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Combined Heat and Power in Resilience Planning and Policy

Issue Brief

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Foreword

This publication was written collaboratively by the U.S. Department of Energy Advanced Manufacturing Office (AMO) staff, AMO support contractors, and Combined Heat and Power Technical Assistance Partnerships (CHP TAPs) staff. Every effort has been made to confirm the accuracy of the provided information at the time of publication.

Combined Heat and Power in Resilience Planning and Policy

For policymakers and planners focused on resilience, combined heat and power (CHP) is an energy-efficient resource that supports efforts to increase resilience at critical facilities and other end-user sites. CHP is a proven solution that provides many resilience benefits to end users, the utility grid, and surrounding communities, as shown in Figure 1. This issue brief highlights CHP's current use in critical infrastructure applications, operational aspects of using CHP to enhance resilience, tools and resources for policymakers, and example approaches for incorporating CHP in resilience planning and policies.

End Users

- Provides a continuous supply of electricity and thermal energy for critical loads
- Can be configured to switch automatically to "island mode" during a utility outage and to "black start" without grid power
- Can withstand long, multiday outages

Utilities

- Enhances grid stability and relieves grid congestion
- Enables microgrid deployment for balancing renewable power and providing a diverse generation mix

Communities

- Ensures critical facilities such as hospitals and emergency services remain operating and responsive to community needs
- Allows areas of refuge to operate during grid outages to provide shelter-in-place opportunities for those in need

Figure 1. Resilience benefits with CHP

CHP in Critical Infrastructure Applications

During and after recent Hurricanes Harvey, Irma, and Maria in 2017, and Hurricane Sandy in 2012, CHP systems enabled a number of critical facilities to continue operations when the electric grid failed. Repeatedly, CHP has proved its value as a dependable source of power and thermal energy (heating and cooling) during emergencies. CHP has been demonstrated as a cost-effective and reliable means of ensuring energy infrastructure's increased resilience in the face of extreme weather events.

Critical infrastructure refers to systems and assets, whether physical or virtual, vital to the United States; the incapacity or destruction of such systems and assets would have a debilitating impact on national security, economic security, public health or safety, or any combination of those matters.[1] Critical infrastructure applications include hospitals, water and wastewater treatment facilities, financial institutions, police and security services, and areas of refuge. Facilities that may serve as areas of refuge include, but are not limited to, schools, colleges, and universities; armories; government buildings; hotels and convention centers; and sports arenas.[2] Prior to September 11, 2001, emergency management planning focused primarily on preparedness and

Who Can Use CHP?

Host facilities must have a consistent electric and thermal demand and a reliable source of fuel (pipeline natural gas, anaerobic digester gas, etc.). Critical infrastructure sectors conducive to CHP include the following:

Airports	Chemicals & Pharmaceuticals	Colleges & Universities	Critical Manufacturing	Data Centers
Distribution Centers	Fire Stations	Food Processing	Food Sales & Supermarkets	Government Facilities
Hospitals & Healthcare	Hotels & Lodging	Laundries	Military Bases	Multifamily Residences
Nursing Homes	Police Stations	Prisons	Schools	Wastewater Treatment Plants

Figure 2. Critical infrastructure sectors conducive to CHP

[1] Critical infrastructures protection, 42 U.S.C.§ 5195c (2011). https://www.law.cornell.edu/uscode/text/42/5195c

[2] NYSERDA. The Contribution of CHP to Infrastructure Resiliency in New York State (2009). https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Other-Technical-Reports/chp-infrastructure-resilency.pdf

response—that is, what happens at the moment of an emergency and in the minutes, hours, days, and weeks thereafter. In the years since 2001, however, the idea of infrastructure resilience in key assets, systems, and functions—the ability to maintain operations despite a devastating event—has become a key principle in disaster preparedness.[3] Resilience is increasingly important, given the frequency of recent hurricanes and other natural disasters.

CHP provides an opportunity to improve and contribute to critical infrastructure resilience, mitigating the impacts of an emergency by keeping critical facilities running without any interruption in service. If the electricity grid is impaired, a properly configured CHP system can continue to operate, ensuring an uninterrupted supply of power and heat to the host facility. The installation of CHP systems at select critical facilities could increase their ability to ride through a prolonged electrical grid outage. The uninterrupted functioning of critical facilities also increases the resilience of the surrounding community.[4]

Critical facilities are typically outfitted with backup generators to supply electricity for on-site needs in the case of a grid failure.[5] CHP systems have several advantages over backup generators and provide their host facilities with continuous benefits, rather than just during emergencies. The table below highlights the advantages that CHP systems have over backup generators. However, in some sectors, such as hospitals, the presence of a CHP system may not override the necessity of a backup generator, which is required by current law.

Table 1. CHP Compared to Backup Generation

Metric	CHP	Backup Generation
System Performance	▪ Is designed and maintained to run continuously ▪ Provides better performance and reliability	▪ Is used only during emergencies
Fuel Supply	▪ Typically uses natural gas infrastructure that is not impacted by severe weather	▪ Is limited by on-site storage—finite fuel supply for diesel generators*
Transition from Grid Power	▪ May be configured for “flicker-free” transfer from grid connection to “island mode”	▪ Entails a lag time that may impact critical system performance
Energy Supply	▪ Supplies both electricity and thermal energy (heating, cooling, hot/chilled water)	▪ Supplies only electricity
Emissions	▪ Typically is natural-gas-fueled ▪ Achieves greater system efficiencies (80%) ▪ Produces lower emissions	▪ Commonly burns diesel fuel**

**Some backup generators are fueled by natural gas.*

***Some backup generators have installed environmental controls to help reduce emissions.*

Operational Requirements for CHP in Critical Infrastructure

Not all critical infrastructure facility types can support CHP. To utilize the outputs from a CHP system, a facility must have a consistent demand for both electricity and thermal energy, as well as access to a reliable fuel source. CHP systems installed for resilience at critical infrastructure facilities have higher performance requirements than CHP systems in non-critical facilities. These requirements may also come with additional costs. To ensure uninterrupted operation during a grid outage, the CHP system must have the following features:

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[3] FEMA. Developing and Maintaining Emergency Operations Plans, Comprehensive Preparedness Guide (CPG) Version 2.0 (2010). https://www.fema.gov/media-library/assets/documents/25975

[4] ICF (prepared for Oak Ridge National Laboratory). Combined Heat and Power: Enabling Resilient Energy Infrastructure for Critical Facilities (2013). https://www.energy.gov/sites/prod/files/2013/11/f4/chp_critical_facilities.pdf

[5] FEMA. Emergency Power Systems for Critical Facilities: A Best Practices Approach to Improving Reliability (2014). https://www.fema.gov/media-library/assets/documents/101996

- **Black-start capability:** The CHP system must have a battery-powered starting system.
- **Generator capable of operating independently of the grid:** The CHP electric generator must be able to continue operation without the grid power signal. High-frequency generators (microturbines) or DC generators (fuel cells) need to have inverter technology that can operate independently from the grid.
- **Ample carrying capacity:** The facility must match the size of the CHP generator to the critical loads.
- **Parallel utility interconnection and switchgear controls:** The CHP system must be able to properly disconnect itself from the utility grid and switch over to providing electricity to critical facility loads.

The Importance of Design for Resilient CHP Systems

When designing a CHP system for reliability, both power reliability requirements and geographic factors need to be considered. Design criteria of the CHP system, enclosure, and mounting system, as well as a variety of other design criteria, can significantly affect CHP system resilience during severe weather events. Factoring in the types of storm events that are typical for a region can help ensure that the system will not be adversely affected by flooding, high winds, ice, or other factors. Key design considerations for CHP systems at critical facilities can include the following:

- Elevate equipment above flood and storm surge levels.
- Use containerized or indoor systems to protect from high winds and debris.
- Use shock-mount system enclosures in earthquake-prone areas.
- Equip with fire protection systems for above-ground gas delivery systems.

Figure 3. The Texas Medical CHP system remained operational throughout Hurricane Harvey despite significant flooding in the Brays Bayou area. The photo on the left shows Brays Bayou during normal conditions in 2012. The photo on the right shows the flooding caused by Hurricane Harvey in 2017.

Source: DOE. CHP Installation Keeps Hospital Running During Hurricane Harvey.
https://www.energy.gov/eere/amo/articles/chp-installation-keeps-hospital-running-during-hurricane-harvey

CHP for Resilience Tools and Resources

The CHP for Resiliency Accelerator, a collaborative effort between the U.S. Department of Energy (DOE), cities, states, utilities, and other stakeholders, examined the role that CHP can play in resilience planning and critical infrastructure applications. The accelerator produced multiple resources that can support decision making and help policymakers understand how to incorporate CHP in critical infrastructure and resilience planning efforts. These resources are detailed below:

- **Distributed Generation (DG) for Resilience Planning Guide:** This guide provides information and resources on how CHP can help communities meet resilience goals and ensure critical infrastructure remains operational regardless of external events.[6]
- **CHP for Resilience Site Screening Tool:** This Excel-based tool provides individual site screening assessments for CHP based on a variety of user inputs and pre-determined metrics.[7]
- **Distributed Energy Resources Disaster Matrix:** This tool explores how different distributed energy resources (DERs) are impacted by various types of natural disasters. The outputs help stakeholders evaluate the technology options best able to meet resilience priorities.[8]
- **Partner Profiles:** The individual profiles highlight partner successes in resilience planning and programs related to resilience, CHP/DG, or individual CHP/DG projects. Lessons learned are also provided.[9]

The Current Market for Combined Heat and Power in Critical Infrastructure

The DOE CHP Installation Database tracks CHP installations across the country, including those at critical facilities. Figure 4 displays all current CHP installations (known to DOE) at critical facilities throughout the United States.[10]

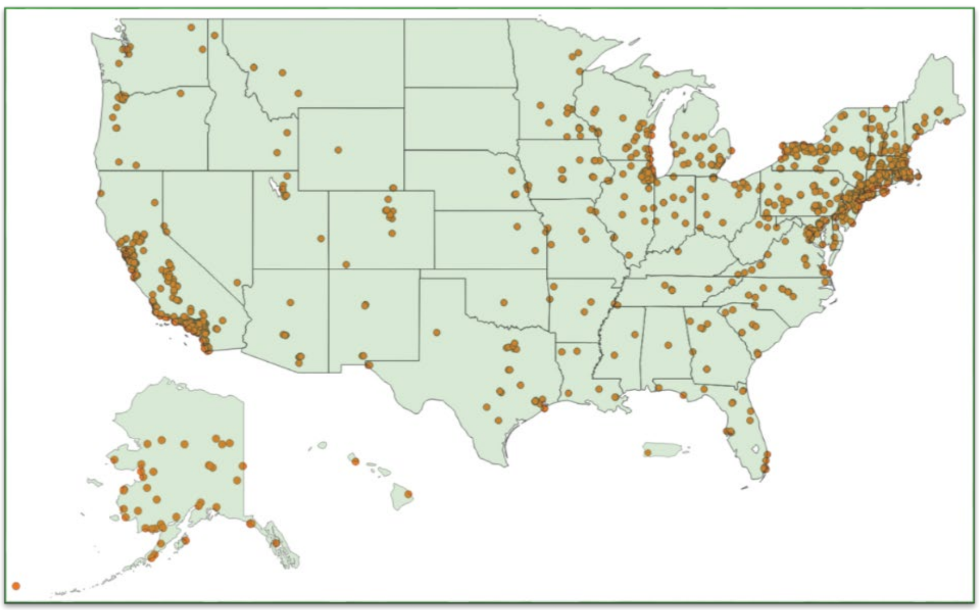

Figure 4. CHP installations at critical infrastructure facilities throughout the United States

Not every critical infrastructure facility is a good fit for CHP. CHP systems are typically installed in critical infrastructure subsectors such as hospitals, food stores and food processing facilities, nursing homes, prisons, colleges and universities, chemical plants, and water treatment facilities. In some cases, CHP systems can also be utilized at areas of refuge and other critical manufacturing facilities. CHP may not be an ideal

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6 DOE. CHP for Resiliency Accelerator. The DG for Resilience Planning Guide. https://resilienceguide.dg.industrialenergytools.com/caseStudies
7 DOE. CHP for Resilience Screening Tool. https://betterbuildingsinitiative.energy.gov/resources/chp-resilience-site-screening-tool-excel-version
8 DOE. DER Disaster Matrix Issue Brief. https://betterbuildingsinitiative.energy.gov/sites/default/files/attachments/DER_Disaster_Impacts_Issue%20Brief.pdf
9 DOE. CHP for Resiliency Accelerator Partner Profiles. https://betterbuildingssolutioncenter.energy.gov/accelerators/combined-heat-and-power-resiliency/chpr-partner-profiles

solution for smaller facilities with limited thermal demand, such as police stations, emergency response facilities, and telecommunication towers. However, if these buildings are clustered, there may be opportunity to provide for the host facilities using a microgrid anchored by a CHP system. Figure 5 highlights the current CHP in critical infrastructure installations by sub-sector.[10]

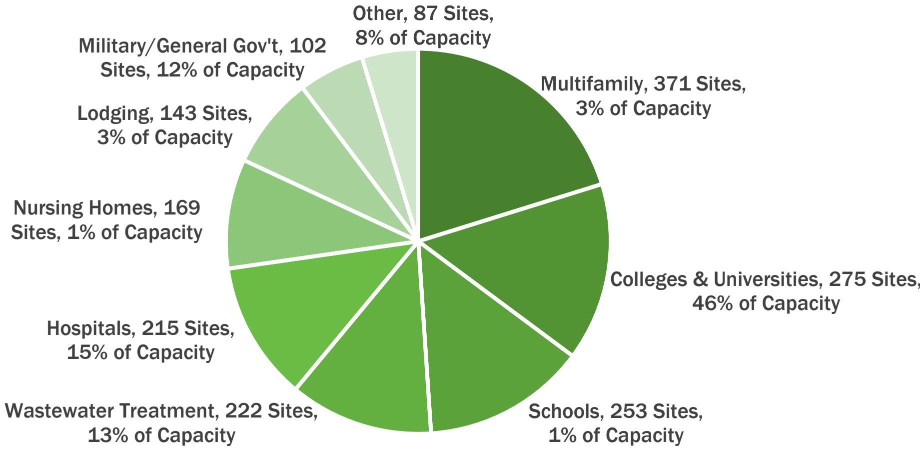

Figure 5. Critical infrastructure CHP installations by sub-sector

Examples of Critical Infrastructure CHP Installations

A variety of examples demonstrate how CHP systems in hospitals have continued operating throughout grid failures. Sustaining hospital operations is always a high priority, but it is an even higher and more widely recognized priority during emergency incidents. It is imperative to ensure that hospitals function during an incident to provide essential emergency response services. Example 1 highlights the University of Texas Medical Branch's (UTMB's) use of CHP to serve this critical healthcare function.[11]

Example 1. University of Texas Medical Branch

UTMB was devastated by Hurricane Ike in 2008, leading to a complete loss of power and thermal energy across the campus. The campus was also flooded with nearly 8 feet of water. To improve energy resilience for the campus and hospital operations, UTMB installed two 7.5 MW CHP systems to provide power, steam, and chilled water to the campus. In addition, significant infrastructure upgrades were made to elevate the existing steam system and one of the new CHP systems and to protect the other CHP system with a floodwall. These improvements were critical in ensuring the CHP system remained operational during Hurricane Harvey while the surrounding grid was without power.

A variety of facilities from several different sectors may be identified as potential areas of refuge. These facilities can play a crucial role in supporting public health and safety, and they possess attributes that make them suitable for a role as an area of refuge. They can provide accommodations for a large number of people, are easily accessible to people in the community, and typically possess kitchens and sanitary facilities, which

[10] DOE. CHP Installation Database. https://doe.icfwebservices.com/chpdb/

[11] Affiliated Engineers. UTMB Galveston CHP system vs. Hurricane Harvey. https://aeieng.com/news/utmb-galveston-chp-system-vs-hurricane-harvey

are required to sustain people dislocated during a crisis. Example 2 highlights the versatility of CHP in serving vulnerable populations during emergencies.

The "DG for Resilience Planning Guide" includes case studies in which CHP provides necessary power and thermal energy to critical facilities such as hospitals, areas of refuge, wastewater treatment plants, universities/schools, and multifamily buildings.[12]

Example 2. The Fajardo Sports Complex

The Fajardo Sports Complex in Fajardo, Puerto Rico, was used as a shelter and distribution center after Hurricane Maria. A 120 kW CHP system provided electricity and refrigeration services to individuals after the storm. The Rafael Hernandez airport in Aguadilla, Puerto Rico, originally installed the CHP system as part of Lufthansa's operations. In the aftermath of Hurricane Maria, the system was relocated across the island to the sports complex to provide emergency services for nearby residents. The system is fueled by local waste biomass resources, such as woody biomass, and is the first non-diesel power generation system in the region.

Policy Approaches for Increasing Resilience through Combined Heat and Power

State and local governments are developing policies to include CHP in critical infrastructure planning, thereby ensuring the energy security and reliability of emergency facilities. The nation's infrastructure is dependent upon electricity. Focusing on infrastructure resilience (instead of protection) enhances critical infrastructure security by investing resources so that, regardless of the attack or disaster, the nation's most critical infrastructure systems will remain functional, and those parts of the system that are compromised will resume functionality as quickly as possible. In this context, the value of CHP to infrastructure resilience is clear. Critical assets across sectors can be insulated from grid disruption through the use of CHP and other forms of distributed energy. Special attention can be paid to the crucial points of infrastructure interdependence, where relatively small investments in distributed energy markedly increase the resilience of the nation's critical infrastructure systems.

A number of market and regulatory factors at the state and utility service territory levels impact how and where DG is deployed during normal operations. Policymakers have played significant roles in developing new initiatives aimed at addressing these factors to encourage the use of CHP and enhance critical infrastructure resilience. Table 2 highlights examples from leading states that have developed policies to enhance resilience through CHP.

Table 2. State Policies Enhancing Energy Resilience through CHP

State	Policy Description
Connecticut	The Connecticut legislature passed Public Act No. 12-148, *An Act Enhancing Emergency Preparedness and Response,* which directed the Department of Energy and Environmental Protection (DEEP) to establish the Microgrid Grant and Loan Pilot Program. This initiative supports CHP-powered microgrids and onsite renewables at critical facilities.[13] DEEP also included a number of strategies in the state's 2018 Comprehensive Energy Strategy, which promotes DG to help keep critical facilities and core services in cities and towns operating during grid outages.[14]
Louisiana	On June 1, 2012, the Louisiana Legislature passed Resolution No. 171, which requests that the Department of Natural Resources and the Louisiana Public Service Commission establish guidelines to evaluate CHP feasibility in critical government facilities. To be deemed feasible, CHP must be able to provide a facility with 100% of its critical electricity needs, sustain emergency operations for at least 14 days, and have 60% efficiency.[15]

[12] DOE. CHP for Resiliency Accelerator. The DG for Resilience Planning Guide. https://resilienceguide.dg.industrialenergytools.com/caseStudies
[13] Connecticut DEEP Microgrid Program. https://www.ct.gov/deep/cwp/view.asp?a=4405&Q=508780
[14] Connecticut 2018 Comprehensive Energy Strategy. https://www.ct.gov/deep/cwp/view.asp?a=4405&q=500752&deepNav_GID=2121
[15] Louisiana Legislature Resolution No. 171.

State	Policy Description
Maryland	The Maryland Energy Administration CHP grant program focuses on encouraging CHP at critical facilities (healthcare, wastewater treatment, and essential state and local government facilities). The program offers incentives up to $575/kW and offers additional incentives for micro-CHP installations (<60 kW); up to $4 million in incentives is available for 2019.[16]
Massachusetts	Massachusetts created the Community Clean Energy Resiliency Initiative (CCERI) in 2014 to support the use of clean energy solutions to enhance energy resilience in the face of several climate events. The program provides grants for a variety of resilient energy technologies, including solar, energy storage, and CHP. The program is administered by the Massachusetts Department of Energy Resources and has currently provided over 40 project implementation and technical assistance awards.[17]
New York	The New York State Energy Research and Development Authority (NYSERDA) recently partnered with the New York State Office of Emergency Management to educate the state's emergency managers about CHP so that it can be included in strategic plans for emergency and place-of-refuge facilities. NYSERDA also implemented a successful CHP incentive program that provided technical and financial assistance for CHP projects that were black-start capable (able to operate independently during grid outages).[18]
New Jersey	New Jersey launched the country's first Energy Resilience Bank (ERB), a resilience financing initiative aimed at funding distributed energy technologies, including CHP, at critical facilities. For CHP, the ERB finances all costs associated with resilience, including black-start components, interconnection costs, flood-proofing, and third-party service contracts. The first project to receive funding approval was the installation of a CHP system at St. Peter's University Hospital in New Brunswick.[19]
Texas	Texas bills HB 1831 and HB 4409 required that, as of September 1, 2009, all government entities (including all state agencies and all political subdivisions of the state such as cities, counties, school districts, institutes of higher education, and municipal utility districts) must identify which government-owned buildings and facilities are critical in an emergency. Prior to new construction or extensive renovation of a critical facility, these entities must obtain a feasibility study to consider the technical opportunities and economic value of implementing CHP.[20]
Washington	In 2015, the Washington State Legislature passed HB 1095, requiring state agencies to conduct a life-cycle cost analysis of energy consumption for each new state building or major renovation. The consideration of renewable energy and CHP as an energy source for new or renovated buildings is required as part of each analysis.

Conclusions

By allowing critical facilities to remain functional in a disaster and enabling non-critical loads to resume functionality as quickly as possible, CHP can effectively support state and local efforts to increase resilience. More deployment of CHP for resilience in critical infrastructure will depend on overcoming institutional barriers and engaging the support of decision makers who build, manage, and operate these facilities. Looking forward, deployment of CHP for resilience will likely include a combination of renewable technologies, energy storage, and increased communication capabilities, often installed in a microgrid configuration. Improved coordination between government emergency planners, the electricity sector, emergency management professionals, distributed energy solution providers, and other stakeholders can support increased resilience and emergency response planning. State utility regulators and other policymakers can facilitate greater coordination to address market and regulatory barriers so that CHP can be more easily installed, making critical infrastructure more resilient in applications across the country.

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[16] Maryland CHP Grant Program. https://energy.maryland.gov/business/Pages/MEACHP.aspx
[17] Massachusetts CCERI. https://www.mass.gov/community-clean-energy-resiliency-initiative
[18] NYSERDA CHP Program. https://www.nyserda.ny.gov/Researchers-and-Policymakers/Power-Generation/CHP
[19] New Jersey Energy Resilience Bank (ERB). https://www.state.nj.us/bpu/commercial/erb/
[20] Texas Bills HB 1831 and HB 4409. https://capitol.texas.gov/tlodocs/81R/billtext/html/HB01831F.HTM, https://capitol.texas.gov/tlodocs/81R/billtext/html/HB04409F.HTM

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