backup power (Minimum) (hours)	33
Duration of backup power (Typical) (hours)*	72
Total solar+storage system cost	$557,000
Year 1 utility savings	$21,700
Annual operations and maintenance cost	$4,100
Net Present Value of installation (20-year at 6% discount rate)	($141,000)

* All typical results greater than 72 hours are capped at 72

Duration of Backup Power: 33 hours minimum, over 72 hours typical. This site is an example of how a separate set of resilience goals driven by location-specific hazards can override the typical design considerations for a cooling center. In this case, those goals led to a large, very capable system, and a longer backup power duration.

SITE 6

Middle School Gymnasium in the Northwest

Facility Description: Located in rural community, a Middle School gymnasium intending to be a community shelter during an emergency.

Resilience Goal: Full gymnasium operation.

HVAC system: Multiple zoned rooftop units.

Considerations: This facility had an existing 50-kW diesel generator. The facility had a two-week resilience goal, which resulted in a very large solar installation (larger than needed for net-zero).

Constraints: A budget limitation along with the uncertainty in future load due to HVAC changes and a potential expansion of operations resulted in a phased approach to the installation of solar and battery storage.

Duration of Backup Power: Three hours minimum, over 52 hours typical; two weeks typical with generator. The battery design is large enough that it can reliably carry the building through the night, and the large solar system can recharge the battery even on cloudy days. The generator provides backup power in the event of sustained cloudy but hot days. Supplemental energy from the generator could extend backup power to two weeks.

Site 6: Middle School Gymnasium

Region: Northwest	
Annual electricity consumption (kWh)	157,000
Ratio of backup load consumption to annual consumption (percent)	100%
Solar installation size (kWdc)	161
Annual solar production (kWh)	211,000
Ratio of solar production to backup load consumption (percent)	134%
Battery power (kW)	60
Battery capacity (kWh)	240
Duration of backup power (Minimum) (hours)	3
Duration of backup power (Typical) (hours)*	52
Total solar+storage system cost	$781,000
Year 1 utility savings	$13,400
Annual operations and maintenance cost	$4,900
Net Present Value of installation (20-year at 6% discount rate)	($645,000)

* All typical results greater than 72 hours are capped at 72

SITE 7

Community Center in the Midwest

Facility Description: A new-construction community center intended to be a Resilience Hub for an under-resourced community in a dense urban area.

Resilience Goal: Full building operations.

HVAC system: Multiple packaged rooftop units with gas heat.

Considerations: This facility had an existing 80-kW diesel generator. The packaged rooftop units communicate with the off-site controller. A link between the HVAC controls and the resilient power controller will need to be established to avoid concurrent starting of all HVAC units. Significant winter snowfall is expected at this location, so the generator must be sized to carry the load of the building in case it must provide services due to a winter storm.

Constraints: The site had limited roof space, which constrained solar potential. Winter weather may preclude solar generation for periods of time (i.e., snow fall on solar panels may decrease solar output for long periods of time).

Duration of Backup Power: Two hours minimum, six hours typical; over one week typical with generator. The low solar production (relative to the load) on the site indicates that the battery will routinely need supplemental energy from the generator at night, even during the summer months, which will extend the two-hour minimum (solar+storage only) to over one week for the hybrid system.

Site 7: Community Center

Region: Midwest	
Annual electricity consumption (kWh)	265,000
Ratio of backup load consumption to annual consumption (percent)	100%
Solar installation size (kWdc)	69.5
Annual solar production (kWh)	86,000
Ratio of solar production to backup load consumption (percent)	32%
Battery power (kW)	100
Battery capacity (kWh)	165
Duration of backup power (Minimum) (hours)	2
Duration of backup power (Typical) (hours)*	6
Total solar+storage system cost	$513,000
Year 1 utility savings	$10,800
Annual operations and maintenance cost	$7,200
Net Present Value of installation (20-year at 6% discount rate)	($465,000)

* All typical results greater than 72 hours are capped at 72

Compilation of Data from the Seven Case Studies

ORIGINAL STUDY RESULTS

A compilation of the case study results across all seven sites is depicted in Table 1. These results take into account the unique physical and economic constraints of each individual site, as well as their site-specific resilience goals.

Table 1

Original Study Results

	Site 1 Library	**Site 2** Community Center	**Site 3** Community Center	**Site 4** Municipal Building	**Site 5** Museum and Community Center	**Site 6** Middle School Gymnasium	**Site 7** Community Center
Region	**Southeast**	**Mid-Atlantic**	**Northeast**	**Southwest**	**West Coast**	**Northwest**	**Midwest**
Annual electricity consumption (kWh)	488,000	1,070,000	50,000	146,000	74,000	157,000	265,000
Ratio of backup load consumption to annual consumption (percent)	41%	37%	82%	37%	66%	100%	100%
Solar installation size (kWdc)	115	237	43	40	77	161	69.5
Annual solar production (kWh)	151,000	323,000	51,000	67,000	94,000	211,000	86,000
Ratio of solar production to backup load consumption (percent)	75%	83%	124%	124%	192%	134%	32%
Battery power (kW)	100	250	30	125	125	60	100
Battery capacity (kWh)	198	2000	60	250	220	240	165
Duration of backup power (Minimum) (hours)	3	27	3	28	33	3	2
Duration of backup power (Typical) (hours)*	12	72	51	72	72	52	6
Total solar+storage system cost	$182,000	$2,160,000	$194,000	$268,000	$557,000	$781,000	$513,000
Year 1 utility savings	$6,600	$41,000	$10,700	$9,500	$21,700	$13,400	$10,800
Annual operations and maintenance cost	$2,700	$36,000	$1,700	$3,300	$4,100	$4,900	$7,200
Net Present Value of installation (20-year at 6% discount rate)	($152,000)	($835,000)	($11,000)	($200,000)	($141,000)	($645,000)	($465,000)

* All typical results greater than 72 hours are capped at 72

STANDARDIZED RESULTS OF ASSESSMENTS

Due to the fact that site-specific constraints and performance requirements have such a strong effect on the final resilience power system design, an additional analysis was performed that standardizes some of the variables, such as percentage of backup load and solar sizing, across three endurance scenarios.

For each site, only the required battery capacity size and total system cost vary depending on the endurance scenario. While this is not a perfect basis for comparison, it provides a common baseline from which to extrapolate for other potential cooling center facilities. See the Standardized Results in Table 2.

Table 2

Standardized Results

	Site 1 Library	**Site 2** Community Center	**Site 3** Community Center	**Site 4** Municipal Building	**Site 5** Museum and Community Center	**Site 6** Middle School Gymnasium	**Site 7** Community Center
Region	**Southeast**	**Mid-Atlantic**	**Northeast**	**Southwest**	**West Coast**	**Northwest**	**Midwest**
Annual electricity consumption (kWh)	488,000	1,070,000	50,000	146,000	74,000	157,000	265,000
Ratio of backup load consumption to annual consumption (percent)	50%	50%	50%	50%	50%	50%	50%
Solar installation size (kWdc)	115	237	43	40	77	161	70
Annual solar production (kWh)	151,000	323,000	51,000	67,000	94,000	211,000	86,000
Ratio of solar production to backup load consumption (percent)	62%	61%	204%	92%	254%	271%	65%
Battery power (kW)	85	250	30	125	125	60	125
Annual generator CO_2 emissions avoided (MT)*	3.1	7.2	1.2	1.5	1.0	1.7	1.7
"Low Endurance" scenario (assumes a 4-hour worst-case backup power duration)							
Battery capacity (kWh)	250	550	85	90	45	100	110
Duration of backup power (Minimum) (hours)	4	4	4	4	4	4	4
Duration of backup power (Typical) (hours)	11	12	72	23	19	72	10
Total solar+storage system cost	$551,000	$1,075,000	$254,000	$287,000	$330,000	$420,000	$394,000
"Medium Endurance" scenario (assumes a 24-hour typical backup power duration)							
Battery capacity (kWh)	450	900	23	92	51	65	225
Duration of backup power (Minimum) (hours)	7	7	1	4	5	2	8
Duration of backup power (Typical) (hours)	24	24	24	24	24	24	24
Total solar+storage system cost	$693,000	$1,256,000	$210,000	$288,000	$334,000	$395,000	$476,000
"High Endurance" scenario (assumes a 72-hour typical backup power duration)							
Battery capacity (kWh)	1,100	2,500	65	210	70	95	600
Duration of backup power (Minimum) (hours)	26	26	3	12	8	3	28
Duration of backup power (Typical) (hours)	72	72	72	72	72	72	72
Total solar+storage system cost	$986,000	$2,087,000	$240,000	$372,000	$347,000	$416,000	$669,000

* Assumes appropriately-sized diesel engine for 50 hours per year at 100% power

Standardized results assumptions:

- Backup load is 50% of normal load
- Solar size is the maximum possible
- All batteries are located in an outdoor enclosure
- No fossil-fuel generator
- System cost reflects a "from scratch" installation of system at current pricing; existing solar arrays were not taken into consideration
- Endurance scenarios:
  - "Low" = 4-hour minimum endurance
  - "Medium" = 24-hour typical endurance
  - "High" = 72-hour typical endurance

Key Takeaways

While the specifics of the facilities are different, and the assessments lead to quite different outcomes, there are some trends that become clear based on a review of all the sites and the standardized results.

- **Minimal locational dependence:** Although the seven sites are distributed across the country, the physical location of the building is not normally the determining factor in cooling center resilience performance. The proportion of load attributable to HVAC is typically higher in hot environments; but particular building characteristics, especially amount of backup load, vary more widely and tend to mask the impact of location.

- **Importance of estimating backup loads:** The backup load profile, which is often different than the typical load profile, is the baseline requirement that drives all other decisions. It is dependent on all the characteristics of the facility and backup equipment selection and operation during outages. These factors vary widely across building uses and ages and must be estimated as accurately as possible for each individual site.

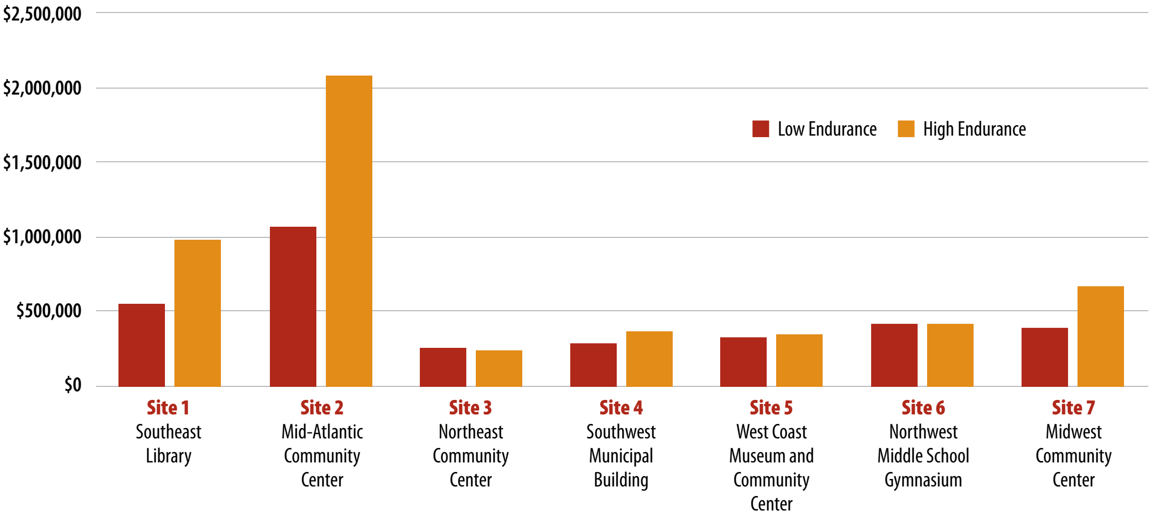
- **Battery size drives short-durance endurance:** The capacity (kWh) of the battery is the main driver for short-duration resilience performance. For design requirements of less than one day, the battery is assumed to carry the load with little solar input (i.e., a low-solar day). That being the case, the duration of backup power is proportional to battery capacity and solar has minimal effect on worst-case performance.

- **Solar performance drives long-duration endurance:** The ratio of solar production to backup load is the main driver for long-duration resilience performance. The ability of the solar system to fully recharge the battery, with some margin to protect against low-solar days, determines whether the system can sustain the building for extended periods. A net-zero solar installation typically overproduces in the summer and is a good target if 100 percent backup load is desired. For most buildings, solar is also the primary savings mechanism so almost all optimal designs maximize the solar installation size.

- **Relationship between system cost and endurance:** As represented in Figure 1, the cost of a resilient power system designed for high endurance (72 hours typical)—compared to a system designed for medium or low endurance—is minimal for four of the seven facilities described in the case studies (Sites 3, 4, 5, and 6). Only the two largest facilities (Sites 1 and 2) have a significant cost difference between the two endurance scenarios. Based on these results, certain facilities (small to medium size) may want to consider investing in a larger battery as the total system cost differential is minimal versus the benefit of a significantly higher endurance.

Figure 1

System Cost per Site: High Endurance vs. Low Endurance



- **Limiting budget constraints:** Most projects have a set budget that limits the proposed resilient power system's maximum power performance. Unlike the standardized resulted, the individual site results include that limitation, so the performance outcomes may be lower than would otherwise be expected based on what the physical and electrical characteristics of the building would suggest—particularly if some of the budget is consumed by related electrical upgrades.

- **Challenging economics.** In most parts of the country, the economics of battery storage remains challenging. Utility savings generated through solar, particularly where net-metering is available, can help to offset the costs of the battery, but it remains an investment that likely won't pay for itself through utility bill savings alone. New federal incentives and determining parameters to factor in a value of resilience could dramatically help improve project economics (to learn more see Part 6: Economic Opportunities and Obstacles.)

- **Emissions reduction:** The generator annual carbon dioxide (CO_2) emissions avoided for each facility are significant. Assuming an appropriated-sized diesel engine operating an average of 50 hours per year at 100 percent power, the smallest facility with the smallest annual electricity consumption (Site 3) would still offset 24 metric tons of CO_2 over a 20-year period. The largest facility (Site 2) would offset over 7 metric tons of CO_2 *each* year. These results make evident that solar+storage solutions greatly reduce the environmental impacts of backup power generation.

Part 6

Overcoming Economic Obstacles through Policy and Valuing Resilience

One of the most significant obstacles to resilient solar+storage adoption is system economics. In many cases, the price of including battery storage for resilience typically makes the entire solar+storage system less cost effective. However, state policies that provide incentives for battery storage, as well as changes to the federal Investment Tax Credit, can greatly reduce lifetime system costs. Additionally, incorporating a value of resilience into an economic analysis can help build a more accurate picture of the monetary value of a resilient power system, beyond utility bill savings. In this section, these topics are explored as opportunities to improve resilient power access in underserved communities, including for cooling centers at critical facilities.

State Policy

The status of current state policy for battery storage is best summarized by Clean Energy Group Senior Project Director Todd Olinsky-Paul in a 2021 report, *ConnectedSolutions: A New State Funding Mechanism to Make Battery Storage Accessible to All:*

> *"…despite the fact that bringing behind-the-meter (BTM) energy storage to scale is key to achieving numerous state clean energy goals, state policy also has not kept pace with advances in the technology…"*[42]

Fortunately, some states are acting as early adopters by demonstrating how policies that incentivize battery storage can spur solar+storage development; several examples are provided here.

ConnectedSolutions. In Massachusetts, the ConnectedSolutions program directs utilities to provide customers (residential, commercial, and industrial) that install battery storage systems with performance payments for allowing the utility to control the discharge from the battery system when systemwide electricity demand is at its peak. Customers are compensated on a pay-for-performance basis for their average kilowatt curtailment during utility-defined peak demand events each season.[43]

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[42] To read the report in its entirety, see: Olinsky-Paul, Todd, "ConnectedSolutions: A New State Funding Mechanism to Make Battery Storage Accessible to All," *cleanegroup.org*, February 2021, https://www.cleanegroup.org/wp-content/uploads/connected-solutions-policy.pdf (accessed September 30, 2022).

[43] To learn more about the success of Massachusetts ConnectedSolutions program, see: Applied Economics Clinic and Todd Olinsky-Paul, "Energy Storage for Winter Grid Reliability How batteries became the low-cost solution for power assurance in Massachusetts," *cleanegroup.org*, December 2021, https://www.cleanegroup.org/wp-content/uploads/Energy-Storage-for-Winter-Reliability.pdf (accessed September 30, 2022).

Energy Storage Solutions. Connecticut's Energy Storage Solutions program, which is administered by the Connecticut Green Bank, is modeled on the ConnectedSolutions program and includes additional equity provisions, such as low-income carveouts and incentive adders for underserved populations.[44] The program includes both an upfront incentive and performance incentive.

Self-Generation Incentive Program (SGIP). In California, SGIP reduced the costs associated with purchasing and installing a battery storage system. SGIP includes a funding carveout called the Equity Resilience Budget, which provides higher incentives for residents and critical community facilities in wildfire-prone communities and disadvantaged and low-income communities. The Equity Resilience Budget is also available to medically vulnerable households in areas of high wildfire risk. In some cases, these incentives cover the full installed cost of a resilient battery system.[45]

State policies that support solar+storage economics through both battery storage incentives and pay-for-performance programs are essential to developing a resilient power market. In order for that market to reach the most vulnerable communities, programs like these must include funding carve-outs and higher incentive amounts for critical community facilities serving vulnerable populations.

State policies that support solar+storage economics through both battery storage incentives and pay-for-performance programs are essential to developing a resilient power market.

Federal Investment Tax Credit

In August 2022, the Biden administration signed into law the Inflation Reduction Act (IRA). The changes made to the Investment Tax Credit (ITC) through the IRA are significant. The ITC is a percent-based tax credit for individuals and organizations installing solar and/or battery storage systems. Prior to the IRA, the ITC was a 26 percent tax credit that was set to reduce to 22 percent in 2023, reducing each year after that. The IRA increased the ITC to 30 percent for the next ten years. Additionally, it provides targeted support for low-income projects through adders – some projects may be eligible for up to 70 percent tax credit. Adders include 10 percent for projects in energy communities (brownfields, former coal mining communities) and 20 percent for projects that serve low-to-moderate income communities.

The IRA also removes barriers for nonprofits to access the ITC by providing a direct payment option instead of a tax credit. Currently, tax-exempt organizations, which do not have the tax burden necessary to utilize the ITC, must jump through hoops to receive

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[44] To learn more about Connecticut's Energy Storage Solutions program, visit: "Introducing Energy Storage Solutions," *energystoragect.com*, 2022, https://energystoragect.com (accessed September 30, 2022) or watch Clean Energy State's Alliance webinar with CT Green Bank: "Connecticut's New Energy Storage Solutions Program: How it Provides Benefits to Ratepayers, Participants and the Grid," *cleanegroup.org*, March 1, 2022, https://www.cleanegroup.org/webinar/connecticuts-new-energy-storage-solutions-program (accessed September 30, 2022).

[45] To learn more about the SGIP program, see: Mango, Marriele, "Preventative Shutoffs are Resulting in a Medical Crisis: Resilient Power Can Help," *cleanegroup.org*, October 29, 2019, https://www.cleanegroup.org/preventative-shutoffs-are-resulting-in-a-medical-crisis-resilient-power-can-help (accessed September 30, 2022).

even a portion of the credit towards their project. Over the past decade, financial models and products have been developed to address this issue, but each of these solutions require financial compromise on the side of the nonprofit and make other priorities, such as local ownership, much harder to achieve.[46] The direct payment option allows nonprofits to receive the benefits of the ITC as a payment, rather than a tax credit, thereby avoiding the complications currently associated with utilizing the ITC as a nonprofit. Direct payment could be a gamechanger for enabling nonprofit financing and ownership of solar and battery storage.

There are additional programmatic limitations, even with the adjustments to the ITC made through the IRA. Only projects below 1 MW automatically get the 30 percent ITC, larger projects need to meet prevailing wage, apprenticeship, and domestic sources requirements. Furthermore, beyond affordable housing, it is currently unclear what types of projects will qualify as a "low-income economic benefit project."

Many of the details for the IRA adjustments to the ITC will be dependent on agency guidelines that have yet to be released at the time of this publication. However, it could be a significant incentive for nonprofit organizations interested in developing solar+storage in underserved communities.

Value of Resilience

The primary drivers for calculating the monetary benefits of solar+storage systems are utility bill savings and revenue through participation in utility programs (e.g., like the ConnectedSolutions pay-for-performance model). System economics can be further improved by incorporating federal and state incentives, such as the Investment Tax Credit.

However, limiting the benefits of solar+storage to these monetary opportunities makes for an incomplete analysis. The reliable backup power the systems provide to critical facilities and the communities they serve in the event of an outage is itself a significant benefit. The money saved by not experiencing an outage—the "avoided costs of outages"—represents the value of losses that would be incurred if a facility were to experience a power outage. For critical community facilities, avoided outage-related costs could range from losses due to interruption of business continuity to loss of life due to lack of medical care or disaster response services.

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[46] Mango, Marriele, "The Inflation Reduction Act Is a Game Charger for Nonprofits Seeking Solar+Storage," *cleanegroup.org,* August 18, 2022, https://www.cleanegroup.org/the-inflation-reduction-act-is-a-game-charger-for-nonprofits-seeking-solarstorage (accessed September 30, 2022).

Blue Lake Rancheria Microgrid Provides Reliable Power during Grid Shutoffs

During a 2019 Public Safety Power Shutoff (PSPS) in California, the Blue Lake Rancheria Microgrid (BLR) provided critical services through the outage.[47] Owned by Blue Lake Rancheria, a federally recognized Native American tribe in northwestern California, the microgrid serves tribal government offices, EV charging, a hotel and casino. During the outage, the hotel hosted eight community-members with medical needs reliant on electricity. The Humboldt County Department of Health and Human Services credited Rancheria with "saving their lives, due to their critical needs for power."

Blue Lake Rancheria Tribe Microgrid Project in Humboldt Bay, CA
Photo: FEMA

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[47] To learn more about the Blue Lake Rancheria microgrid, visit https://www.bluelakerancheria-nsn.gov.

For public health, recognizing the value of resilience has much broader implications. Cooling centers, for instance, can reduce hospitalizations, ambulatory services, and even save lives in the event of an outage during extreme heat. While monetary value for this category of services is difficult to determine, it should nevertheless be factored in as a significant, tangible economic benefit.

A 2019 report by Clean Energy Group, *Resilient Southeast Exploring Opportunities for Solar+Storage in Five Southeastern Cities*, explores resilient solar+storage economics for critical facilities across five Southeastern states. The biggest takeaway from the report: When the value of resilience is factored in, solar+storage makes economic sense for all building types evaluated across all five cities.[48,49]

When the value of resilience is factored in, solar+storage makes economic sense for all building types evaluated across all five cities.

Federal and state policies should recognize the benefits that battery storage provides to vulnerable communities in the event of an outage, as well as to the grid during regular operations. Programs like ConnectedSolutions and Energy Storage Solutions should serve as proof-of-concept demonstrations for the rest of the country, demonstrating that incentivizing battery storage is good for all ratepayers. Solar+storage developers should support critical service providers in their efforts to understand the broad-spectrum of benefits that solar+storage can provide—including valuing resilience in and of itself. In doing so, community organizations, especially those serving the most vulnerable populations, can feel empowered to invest in resilient power systems to keep critical services up and running when the grid fails, including cooling centers.

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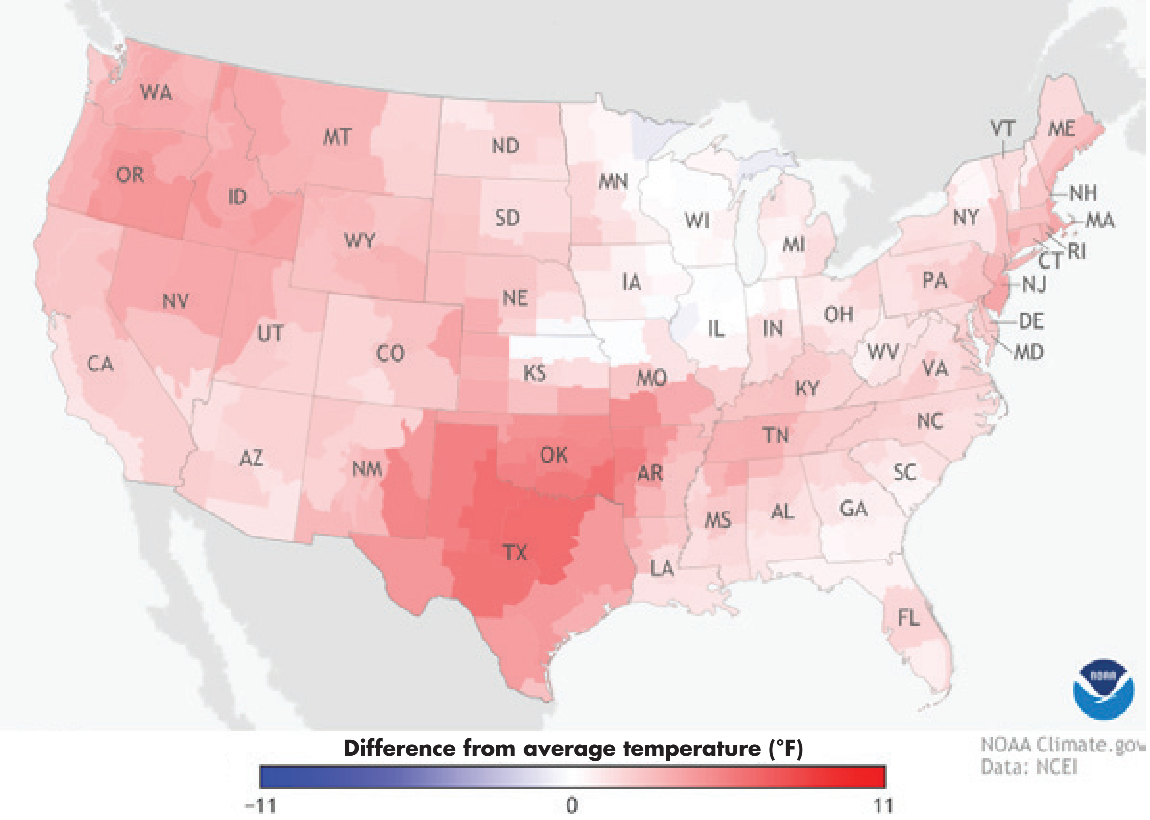
[48] Mullendore, Seth, and Marriele Robinson, "Resilient Southeast Exploring Opportunities for Solar+Storage in Five Southeastern Cities," *cleanegroup.org*, April 2019, https://www.cleanegroup.org/wp-content/uploads/Resilient-Southeast-Series-Overview.pdf (accessed September 30, 2022).

[49] This analysis uses a methodology developed by the Lawrence Berkeley National Laboratory to estimate avoided outage costs, see Lawrence Berkeley National Laboratory and Nexant, Inc., "The Interruption Cost Estimate (ICE) Calculator," *icecalculator.com*, https://icecalculator.com/home (accessed March 22, 2019).

Conclusion

Weather predictions and the impacts of climate change indicate that extreme heat events are going to get progressively worse. Each summer brings with it further evidence that triple-digit temperatures and longer durations of extreme heat are becoming the norm. Yet, air conditioning is still viewed as a luxury and not essential to public health.

Access to cooling in the event of a power outage can be the difference between life or death. This is especially true for low-income communities, communities of color, and medically vulnerable individuals—yet these populations are less likely to have air conditioning or easy access to a cooling center in their community. Until cooling centers are accessible in every community and are equipped with reliable and resilient backup power to provide electricity in the event of an outage, these inequalities will continue to widen, exacerbating public health issues in communities throughout the US.



Heat map detailing increase from average temperatures across the continental US in July 2022 as compared to average July temperature from 1981–2010.
Photo: NOAA

APPENDIX A

Heating, Ventilation, and Air Conditioning System (HVAC) Options, Operations, and Impact on Resilient Power System Design

There are many factors that must be considered when developing a solar+storage system to support cooling equipment, and most importantly is the design and energy needs of the facility's heating, ventilation, and air conditioning system (HVAC). The size of the HVAC system, type, and efficacy are critical components to sizing the battery storage to appropriately backup a cooling center. Below, key topics to consider in assessing a resilient power system for a cooling center. (To learn more about hybrid resilient systems (solar+storage+generator) and alternative cooling options, see Appendix B.)

HVAC equipment upgrades

As HVAC equipment comes to the end of its useful life, facilities have an opportunity to address energy costs as they can replace old equipment with newer, more efficient models. Higher Seasons Energy Efficiency Ratio (SEER) ratings indicate greater efficiency. Both upgraded compressor units and variable-speed air handling motors have been shown to dramatically reduce energy use for comparable interior comfort.

HVAC System Size

HVAC system size will be highly dependent on individual building characteristics. When considering a new HVAC system, a qualified HVAC professional can provide guidance on sizing specific to the features of each facility. Undersized HVAC systems will result in inadequate cooling, and so are likely to be immediately noticed by building occupants. The impact of an oversized system is not as obvious, because it will have no trouble maintaining the desired temperature; however, there are potential downsides. Aside from the excess cost of the HVAC equipment itself and less control of humidity level, oversized HVAC units are significantly less efficient in overall energy use.[50] Also, and of particular interest to a resilient power system, an oversized HVAC system will normally have a larger starting surge, which requires higher power ratings on solar+storage generation equipment to support.[51]

[50] Burdick, Arlan, "Strategy Guideline: Accurate Heating and Cooling Load Calculations," *nrel.gov*, June 2011, https://www.nrel.gov/docs/fy11osti/51603.pdf (accessed September 30, 2022).

[51] Mowris, Robert and Ean Jones, "Peak Demand and Energy Savings from Properly Sized and Matched Air Conditioners," *aceee.org*, 2008, https://www.aceee.org/files/proceedings/2008/data/papers/1_692.pdf (accessed September 30, 2022).

Facility Energy Use: Zoning of HVAC System

The energy use of multiple HVAC units serving discrete areas or zones within a building is more easily controlled than that of a single centralized HVAC unit. If certain areas of the building will not be used during an outage, HVAC units in that zone can remain powered off. In addition, the startup surges from multiple small HVAC units can be staggered to minimize the maximum current the resilient power system must support.

If no zoning is possible and only a portion of the building will be in use during an outage, a mini-split heat pump system may be the most energy-efficient means of providing cooling to a specific area. If that area is not well-served by a central HVAC system (e.g., having one room be too warm when the rest of the building is comfortable), a mini-split heat pump may also add value to the building during normal operations.

Operation Considerations

Consider imposing additional controls on access to the building, especially as it relates to airflow through the conditioned space. For example, to prevent an unintended air exchange, avoid having doors on opposite sides of a building open at the same time. Using revolving doors instead of standard doors also limits air exchange between the interior and the exterior of a building.

Adjustments to the temperature setpoint for the HVAC system directly affects the total energy consumed. Because the total energy input is proportional to the indoor-outdoor temperature difference, raising the temperature setting from 70 to 80 degrees on a 100-degree day can reduce HVAC energy consumption by 33 percent.

Energy usage and power requirements

Estimates of the proportion of total annual energy consumption by a building that can be attributed to HVAC have some variation but are typically near 40 percent.[52] While that is a reasonable starting point, for any given building, that percentage can vary significantly based on a building's envelope and insulation, type and quantity of windows, HVAC equipment, and much more. One way to get a closer estimate of how much energy HVAC typically requires is to calculate the expected annual energy use based only on the "shoulder seasons" (i.e., periods of low HVAC use in spring and fall) and compare it to the annual billed amount. Conceptually, the additional energy used during the summer can be assumed to be mostly from HVAC operation. More detailed information can be obtained by directly measuring the energy consumption of the circuit supplying the HVAC equipment.

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[52] U.S. DOE Quadrennial Technology Review, 2015, Chapter 5, *energy.gov*, September 2015, https://www.energy.gov/sites/prod/files/2017/03/f34/qtr-2015-chapter5.pdf (accessed September 30, 2022).

Start Options

Startup surges from HVAC equipment can be the largest single electrical current draw in a building, and the resilient power system must be sized to accommodate that surge. This is especially true for inverter-based systems using battery storage as the primary source of power. The following are four HVAC start options:

- **Typical uncontrolled motor start.** In the worst case, the HVAC compressor and air handling motors will start up at the same time (in addition to the base load of the facility). Most of these motors are induction motors, which draw their maximum current when the rotor is stationary. While the motor's peak current can be measured directly, a useful proxy for evaluating the initial requirement is to use the locked rotor amperage (LRA) as provided on the machine's label plate. This will typically be 8 times the Rated Load Amperage (RLA) or Full Load Amperage (FLA), which are also noted on the label plate.
- **Assisted start with hard starters.** One way to reduce maximum current is a hard-start device, which can be added to most compressor units. The hard-start device stores energy in a capacitor and rapidly discharges it during startup, lowering the amount of energy required from external systems. These devices are inexpensive but may shorten the life of the compressor if they over-power the motor during starting.
- **Managed start with soft starters.** A soft starter throttles the amount of current available to the motor during start up, resulting in lower current required from external systems. Retrofit kits are available from many suppliers, and while they are more expensive than hard-start kits, they have other benefits such as reduced stress on internal parts.[53]
- **Inverter-based systems.** Newer HVAC systems may use a combination of variable frequency drive (VFD) and variable refrigerant flow (VRF) controls that optimize the energy required for any given set of outdoor conditions and indoor setpoints. These improve the efficiency of the system and can deliver a more comfortable environment while using energy more efficiently. The inverter-based designs can be programmed to ramp up in power at the desired level, which limits the peak current required from the power system.

Controls

A resilient power controller can be configured to communicate with a building automation system (BAS) for linked control of HVAC energy use. Depending on each system's capabilities, the resilient power controller can automatically control temperature setpoints or isolate sections of the HVAC system based on the power system's fuel/battery reserves. The following are three types of controls that can be used for operating a HVAC system:

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[53] Eaton, "Solid-state soft start motor controller and starter," Eaton Application Paper AP03902001E, 2011, *documents.pub*, https://documents.pub/document/effective-february-2011-application-paper-ap03902001e-3-application-paper.html?page=1 (accessed October 7 2022).

- **Manual individual control.** The simplest HVAC systems have individual controls for each independent system. They may or may not be electronic and have humidity controls, but they rarely have the capability to receive external commands. These systems are difficult to control remotely. Without upgrading the thermostat itself, additional electrical components controlled by the resilient power controller can be installed to interrupt power if necessary.
- **Networked individual control.** Many modern electronic thermostats are able to connect to the internet, which affords new opportunities for external control. While the default response is an operator/owner changing to the temperature setpoint after notification of a power outage, there are services available that can monitor and control those setpoints automatically.
- **Centralized control.** Commercial buildings sometimes have some form of building management or automation system (BMS or BAS) that monitors and adjusts building machinery as needed depending on conditions. The BMS/BAS should have the capability to change settings on all of the building's HVAC equipment simultaneously, and they can be programmed to receive external inputs from a resilient power controller. The communication protocol must be taken into account.

HVAC System Types

Below are key descriptors of nine types of HVAC systems that could be used in a cooling center.

1) VARIABLE REFRIGERANT FLOW (VRF)

These are large-scale, ductless HVAC systems that can perform at a high capacity. Complex VRF systems have the ability to both heat and cool different sections of a building simultaneously.[54] They are easy to install, compact enough to install in areas with limited space, and fairly quiet compared to other HVAC equipment. There are three types of VRF systems:

- Cooling Only. Only provide cooling; they have no heating capabilities. For cooling centers in warm climates that do not have a need for heating, this could be an efficient solution.[55]
- Heat Pump. Can heat and cool but not simultaneously. These are most common and can be used in cooling centers that double as warming centers in winter. Additionally, they are small enough to fit in most rooms and do not use ductwork. This frees up space inside the building and makes them less expensive to install.[56]

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[54] "What is VRF in HVAC?," *ferguson.com*, January 23, 2018, https://www.ferguson.com/content/trade-talk/tricks-of-the-trade/what-is-a-vrf-system (accessed September 30, 2022).

[55] "What's the Difference Between VRV and VRF?" *coolautomation.com*, November 17, 2019, https://coolautomation.com/blog/vrv-or-vrf (accessed September 30, 2022).

[56] Peters, Kyle, "VRF Heat Pumps: A Heating & Cooling Technology That Can Make Everyone Happy," *freedoniagroup.com*, March 28 2017, https://www.freedoniagroup.com/Content/Blog/2017/03/28/VRF-Heat-Pumps–A-Heating–Cooling-Technology-That-Can-Make-Everyone-Happy (accessed September 30, 2022).

- Heat Recovery. Allow cooling and heating simultaneously. The user can set the desired temperature in a room to their liking and the VRF system will respond. Heat Recovery systems achieve this by transferring exhaust heat from one area that is currently being cooled to a separate area that is currently being heated. This efficiency can lead to lower energy usage by 30 percent or more.[57]

2) VARIABLE FREQUENCY DRIVE (VFD) FANS

These are electrical devices used to control the rotation speed of an alternating current electric motor by adjusting the frequency of the electrical power supplied to the motor.[58] They can increase efficiency in a HVAC system by adjusting the speed of the motors based on the system load requirements and operation schedule, which results in significant energy consumption reductions. VFD fans can save energy, reduce demand, and prolong the equipment life.

3) PACKAGED ROOFTOP UNITS (RTU)

These units are simple, compact, self-contained units that provide air conditioning to defined areas. They are connected to ducts, which provide defined routes for the RTU to push cool air through. The systems contain everything inside the unit unlike similar counterparts that need to be connected to chillers and boilers to provide their cooling and heating.[59] They are designed to be installed on the roof of commercial and industrial buildings, so they are weatherproof to handle extreme and direct sunlight, heavy rain, snow, or other adverse weather conditions.

4) HEAT PUMPS AND FURNACES

Heat pumps have outdoor condensers that use outside air to cool your facility in the summer and warm it in the winter. They specialize in transferring warm air where it is not needed to where it is needed. If heat needs to be removed from a building, the heat pump will extract the warm air from inside and move it outside creating a cooler environment indoors. Furnaces can only provide heat so are best used for warming centers.

5) GROUND SOURCE HEAT PUMP (GSHP)

GSHPs utilize the stable temperature of the ground to transfer heat to or from a facility. In the winter, the ground temperature will be warmer than the surface air so the system will transfer the heat from underground to the air above ground. In the summer when the surface air is hot, the system will work in reverse and transfer the hot surface air to the ground in exchange for the stable cool ground temperature. They work well in all climates, last longer than standard heating and cooling systems, are more environmentally

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[57] "What are the Benefits of Heat Recovery VRF?," *hitachiaircon.com*, https://www.hitachiaircon.com/au/news/what-is-a-heat-recovery-vrf-system (accessed September 30, 2022).

[58] Li, Yunhua, "Variable Frequency Drive Applications in HVAC Systems," *intechopen.com*, December 9, 2015, https://www.intechopen.com/chapters/49511 (accessed September 30, 2022)

[59] Evans, Paul, "RTU Rooftop Units Explained," *theengineeringmindset.com*, November 11, 2018, https://theengineeringmindset.com/rtu-rooftop-units-explained (accessed September 30, 2022).

sustainable, and require low maintenance. But they can have a high up-front installation cost.[60] There are two main types of GSHP systems: closed-loop and open-loop systems:

- Closed-loop systems circulate antifreeze through a closed loop, which is typically made of a high-density plastic tubing buried underground or submerged in water.
- Open-loop systems use well or surface body water as the heat exchange fluid that circulates directly through the GSHP system. Once it has circulated through the system, the water returns to the ground through the well, a recharge well, or surface discharge.[61]

6) HYDRONIC SYSTEMS

These systems take advantage of characteristics of water, like its heat transfer ability, abundance, low-cost, and non-toxicity. Systems must have a cooling source like a chiller or cooling tower. The cooled water is pumped throughout the building to air handling units where it transfers energy with air from the ventilation system before it recirculates to the cooling source. Hydronic systems are unique in that they pump water throughout the building and not chilled air or other solutions.

7) MINI-SPLITS

Mini-split heat pumps are efficient, energy saving, quiet, and provide climate-controlled zones. Users can control which rooms receive cooling (or heating) and set different temperatures for each room there is a mini-split. Mini-splits run on electricity and are much more efficient than central air systems that use ductwork because the ducts can account for more than 30 percent of energy loss, however their efficiency comes at a higher price point.[62] Mini-splits are a good upgrade option for current infrastructure as they are easy to install and do not require ductwork. They can be mounted on a wall, the ground, or come through the ceiling, which gives them more flexibility than other HVAC units.

8) ENERGY RECOVERY VENTILATORS (ERV) AND DEDICATED OUTDOOR AIR SYSTEMS (DOAS)

DOAS are combined with ERVs to bring in fresh air from outside into a building and pump inside air outside the building. This is critical for replacing the CO_2 people exhale inside buildings with fresh air from outside. DOAS and ERV combine to limit wasted energy during the process of refreshing air inside a building, making them an energy efficient option. Unlike conventional HVAC units, a DOAS brings in fresh air without heating or cooling it, which greatly diminishes the power load.[63]

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[60] "How Much Does a Geothermal Heat Pump Cost?," *energysage.com*, May 3, 2022, https://www.energysage.com/clean-heating-cooling/geothermal-heat-pumps/costs-benefits-geothermal-heat-pumps/ (accessed September 30, 2022).

[61] "Geothermal Heat Pumps," *energy.gov*, https://www.energy.gov/energysaver/geothermal-heat-pumps (accessed September 30, 2022).

[62] "Ductless Minisplit Air Conditioners," *energy.gov*, https://www.energy.gov/energysaver/ductless-mini-split-air-conditioners (accessed September 30, 2022).

[63] "DOAS and ERV controlled ventilation for enhanced comfort and savings," *Be-Exchange.org*, 2019, https://be- exchange.org/wp-content/uploads/2019/06/HPRT_techprimer_DOAS_.pdf.

9) DESTRATIFICATION FANS

These fans circulate air inside large areas like gymnasiums, bringing warm air from the top of the room down to the floor level. Warm air rises so when a building heats its rooms, the warm air will go to the ceiling away from where people are located. To prevent overheating a room, counteract rising hot air, and maintain comfort level, destratification fans bring the hot air back down to the ground level to balance hot and cool air. This improves energy efficiency by reducing the need to continuously heat cooler air.[64] While they are mostly used for heating efficiency in the winter, destratification fans can create pockets of hot and cool air on the ground floor, which creates a comfortable environment for everyone. They can be very useful for cooling centers that double as warming shelters in winter.

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[64] Avedon, Christian, "This is Why You Should Use Destratification Fans," *airiusfans.com*, March 28, 2022, https://www.airiusfans.com/this-is-why-you-should-use-destratification-fans/ (accessed September 30, 2022).

APPENDIX B

Alternative Cooling Strategies

Radiant Cooling System. Heat has a natural tendency to radiate towards cooler bodies to reach thermal equilibrium, which is the point where all temperatures are equal. Radiant cooling takes advantage of this. When heat transfers from one area to another, it creates a cooler environment in the first area. Radiant cooling does this by pumping in cold liquid through pipes in a building and having that liquid in the pipes absorb the hot air as it radiates towards the pipes. This naturally creates a cooler environment around the first area.[65]

Evaporative Cooling. A unique cooling strategy, this system uses water to cool outside air being pulled into the building. Water cools the hot outside air as it enters the building and then is evaporated by that hot air. By introducing the outside air to cool water before it enters the building, the energy needed for other systems to cool that air is reduced as the air is cooled naturally. Due to the systems using evaporation as the cooling method, they work best in dry climates that don't have high humidity, which can make evaporation more difficult.[66]

Thermal Energy Storage. Thermal energy storage works by utilizing lower energy costs from off-peak hours at night (which are cheaper than on-peak hours) to chill water-based solutions for use during the following day. This method shifts a building's demand from the daytime to the nighttime when energy costs are cheaper and flattens out the building's overall energy demand. The chilled solution is pumped through a storage tank and offsets the energy needed by an electric chiller to deliver cool air to the occupants.[67]

Hybrid Resilient Power Configurations

The combination of a solar+storage system and a conventional generator can yield results greater than the sum of their parts. The purpose of the conventional generator is to provide weather-independent power as needed for the facility. However, the generator is limited by the fuel storage on site – and that fuel may be difficult to resupply during a disruption. The extent to which the systems complement each other depends on the overall design.

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[65] "Radiant Cooling," *rehau.com*, https://www.rehau.com/in-en/radiant-cooling (accessed September 30, 2022).

[66] "Evaporative Coolers," *energy.gov*, https://www.energy.gov/energysaver/evaporative-coolers (accessed September 30, 2022).

[67] "Thermal Energy Storage Strategies for Commercial HVAC Systems," *pge.com*, 1997, https://www.pge.com/includes/docs/pdfs/about/edusafety/training/pec/inforesource/thrmstor.pdf (accessed September 30, 2022).

In the descriptions below, the terms "large" and "small" refer to the power ratings of each component (i.e., not the energy capacity), where the "large" version is sized to support the peak resilient load of the building.

- **Large battery—Large generator.** In this system, the battery inverter supports the full building load and is replenished by the solar system. If stored energy runs out, the generator turns on and supports building load while also recharging the battery. When the battery is recharged, the generator shuts down and the battery resumes supporting the loads of the building. The generator runs only when needed (depending on the situation, it may not turn on at all during an outage) and operates at its most efficient load. This system provides true redundancy and can continue operation if either component fails. This type of system typically has a relatively low environmental footprint, the longest endurance, and the most robust backup. It also carries the highest cost.
- **Small battery—Large generator.** In this system, the generator must start and run for the duration of the outage. Some amount of solar power is used during the day to offset the load on the generator, and the battery can discharge stored solar energy at night to do the same, allowing the generator to run with lower load. While this a less efficient way to operate the generator, it will use less fuel each day and therefore extend the resilient duration. This type of system provides extended endurance at a relatively low cost; however, it relies on the generator starting as expected and running at all times. Proper maintenance will reduce the chance of failure.
- **Large battery—Small generator.** As in the large-large combination, the battery and solar support building loads until the battery requires recharging. In this case, the generator is not large enough to carry the full building and the battery remains the load-following component while the generator provides a small amount of supplemental power. While this combination is the least reliant on fossil fuels, it can be difficult to implement for generator ratings below about 200 kW. For small engines, the generator controller may not be capable of synchronizing with and following the battery's lead—but the battery must stay in the lead because an undersized generator is likely to be unstable without additional sophisticated controls. Alternate arrangements (i.e., rectifying the generator's output and DC-coupling it to the battery) are possible but may exceed the cost savings from using a smaller generator. Once a generator is included in the system, it is a relatively small cost increase to raise its power level to the point where it can support the building; for that reason, this arrangement is uncommon unless there is an overriding sustainability concern. This type of system has the best potential for minimizing environmental footprint. However, it is difficult to find components that will work because most small generators are not set up to parallel with the battery, and control systems capable of stabilizing an undersized generator are uncommon.
- **Small battery—Small generator.** Because neither component is large enough to completely cover the building load, both must operate at the same time and automatically share load. While this theoretically has the lowest cost because component sizes are minimized, it also introduces two single-point failures in the system (i.e., if either one has a problem, nothing works). Automatic load-sharing can also be difficult to implement. It can be done using voltage droop matching or other sophisticated controls, but most readily available components are not set up to do so and the additional

cost of robust controls may be more expensive than increasing the generator power. This type of system promises lowest-cost components, but has more opportunity for failure, is the most difficult to control, and will have the longest development cycle of any combination.

- **No battery—Large generator.** It is possible to integrate solar with a generator, though the amount of solar that can be used to offset generator load is both limited and only available during the day. As such, the endurance gain is relatively small and typically not worth the investment in additional controls required.

APPENDIX C

Solar+Storage System Sizing and Operations Considerations

The size of a solar+storage system depends on what critical electric loads it is supporting and for how long. Determining the resilient load profile is essential to determining the size of the battery. Furthermore, how the system is operated will have an impact on how long the battery can remain operational. This section overviews establishing a load profile, evaluating power requirements, and deciding how the facility owner will operate the system.

Establish nominal and resilient load profiles. A load profile, which typically takes the form of an hourly or 15-minute power forecast for a full year, is the basis for every other decision regarding the system. An accurate forecast will enable sound decisions about system size and performance forecasts, while an inaccurate profile may result in system instability or other unpleasant performance surprises.

- **Nominal load profile.** The nominal load profile is used to calculate the economic returns of the system when connected to the grid. Annual or monthly averages do not have the fidelity to show the impact and duration of peak and near-peak days. Interval data is sometimes available from the utility; if not, a resilient power developer, energy auditor, or other energy professional can create a representative nominal load profile.
- **Resilient load profile.** The resilient load profile is used to evaluate the performance of the system during an outage. This load profile is more difficult to define because it reflects energy use during abnormal operating conditions. While it is possible to get a very accurate profile by instrumenting the building and shutting down all nonessential functions, getting such data is disruptive and will only yield a narrow window of data—and a full-year profile is needed to predict full-year performance. Resilient load can be estimated using a simple percentage of normal load, by doing a complete bottom-up analysis of loads with individual profiles (a significant engineering effort), or something in between. The resilient power developer can provide guidance on an approach that is helpful for a particular facility.

Evaluate power requirement. The load-following component of a resilient power system, be it the battery, generator, or both, must be individually capable of supporting the peak load of the building. Designers must be aware that the peak forecasted demand on a 15-minute or 1-hour average is not the true peak demand of the building. The instantaneous peak will be higher, and the specific amount higher will be dependent on the connected loads. It will be highest in the exact condition a resilient power system addresses: a full restart of all running equipment at once (aka "black start"). As such, the power rating of the load-following component should be higher than the peak of the resilient load profile.

- **Conventional generator sizing.** Standard recommendations usually state that its power rating should be set such that the 15-minute or hourly demand peak is no more than 75% than the generator rating.[68]
- **Battery inverter sizing.** Power electronics like battery inverters typically have an advertised surge capacity higher than the continuous rating. An undersized inverter that attempts to exceed that capacity may not restore power at all, and repeated attempts to start the building may result in damage to the inverter.[69] This can be thought of as a more rigid overcurrent limit than conventional generators, and designers should consider more margin for these components. Additional inverter power is a relatively small investment in the overall battery system cost and is worth the extra money especially if there is significant uncertainty in building needs during an outage.

Load Control. How the resilient power system is operated is essential to its how long it will be able to provide backup power to critical loads. The following is a description of four different types of resilient load controls used to operate a solar+storage system: manual, automatic, load adjustment, and load shedding.

- **Manual controls.** In practice, there will always be some level of flexibility in resilient load. When the outage begins, the people running the building should be alerted to the outage and then make decisions based on the forecast return of power. This could be as simple as turning off lights in some parts of the building, raising thermostat set-points, or a more intensive checklist that identifies which breakers should be manually opened to put the building in its resilient condition.
  - **Advantage:** Decision-makers in the building during the outage can make real-time decisions about the priority of loads and adjust the building's operation easily.
  - **Disadvantage:** There must be trained personnel willing and able to come to the site to open and close breakers as necessary.
- **Automatic controls.** It is possible to engineer the system so that automatic actions are taken based on outage conditions. This can be done using a resilient power controller. The programmed functions mirror the manual controls but require no human intervention and thus may happen more rapidly and reliably.
  - **Advantage:** Automatic action protects the system's functionality.
  - **Disadvantage:** Additional cost for equipment; reduced flexibility during an outage because reprogramming on short notice is unlikely.

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[68] "Generator Sizing Guide," Eaton Application Paper TD00405018E, *eaton.com*, 2017, https://www.eaton.com/ecm/groups/public/@pub/@electrical/documents/content/td00405018e.pdf (accessed September 20, 2022).

[69] V. Sharma, "Inverters – General Information," *samlexamerica.com*, 2019, https://samlexamerica.com/wp- content/uploads/2019/12/13012-0614_InvertersGeneralInformation.pdf (accessed September 30, 2022).

- **Load adjustment.** The total amount of energy used at a cooling center will likely be dominated by the HVAC system. Adjustment of the setpoint automatically based on the battery's state of charge and the availability of solar power can allow constant monitoring and adjustment of energy flow to optimize comfort and endurance. This function requires communication between the resilient power controller and the building automation/management system (BAS/BMS) or the individual unit thermostats.

- **Load shedding.** The resilient power controller can be programmed to shut or open switches to certain pieces of equipment based on the battery state of charge. This is an intuitive response to system conditions and can dramatically extend the endurance of the system. However, there may not be a warning that the battery is reaching a low level of charge and during operation some portions of the building could unexpectedly go dark.

The most common way to think about the above actions is in the frame of energy management—controlling how much of the battery's capacity is being used and reacting to its performance. Power management is also important, particularly for systems which must manage a black start. The startup surge from large rotating machines such as HVAC equipment far exceeds the normal running load. Sequencing the startup can avoid being forced to size the system large enough to manage concurrent surges, resulting in a lower system cost. Power management can be implemented in at least three ways, with variations and combinations possible:

- **Automatic trips:** a loss of power automatically opens breakers, which must be manually shut to restore power to that circuit. Shutting in sequence avoids concurrent surges.
- **Resilient power controls:** large equipment is set up with contactors that automatically open on a loss of power. Those contactors are automatically shut by the resilient power controller in the programmed sequence during startup.
- **Pre-engineered panels:** some hardware manufacturers produce load centers that automatically shut and open breakers based on the system's condition. These have a resilient power controller embedded in them and can manage power and energy simultaneously. They are a good choice for facilities undergoing significant renovation and/or expansion of the electrical system.

APPENDIX D

Endurance (Backup Power Duration) Considerations

The main factors affecting the duration of backup power a solar+storage provides are endurance and variability.

Endurance

Factors that impact the duration of backup power provided.

- **Load.** Reducing load or allowing the supported load to adjust to system conditions, extends endurance. Reductions in load also imply reduced building capability during the outage, so there is a lower limit to load reduction beyond which the building cannot support its intended function.
- **Battery capacity.** Higher battery capacity (more kWh) increases endurance, but typically carries a high financial burden. A large battery is especially important if a facility has high nighttime load or if periods of low solar generation are anticipated.
- **Solar availability.** Longer backup power durations are possible when the solar system can reliably produce all of the power that is expected to be consumed during a day. A good design starting point is a net-zero solar system, which is sized to produce the same amount of electricity the building consumes in one year. Because solar production typically increases more than load in the summer for most cooling centers, many summer days will have excess solar production. That excess provides some capability to support building loads and replenish the battery from a previous low-solar day. For facilities with a backup load that is substantially lower than normal load, the solar size can be reduced accordingly.
- **Hybrid systems.** The presence of a conventional generator to form a hybrid resilient power system extends endurance by providing additional onsite stored energy and reducing variability by providing firm backup power in periods of low solar productivity.

Variability

The way that specific times of day or the year can impact resilient power system performance.

- **Daily variation.** Most analyses of resilient power performance assume that the battery is fully charged at the start of the outage. In practice, the battery is likely used to maximize daily economic opportunities and so may not be fully charged when the outage begins. Furthermore, the endurance of the system will be longer if the outage begins at the beginning of a clear sunny day than if it occurs at sunset. A system designed for long-duration endurance (e.g., longer than 72 hours) will tend to ride through this type of variation because the battery will be large enough to get through the night, and the solar system will be necessarily larger than a system designed for shorter-duration endurance. Short-duration system performance has more daily variation because the time of day and near-term availability of solar power make a big difference.

- **Seasonal variation.** Solar production increases in the summer, often by several times more than winter months. However, cooling center load also increases in the summer, but the degree to which it rises depends greatly on the facility. The resulting endurance variation depends on both.
- **Performance metrics.** A complete analysis of the system's performance includes simulation of many outages during the year and a statistical analysis of the results. In doing so, it is possible to pick out minimum (or worst-case) performance as well as typical results on any timescale of interest. This can be translated into a performance narrative for the resilient power system, for example "The system is designed to support the building for 24 hours and will provide 8 hours of backup in the worst-case scenario."

Clean Energy Group (CEG), a national nonprofit organization, works at the forefront of clean energy innovation to address the urgency of the climate crisis. Its mission is to accelerate an equitable and inclusive transition to a resilient, sustainable, clean energy future. CEG fills a critical resource gap by advancing new energy initiatives and serving as a trusted source of technical expertise and independent analysis in support of communities, nonprofit advocates, and government leaders working on the frontlines of climate change and the clean energy transition. CEG collaborates with partners across the private, public, and nonprofit sectors to accelerate the equitable deployment of clean energy technologies and the development of inclusive clean energy programs, policies, and finance tools.

Since 2013, Clean Energy Group's Resilient Power Project has advanced the deployment of resilient, clean energy solutions—primarily solar PV paired with energy storage (solar+storage)—in critical community facilities serving environmental justice communities, low-income communities, and communities of color. The project's goal is to advance clean energy equity and build energy security by ensuring that all communities have access to the economic, health, and resilience benefits that solar and energy storage technologies can provide.

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American Microgrid Solutions (AMS) delivers hybrid power systems that improve security, savings, and sustainability for a wide range of facilities. These microgrids combine solar, battery storage, and conventional generation for the optimal mix of performance, economics, and carbon reduction. From concept to commissioning, AMS provides a turnkey, hassle-free experience to meet our clients' goals, budget, and schedule. AMS supports clients in unlocking this potential and maximizing returns. Using advanced modeling tools and real-world experience, AMS works with clients to identify their needs, design solutions, integrate the technology, and then manage the team that delivers a turnkey solution.

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