Combined Heat and Power: Enabling Resilient Energy Infrastructure for Critical Facilities

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Combined Heat and Power: Enabling Resilient Energy Infrastructure for Critical Facilities

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Executive Summary

Critical infrastructure (CI) collectively refers to those assets, systems, and networks that, if incapacitated, would have a substantial negative impact on national or regional security, economic operations, or public health and safety. [1] Combined heat and power (CHP) offers the opportunity to improve CI resiliency, mitigating the impacts of an emergency by keeping critical facilities running without any interruption in electric or thermal service. If the electricity grid is impaired, a specially configured CHP system can continue to operate, ensuring an uninterrupted supply of power and heating or cooling to the host facility.

When Superstorm Sandy made landfall on the eastern coast of the United States –New Jersey, New York and Connecticut were the most heavily hit areas. Extended power outages affected the region for days. However, some commercial and industrial facilities in the area were able to power through Superstorm Sandy due to onsite CHP. This report summarizes how these CI facilities with CHP systems operated during Superstorm Sandy. Several examples from other storms and blackout events in other regions of the country are also included. The report provides information on the design and use of CHP for reliability purposes, as well as state and local policies designed to promote CHP in critical infrastructure applications. The following case studies are included in this report:

- South Oaks Hospital - Amityville, NY, 1.25 MW reciprocating engine
- Greenwich Hospital - Greenwich, CT, 2.5 MW reciprocating engine
- Christian Health Care Center - Wyckoff, NJ, 260 kW microturbine
- Princeton University - Princeton, NJ, 15 MW gas turbine
- The College of New Jersey - Ewing, NJ, 5.2 MW gas turbine
- Salem Community College - Carney's Point, NJ, 300 kW microturbine
- Public Interest Data Center - New York, NY, 65 kW microturbine
- Co-op City - The Bronx, NY, 40 MW combined cycle
- Twentynine Palms - Twentynine Palms, CA, 7.2 MW gas turbine
- Louisiana State University - Baton Rouge, LA, 23.7 MW gas turbine
- Nassau Energy Corporation – Garden City, NY, 57 MW combined cycle
- Bergen County Utilities Wastewater Plant – Little Ferry, NJ, 2.8 MW reciprocating engine
- New York University – New York, NY, 14.4 MW gas turbine
- Sikorsky Aircraft Corporation – Stratford, CT, 10.7 MW gas turbine

The requirements for a CHP system to deliver power reliability for a CI facility are straightforward, but may add some costs[2] relative to CHP located at a non-critical facility. In general, a CHP system that runs consistently throughout the year is more reliable in an emergency than a backup generator system that only runs during emergencies. Because it is relied upon daily for needed energy services, a CHP system is also more likely to be properly maintained, operated by trained staff, and to have a steady supply of fuel.

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[1] Patriot Act of 2001 Section 1016 (e)

[2] The ability to seamlessly transfer from being grid interconnected to operating in island mode can cost from $45 to $170 per kW, based on the complexity of the system.

During and after a natural or man-made disaster, CHP can play a vital role in ensuring that the appropriate emergency response services are available and critical infrastructure remains operational. The damage caused by hurricanes along the Texas and Louisiana Gulf Coast in the past several years acted as a focusing event, which propelled the adoption of critical infrastructure policies in these two states. Additionally, due in part to the Northeast Blackout in 2003, storm events, security threats and other concerns, New York State has also been a strong proponent of CHP at critical infrastructure facilities.

Successful application of CHP in CI facilities will depend on engaging the support of decision-makers who build, manage, and operate these facilities, as well as overcoming institutional barriers. To ensure continued progress towards addressing grid and critical infrastructure resiliency through technologies such as CHP, improved coordination between government emergency planners and the electricity sector must occur. State utility regulators can facilitate that coordination and help reduce regulatory barriers to CHP so that these systems can be safely and more easily installed in critical infrastructure applications.

Introduction

The U.S. electric power system is vast and complex, with thousands of miles of high-voltage cables that serve millions of customers around the clock, 365 days per year. Although normally this "instant" supply of electricity is taken for granted, terrorist attacks and natural disasters remind us how dependent we are on electricity and how fragile the grid can be. Nearly every critical infrastructure (CI) application, including – water systems; oil and gas pipelines; communications systems; residential, commercial, industrial, and institutional buildings; transportation; healthcare systems; and emergency operations; is in some way dependent on electricity.

CI collectively refers to those assets, systems, and networks that, if incapacitated, would have a substantial negative impact on national or regional security, economic operations, or public health and safety.[3] These applications include hospitals, water and wastewater treatment facilities, police and security services, and places of refuge. Prior to September 11, 2001, emergency management planning focused primarily on preparedness and 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, the idea of infrastructure resilience—the ability to maintain operations despite a devastating event—has become a key principle in disaster preparedness. Natural disasters such as Superstorm Sandy remind us how dependent we are on electricity and how fragile the grid can be. During times of crisis, it is especially vital that critical infrastructure facilities be without power disruption.

Combined heat and power (CHP) offers the opportunity to improve CI resiliency, mitigating the impacts of an emergency by keeping critical facilities running without any interruption in electric or thermal service. If the electricity grid is impaired, a specially configured CHP system can continue to operate, ensuring an uninterrupted supply of power and heating or cooling to the host facility.

CHP systems are a highly efficient form of distributed generation, typically designed to power a single large building, campus or group of facilities. In the context of critical infrastructure applications, these CHP systems are comprised of on-site electrical generators (primarily fueled with natural gas) that achieve high efficiency by capturing heat, a byproduct of electricity production that would otherwise be wasted. The captured heat can be used to provide steam or hot water to the facility for space heating, cooling, or other processes. Capturing and using the waste heat allows CHP systems to reach fuel efficiencies of up to 80%, compared with about 45% for conventional separate heat and power.[4] This is both environmentally and economically advantageous. CHP systems can use the existing, centralized electricity grid as a backup source to meet peak electricity needs and provide power when the CHP system is down for maintenance or in an emergency outage. If the electricity grid is impaired, the CHP system continues to operate, ensuring an uninterrupted supply of electricity to the host facility.[5]

On October 28, 2012, Superstorm Sandy slammed into the eastern United States, wreaking havoc on local economies, infrastructure, and communities. The storm caused widespread damage and economic

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[3] Patriot Act of 2001 Section 1016 (e)
[4] US Department of Energy, Combined Heat and Power Basics, http://www1.eere.energy.gov/manufacturing/distributedenergy/chp_basics.html
[5] The supply of natural gas is not, in general, dependent on electricity from the grid.

losses across New Jersey, New York, and Connecticut. Extended power outages affected the region for days. At the height of the blackout, 2.6 million facilities, businesses and homes were without power in New Jersey, 2.1 million in New York, and 630,000 in Connecticut.[6] This tri-state area was among the most heavily-hit regions in terms of power outages, and these states were Federal Emergency Management Agency (FEMA)-declared disaster areas.

Figure 2.[7] **FEMA Disaster Areas**

Some commercial and industrial facilities in the area were able to power through Superstorm Sandy due to CHP. This report summarizes how CI facilities with CHP systems operated during this storm. Several examples from other storms and blackout events in other regions of the country are also included. This report also provides information on the use of CHP for reliability purposes, as well as state and local policies designed to promote CHP in CI applications.

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[6] "Powering Through the Storms," Pace Energy and Climate Center.
[7] http://www.fema.gov/disasters

Reliability Benefits of CHP

CHP systems, when designed to operate independently from the grid, can provide critical power reliability for a variety of businesses and organizations while providing electric and thermal energy to the sites on a continuous basis, resulting in daily operating cost savings. CHP systems can be configured in a number of ways to meet the specific reliability needs and risk profiles of various customers, and to offset the capital cost investment for traditional backup power measures.

CI facilities typically have backup generators onsite to supply electricity in the case of a grid failure; however, CHP systems offer several advantages over backup generators. In some sectors, such as hospitals, the presence of a CHP system may not override the necessity of having a backup generator, which is required by law. CHP systems provide regular benefits to their host facilities, rather than just during emergencies. Some advantages that CHP systems have over backup generators include:

- Backup generators are seldom used and are sometimes poorly maintained, so they can encounter problems during an actual emergency. Most CHP systems run daily and are typically better maintained.
- Backup generators typically rely on a finite supply of fuel on site, often only enough for a few hours or days, after which more fuel must be delivered if the grid outage continues. Many CHP systems have a permanent source of fuel on demand; for example, most natural gas infrastructure is underground and rarely impacted by severe weather events.[8]
- Backup generators may take time to start up after grid failure and this lag time, even though it may be brief, can result in the shutdown of critical systems. In many cases, backup generators not permanently located on-site must be delivered to the sites where they are needed, leading to further delays in critical infrastructure recovery. CHP systems are the permanent and primary source of electricity[9] for the site they serve, and if properly sized and configured, are not impacted by grid failure.
- Backup generators typically rely on reciprocating engines burning diesel fuel, a polluting method of generating electricity. CHP systems typically burn natural gas, a cleaner fuel, and achieve significantly greater efficiencies, lower fuel costs, and lower emissions.
- Backup generators only supply electricity; whereas, CHP systems supply thermal loads (heating, cooling, chilled water) as well as electricity to keep facilities operating as usual.

Overall, a CHP system that runs every day and saves money continuously is more reliable in an emergency than a backup generator system that only runs during emergencies.[10] During Superstorm Sandy there were multiple cases of emergency generators that did not function properly such as the

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[8] http://www.naturalgas.org/naturalgas/transport.asp

[9] CHP can be designed to meet some or all of a facility's electricity needs. CI facilities often have ensured their CHP facility is sized to provide the electricity to their top priority energy loads.

[10] NYSERDA collects information on the reliability and availability of some of the CHP demonstration projects funded in New York. Overall, the CHP system reliability figures have shown that they systems are highly reliable. http://chp.nyserda.ny.gov/home/index.cfm

back-up generator at NYU Langone Medical Center[11] and fuel pumps for backup generators failed at Bellevue Hospital after the basement flooded.[12] This forced the hospitals to evacuate patients to other medical centers with CHP systems or backup generators that remained operational during the storm. During the Northeast blackout in 2003, half of New York City's 58 hospitals suffered backup generator failures[13], and the lack of backup power allowed 145 million gallons of raw sewage to be released from a Manhattan pumping station.[14]

Following SuperStorm Sandy, the New York State Energy Research and Development Authority (NYSERDA) conducted an analysis of the operation of CHP systems at sites that had received NYSERDA funding and were located in areas affected by the storm. NYSERDA project managers contacted the 24 sites in affected areas individually. Each site was grouped into one of the following four categories:

- Category 1: Site lost grid power, and the CHP system was designed to operate during a grid outage and operated as expected.
- Category 2: Site lost grid power, and the CHP system was designed to operate during a grid outage, but it failed to operate correctly.
- Category 3: Site never lost power and the CHP system was not put to the test.
- Category 4: Site lost grid power, but the CHP system was an induction unit and not designed to run during a grid outage.

Among the sites that lost grid power, and where the CHP unit was designed to operate during a grid outage, ALL of the CHP systems did perform as expected. There was not a single site that lost grid power, where the CHP unit failed to perform as expected.[15]

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[11] http://www.forbes.com/sites/gregorymcneal/2012/10/29/nyu-hospital-without-power-evacuation-underway/.
[12] http://well.blogs.nytimes.com/2012/11/26/a-return-to-bellevue-after-the-storm/
[13] http://www.txsecurepower.org/Portals/23/Webinar%201_HB%201831.pdf
[14] Ibid.
[15] Email communication from Elizabeth Markham, NYSERDA Assistant Project Coordinator on January 14, 2013 to Northeast CEAC Staff, Timothy Banach and Tom Bourgeois

Context for CHP in Critical Infrastructure Applications

Background on Grid Outages and Critical Infrastructure Needs

Following the Northeast blackout in 2003, and natural disasters such as Hurricane Katrina in 2005, Hurricane Ike in 2008, and Superstorm Sandy in 2012, disaster preparedness planners have become increasingly aware of the need to protect critical infrastructure facilities and to better prepare for energy emergencies. Resilient CI facilities enable a faster response to disasters when they occur, mitigate the extent of damage and suffering that communities endure, and speed the recovery of critical functions. CHP can answer this need while making energy more cost- and fuel-efficient for the user, as well as more reliable and environmentally friendly for society at large. By installing properly sized and configured CHP systems, CI facilities can effectively insulate themselves from a grid failure, providing continuity of critical services and freeing power restoration efforts to focus on other facilities.

The use of CHP systems for CI facilities can also improve overall grid resiliency[16] and performance by removing significant electrical load from key areas of the grid. This is possible when CHP is installed in areas where the local electricity distribution network is constrained or where load pockets exist. The use of CHP in these areas eases constraints by reducing load on the grid. For this reason, CHP placement can be coordinated with the utility; this allows CHP design to be based on the conditions and needs of the host facility, but also on the conditions and needs of the local grid system. Both facility- and grid-level assessments should be part of the cost/benefit analysis for any proposed CHP system at CI facilities.

To ensure continued progress towards addressing grid and CI resiliency through technologies such as CHP, improved coordination between government emergency planners and the electricity sector must occur. Appropriately sized CHP in CI will allow for the continued operation of critical facilities, particularly waste-water treatment plants and medical facilities, during a grid outage. Having critical infrastructure facilities operational during and after a natural disaster will reduce response times of emergency workers to community needs, and allow limited government resources to be utilized in other post-recovery efforts, resulting in a quicker recovery of the community.

CHP Design for Reliability

The aging U.S. electricity infrastructure presents a significant concern to CI facilities in meeting their power needs, as grid outages become increasingly frequent. At a recent electric industry meeting, a representative from the Electric Power Research Institute (EPRI) stated that over $150 billion per year is lost by U.S. industries due to electric network (reliability) problems, and that 500,000 customers are without electricity for a minimum of 1 hour every day in the U.S.[17] CHP systems have demonstrated their ability to provide CI facilities with electric and thermal power during instantaneous as well as prolonged electric utility grid outages (see below case studies).

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[16] Resiliency is defined as the ability of a system to return to its original state after being disturbed. In this paper resiliency refers to the ability to quickly return to a “business as usual” state after a natural disaster or other event causing an electric grid outage.

[17] http://www.galvinpower.org/sites/default/files/Electricity_Reliability_031611.pdf

The primary benefit of a CHP system is that it produces power and thermal energy for the user at a lower cost than the separate heat and power supply it replaces. An additional benefit can be increased energy reliability for the facility if properly incorporated into CHP system design. The reliability of power supply from a typical CHP configuration– a baseload CHP system providing a significant portion of the facility's power and heating/cooling needs with the remaining power needs supplied by the grid – can be higher than the reliability currently offered by grid-only power. In a CHP system designed for reliability, the grid serves as the first level of back-up to the CHP system. When the CHP system is down, either for planned maintenance or due to an unscheduled incident, the grid supplies the entire electricity load to the plant. In the unlikely event that both the CHP system and the grid are down at the same time, critical loads could be maintained through the use of standby generators. In many applications, the value of this additional reliability can outweigh all other factors in the investment decision.

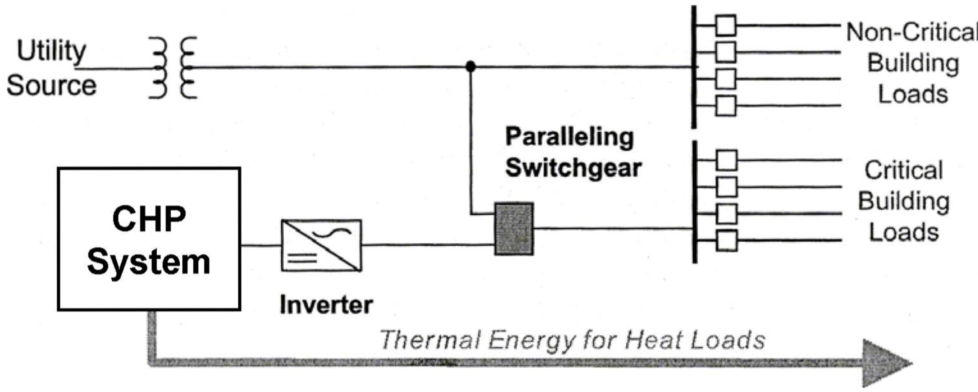
The requirements for a CHP system to deliver power reliability to a CI facility, are straightforward, but often add to system costs relative to CHP located at a non-critical facility (see Table A-1 in the Appendix). While CHP systems may or may not be designed to meet the entire power demand for a facility, the system can be configured to maintain power to critical loads in the event of a utility grid outage. In order to implement this capability, there are often added costs to tie into the critical electrical systems and to devise a load shedding strategy and capabilities. These costs can include engineering, controls, labor and materials. The engineering required to analyze the existing electrical system, determine critical loads, provide a design and determine cost to provide back-up power from the system, may itself be fairly extensive. A system designed to supply the entire power needs of a facility during an outage may need to be oversized compared to the optimal design or require redundant units that would add to the cost.

To ensure uninterrupted operation during a utility system outage, the CHP system must have the following features:

1) ***Black start capability*** – The CHP system needs a battery powered starting device or other supplemental electricity supply system, such as a backup generator, that will allow it to start up independently from the grid.
2) ***Generator capable of operating independently of the utility grid*** – The CHP electric generator must be able to continue operation without the grid power signal (e.g., synchronous generators and supporting controls). High frequency generators (microturbines) or DC generators (fuel cells) need to have inverter technology that can operate grid independently.
3) ***Ample carrying capacity*** – The size of the CHP systems must be matched to the critical loads in the facility.
4) ***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 system must also be able to reconnect itself smoothly after an event. Transfer requirements themselves will impact equipment needs and costs. Facilities that can tolerate a brief power outage while the system is manually transferred to islanding mode will impact costs less than facilities that need to use equipment and controls that provide a seamless transfer.

Figure 1 shows a diagram of a CHP system that is used for power reliability. Further information on the design characteristics of CHP for reliability is provided in Appendix A.

Figure 1. CHP System with Backup Responsibility for Critical Loads[18]



Financial Impact of Grid Outages

Power outages can cause significant financial impacts. For instance, Superstorm Sandy resulted in considerable disruption to businesses. The economic research firm Moody's Analytics attributed nearly $20 billion in losses from suspended business activity.[19] Wall Street's extended closure during Superstorm Sandy included a two-day shutdown of the New York Stock Exchange, which halted financial market trading at a cost of about an estimated $7 billion.[20] IHS Global Insight estimated that the lost output and overall effects of the storms could shave as much as 0.6 percentage points off of annualized fourth-quarter economic growth; and combining all disruptions, early estimates indicate total economic losses to be around $30 to $50 billion dollars.[21] The major disruptions leading to these economic losses included the cancellation of thousands of flights and closure of other transportation services, the two-day shutdown of the New York Stock Exchange, and a number of refineries and several nuclear facilities that were either shutdown or run at a lower capacity.[22]

Rutgers recently published a report on "The Economic and Fiscal Impacts of Hurricane Sandy in New Jersey" that estimates economic losses, not including damages to physical structures, of approximately $11.7 billion in state GDP. [23] The study found that overall GDP losses could have been reduced in New

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[18] EPA CHP Partnership. http://www.epa.gov/chp/basic/benefits.html
[19] http://money.cnn.com/2012/10/29/news/economy/hurricane-sandy-business/index.html
[20] Ibid.
[21] IHS Global Insights. http://press.ihs.com/press-release/country-industry-forecasting/hurricane-sandy-monster-storm-just-time-halloween
[22] Ibid.
[23] Rutgers Regional Report, *The Economic and Fiscal Impacts of Hurricane Sandy in New Jersey*, January 2013. http://policy.rutgers.edu/reports/rrr/RRR34jan13.pdf. This analysis assumed a loss of one week's output for two-thirds of the state's GDP, and then assumes that half of the loss was restored in week two, and the other half in week three. The loss of one week's output for two-thirds of the state's GDP was estimated at $5.56 billion, with losses of $2.78 billion in week two and then $1.39 billion in week three, for a total loss of $9.72 billion over the

Jersey if there had been additional backup sources of power such as CHP, which would have lessened the economic losses associated with power outages.

Other reports have previously analyzed the business implications of power outages.[24] In a 2001 report, EPRI evaluated two million industrial and digital economy businesses to determine the economic costs of power outages and power quality disturbances.[25] The report looked at three specific sectors:

1. Digital Economy (DE) sector: comprised mainly of data storage and retrieval, data processing, or research and development operations such as the telecommunications, data storage, biotechnology, electronics manufacturing, and the financial industry.

2. Continuous Process Manufacturing (CPM) sector: comprised of manufacturing facilities that continuously feed raw materials through an industrial process such as the paper, chemical, petroleum, rubber and plastics, stone, clay, glass, and primary metals industries.

3. Fabrication and Essential Services (F&ES) sector: comprised of all other manufacturing industries, plus utilities and transportation facilities like railroads and mass transit, water and wastewater treatment, and gas utilities and pipelines.

Although the two million businesses analyzed only accounted for 17% of all U.S. businesses, they amounted to 40% of U.S. GDP. Additionally, disruptions in each of these sectors, especially DE and F&ES, have an almost instantaneous effect on other sectors that are dependent on the services they provide. The EPRI study found that industrial and digital economy firms are losing about $45.7 billion per year due to power outages. An additional $6.7 billion in costs resulted from power quality disturbances other than outages. The cost for all industry combined is an estimated at $120 to $190 billion per year. According to the study, New York ranks third in the U.S., behind California and Texas, with an estimated $8.0 to $12.6 billion in costs associated with outages and power quality phenomena.

The New York Times published an article about the struggle that businesses were facing trying to get back to normal operations after Sandy.[26] The article highlights the challenges that core businesses, such as Verizon Communications, the largest telecommunications phone provider in New York, were facing. Verizon's backup power systems failed, leading to a loss in voice, internet, and telephone services in that area. Losses in the financial sector were not as bad as they could have been due in part to backup generators at key financial industry data centers. For example, the New York Stock Exchange has a data

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three weeks. Rutgers estimates that based on current dollars, this yielded a $11.66 billion dollar loss in the fourth quarter of 2012. In calculating this loss, Rutgers included the reduction of residential energy usage to zero for two-thirds of the state for 10-days due to power outages.

[24] Hedman, Bruce and Ken Darrow, EEA, The Role of Distributed Generation in Power Quality and Reliability, Final Report, December 2005, Prepared for NYSERDA, http://www.localpower.org/documents/reporto_nyserda_reliability.pdf.

[25] Consortium for Electric Infrastructure to Support a Digital Society (CEIDS), An Initiative by EPRI and the Electricity Innovation Institute, *The Cost of Power Disturbances to Industrial & Digital Economy Companies*, June 2001, http://www.empoweret.com/wp-content/uploads/2008/09/cost_of_power_outages.pdf.

[26] Schwartz, Nelson, *After Storm, Businesses try to Keep Moving*, The New York Times, October 30, 2012, http://www.nytimes.com/2012/10/31/business/after-hurricane-sandy-businesses-try-to-restore-service.html?pagewanted=all.

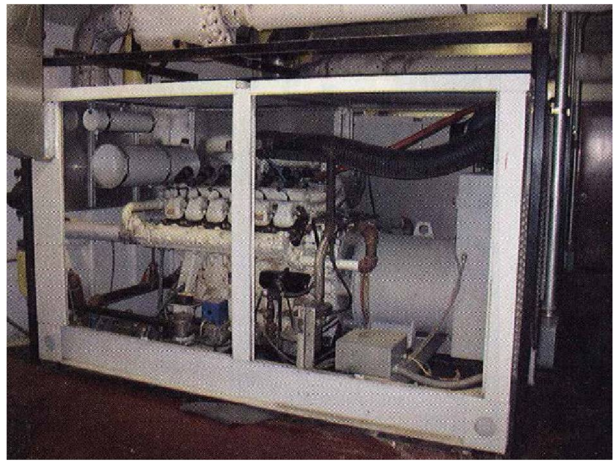
center located in Mahwah, New Jersey, which has backup generators, although not CHP, and was able to continue operation during the storm.[27] An outage occurred at 111 8th Avenue, the Google-owned "carrier hotel" in New York. The building houses major data center operations for Digital Realty Trust, Equinix, Telx and many other providers and networks, as well as 500,000 square feet of office space for Google.[28] Tenants at the 111 8th Avenue complex all experienced some issues related to fuel line and generator failures, along with cooling issues.[29]

[27] http://www.tradersmagazine.com/news/stock-exchanges-going-live-on-halloween-110473-1.html.
[28] http://www.datacenterknowledge.com/archives/2010/12/03/wsj-google-has-bought-111-8th-avenue/
[29] Ibid.

Case Studies

South Oaks Hospital

Facility: South Oaks Hospital
Location: Amityville, NY
Utility: Long Island Power Authority



CHP System Description

South Oaks Hospital is a 245-bed healthcare facility located on the Nassau/Suffolk county border on Long Island, New York. On the same campus are the Broadlawn Nursing Home and the Broadlawn Nursing and Rehab Center, which together have 420 certified beds. South Oaks presently operates five 250 kW natural gas-fired reciprocating engines for a maximum capacity of 1.25 MW. They are now looking into installing a sixth 250 kW generator to ensure that they can operate isolated from the grid, and cover their maximum peak kW summer demand for an extended period of time. In addition to power, the CHP system provides the hospital with steam, cooling and hot water.

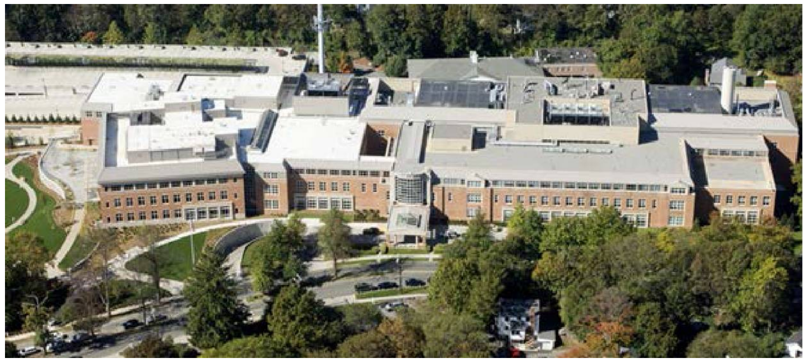
Operation During Superstorm Sandy

South Oaks isolated itself from the Long Island Power Authority (LIPA) grid on the evening of October 28 and remained disconnected from the grid for approximately fifteen days. LIPA was able to restore power to the sub-station that services the facility about five days after the storm. However, the grid was still not stable at that time and LIPA requested that South Oaks remain disconnected from the grid due to continued loss of power and phases in the area. South Oaks was able to provide critical services for two weeks relying solely on their CHP system. They admitted patients from other sites that had been displaced by the storm. They offered refrigeration for vital medicines to those who had lost power and had no means of keeping medicines refrigerated. The staff and local community were welcome to come to the hospital to perform important tasks such as recharging phones and other electronic devices, and having a place to shower.

Site CHP Perspectives

According to Robert Chester, the Director of Engineering, South Oaks has had a long and successful history of CHP operation at their facility. Their first CHP system was 1.3 MW, and consisted of two reciprocating engines, which operated on natural gas and #2 fuel oil. This system operated successfully from 1990 to 2006, including during the Northeast Blackout of 2003. However, New York instituted stricter emissions standards, requiring the installation of a CHP system that could run entirely on natural gas. To meet these state emissions limits, South Oaks installed a new CHP system in 2007. The leadership, management team, and staff, support CHP and agree that CHP has served them well for more than 20 years.

Greenwich Hospital



Facility: Greenwich Hospital
Location: Greenwich, CT
Utility: Connecticut Light & Power

CHP System Description

The Greenwich Hospital is a 175 bed, 500,000 sq ft medical center located in Greenwich, CT. Its CHP system, installed in 2008, consists of two 1,250 kW natural gas-fired reciprocating engines. The hospital also has a 2,000 kW backup generator. The system typically runs 24 hours a day, 7 days a week, except for routine maintenance. The hospital uses the thermal output of the system for hot water and space heating. The hospital also participates in a demand response program with EnerNOC, which calls on the hospital to go off the grid for stabilization purposes if the grid is in danger of an outage. The hospital is compensated at a rate of $30/kW for this service, when called upon to disconnect from the grid. This provides another financial revenue stream from the CHP system, beyond the energy operating savings.

Operation During Superstorm Sandy

The area surrounding Greenwich Hospital lost power due to Superstorm Sandy for approximately 7 days. When the hospital lost grid power, it went down for about 7 seconds before the backup generators kicked in and power was restored. The transition from using grid power to operating solely on the CHP system went as planned, with the CHP system shutting down and restarting in island mode, while power was supplied to the hospital by backup generators. The whole transition process takes approximately 5 minutes. Due to its CHP system, Greenwich Hospital was able to continue normal operations throughout the storm. The hospital admitted 20 additional patients during the outage period, raising the patient count from 136 to 156. In addition, 150 extra staff stayed overnight to ensure the hospital remained fully functioning.[30]

Site CHP Perspectives

Greenwich Hospital's opinion of their CHP system is quite favorable. The system was installed primarily for its cost and reliability benefits. The site has been very pleased with the system and recognizes that the hospital was fortunate to have it in place to provide power during the storm and its aftermath.

[30] http://greenwich.patch.com/articles/next-36-hours-are-critical-as-sandy-arrives-in-greenwich

Christian Health Care Center

Facility: Christian Health Care Center
Location: Wyckoff, NJ
Utility: Orange & Rockland

CHP System Description

The Christian Health Care Center (CHCC) in Wyckoff, New Jersey is a healthcare facility with a wide range of services including assisted living, skilled nursing, psychiatric care and independent senior living. The CHCC currently consists of 12 buildings spread out over an 85-acre campus. The CHP system, installed in 2008, is a 260 kW microturbine running on natural gas. The hospital was able to receive $230,000 in funding for the project by the New Jersey Office of Clean Energy. The microturbine runs 24/7 and provides power to a 300-bed assisted living facility housed in two buildings on the campus. Waste heat is recovered and used for absorption chilling, heating, and hot water.

Operation During Superstorm Sandy

During Superstorm Sandy, the CHCC ran smoothly, with only a momentary loss of power, thanks to its microturbine CHP system and its three emergency backup generators. The CHCC ran independently of the grid for 97 hours, meeting all of its residents' power, heat and hot water needs. No residents needed to be transferred to other facilities. Recent testimony from Capstone (the microturbine manufacturer) before the House Energy and Commerce Committee in February 2013 used the CHCC system as an example to demonstrate the benefits of CHP during Superstorm Sandy.

Site CHP Perspectives

Hadi Raji, the plant operations manager, is pleased with the way the Christian Health Care Center was able to keep its power throughout Superstorm Sandy due to its CHP system. As long as it is affordable, he would recommend a similar system to other facilities. He counts the ability to simultaneously produce power, heat, and hot water as one of the greatest benefits of the system.

Princeton University

Facility: Princeton University CHP Facility
Location: Princeton, NJ
Utility: Public Service Electric and Gas Company (PSE&G)

CHP System Description

Princeton University has a district energy facility which is comprised of a 15 MW gas-turbine CHP system that produces electricity, steam, and chilled water for the campus. The Princeton turbine was the first of its kind in the world to earn certification to operate on bio-diesel fuel and has the ability to switch between natural gas and bio-diesel as price or supply dictates. The CHP system was installed in 1995 and 1996 and began operation in late 1996. The system boasts a 60 to 80% total efficiency depending on the time of year.

Princeton's district energy system has four main components: steam boilers, water chillers, an electric generator, and a large thermal energy storage system. The system supports a total of 150 buildings on campus, including residential and academic buildings, athletic facilities and dining halls. The University's peak load is about 27 MW and the average load is 20 MW to power all facilities, so the University supplements power produced from the CHP system with purchased power from the grid. On a normal day the CHP system provides all of the steam and about half of the electricity for the campus. The University typically produces power during the day from the CHP system, when electricity prices are higher, and buys electricity from the local utility, PSE&G, during the evening when electricity prices drop.[31] The campus also has 6 MW of emergency generators, which are used to support critical assets such as keeping exit lights running in buildings. The entire system serves about 12,000 people each day with power and heat.

Operation During Superstorm Sandy

During Superstorm Sandy, the University was able to continue running normally thanks to the CHP plant. Princeton disconnected from the grid and used its district energy CHP system to power the campus. Non-critical loads around campus such as administration buildings and some classrooms were shut off so that the CHP plant could stay well within its generating capability. The plant produced 100% of campus energy needs from Monday evening to Wednesday evening when the University was able to receive power from the grid again. The CHP system was also able to provide uninterrupted steam and chilled water service. By Thursday morning, power was restored to all buildings on campus. The

[31] http://www.princeton.edu/facilities/info/major_projects/energy_plant/

University declared a campus-wide state of emergency, requiring only critical staff to be at work. Many staff members stayed overnight at the University because of the storm. The CHP plant was vital to maintaining important university facilities such as research labs, experiments and data that could have been compromised by a loss of power.

Site CHP Perspectives

The CHP system at Princeton has garnered a lot of recognition and praise from a number of organizations including the New Jersey Clean Energy Program, U.S. EPA, and the International District Energy Association (IDEA). Most recently the University received a Governor's Environmental Excellence Award in Clean Air from the State of New Jersey. Cost benefits were an important reason for the installation of the system, but it has also helped to greatly reduce Princeton's carbon footprint, supporting the University's overall sustainability goals. Edward T. Borer Jr., Manager of the Energy Plant at Princeton University wrote IDEA the following: "What even fewer people considered was that there was no interruption to steam or chilled water service since all distribution is underground. Yet another reason for district energy!"[32]

[32] http://www.districtenergy.org/blog/2012/11/05/princeton-university-motors-on-through-hurricane-sandy/

The College of New Jersey

Facility: The College of New Jersey
Location: Ewing, NJ
Utility: Public Service Electric and Gas Company (PSEG)

CHP System Description

The College of New Jersey (TCNJ) is located in Ewing Township and includes 39 major buildings set on 340 acres. The current undergraduate enrollment is approximately 6,200 students with 3,600 students being accommodated in residence halls on the campus. TCNJ owns and operates a 5.2 MW gas-turbine CHP system fueled by natural gas. Installed in 1999, the system meets about 90% of the campus's energy needs, produces steam and electricity, and runs nonstop except for routine maintenance shutdowns. The CHP system has an efficiency of 77% and achieves fuel savings of 13% compared to campus energy consumption before installing CHP, reducing carbon emissions by an estimated 900 metric tons. The system is connected to New Jersey's oldest and largest utility, PSE&G. Compared to separate heat and power, the project annually conserves 66 million standard cubic feet of natural gas, and emits 3,800 fewer tons of CO_2. This is equivalent to planting 1,000 acres of trees or offsetting the annual greenhouse gas emissions from 340 households.[33]

Operation During the Superstorm Sandy

During the storm, the TCNJ campus went into "island mode," severing the connection between the campus and the electric grid so that the campus could continue to operate despite grid disruptions. "When the hurricane warnings became more and more threatening, we couldn't take any chances," said Lori Winyard, Director of Energy and Utilities at TCNJ. "Combined heat and power allowed our central plant to operate in island mode without compromising our power supply."[34] The campus stayed in island mode for about a week because of severe utility infrastructure problems. Though TCNJ did not provide power to other off-campus facilities during the storm, TCNJ's equipment was able to assist PSEG in reestablishing service after the grid outage through their dual-feed substation setup. PSEG was able to use TCNJ equipment to back-feed one of their power lines to bring it back in service.

Site CHP Perspectives

TCNJ installed their CHP system primarily for the economic benefits derived from lower overall energy costs; however, the college has experienced large environmental and reliability benefits as well. Lori Winyard, Director of Energy and Utilities at TNCJ, is very pleased with the system and would recommend CHP to other colleges and universities for its economic and operational benefits. To demonstrate thebenefits of the CHP system, the CHP system provides about 47% of the campuses annual electricity needs of 79 million kWh, saving the college an estimated $3.5 million annually.[35]

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[33] EPA Energy STAR Awards, Combined Heat & Power (CHP) Success Stories, http://www.energystar.gov/ia/partners/pt_awards/pt_chp_success_stories.html##college_of_new_jersey.
[34] http://www.cospp.com/articles/2012/11/college-of-new-jersey-defied-sandy-through-cogeneration.html
[35] Foley, Gearoid, Examining Proven Solutions, Applications for DG & CHP, *October 2009*, http://www.njcleanenergy.com/files/file/2009%20Conference%20and%20Leadership%20Awards/presentation_pdfs/1-2-B%20Foley.pdf.

Salem Community College

Facility: Salem Community College
Location: Carney's Point, NJ
Utility: Atlantic City Electric

CHP System Description

Located in Carney's Point, New Jersey, Salem Community College is a 1,300 student, non-residential community college. The main campus consists of five buildings spread over about eleven acres. The college owns and operates a CHP system consisting of three microturbines running on natural gas, each with a capacity of 100 kW, which were commissioned in late 2009. The microturbines are set-up to allow them to island when utility power goes down. The mircoturbines provide about 80% of electricity and 100% of heating and cooling needs to Davidow Hall – a 65,000 square foot campus building that serves as a Red Cross Disaster Relief Shelter. Davidow Hall houses a gym that can hold 1,000 people during emergencies, a 400-seat performing arts theater, classrooms, kitchens, office space, showers, and bathrooms. The College was able to receive a $130,000 grant from the New Jersey Public Utility SmartStart Incentive Program to help fund the project.

Operation During Superstorm Sandy

To avoid any switchover issues, the CHP system was disconnected from the grid on Sunday morning, October 28, 2012. Salem Community College was closed effective the following Monday, October 29, as a safety precaution before Sandy hit land. The American Red Cross opened a disaster relief shelter in the Dupont Field House in Davidow Hall at 6:00 pm Sunday evening in preparation for the storm. The CHP system was the only source of power for Davidow Hall during the storm, and shelter operations ran flawlessly. There were no partial load or mechanical issues. Eighty-five people took advantage of the shelter during the storm, in addition to the 12-15 workers who conducted shelter operations. The CHP system operated continuously from 9:00 am on October 28th until 8:30 am on November 1 for a total of 47.5 hours.

Site CHP Perspectives

There were two primary drivers for installing a CHP system at Salem Community College: cost savings, and providing emergency power and heat/cooling to facilities on campus. The CHP system helps achieve 30% energy savings compared to separate power and heating for Davidow Hall. The Red Cross shelter has successfully operated during Hurricane Irene and Superstorm Sandy, demonstrating the significant value of the CHP system. The system is used daily even in non-emergency situations, and officials at the college would definitely recommend a CHP system to others. Raymond Constantine, the Executive Director of Special Projects for Salem Community College stated, "I'm a strong believer that if this technology was used at other colleges, K–12 schools, municipalities, and county government facilities, there would be significant money saved," he said. "That means money going back to the community. I'm excited we're at the forefront of energy innovation and a model for others to follow."[36]

[36] http://www.capstoneturbine.com/_docs/CS_CAP391_SalemCC_lowres.pdf

Public Interest Data Center

Facility: Public Interest Data Center
Location: New York City, NY
Utility: Consolidated Edison

CHP System Description

The data center at Public Interest Network Services (PINS), located at 50 West 17th Street in Manhattan, provides hundreds of companies with office communications support. It is connected via three different fiber networks to multiple carriers for voice calls, provides multiple tier-1 Internet backbone operators, and is protected against power failure by a full-scale uninterruptible power supply (UPS) and CHP system. The 65 kW microturbine-based CHP system; fueled by natural gas, provides for all of the computer and office lighting electric loads as well as providing space cooling from absorption chillers.

Operation During Superstorm Sandy

During Superstorm Sandy the power to the building and surrounding area was out for over two days; however, the data center was able to remain fully operational. No staff were at the building when the power went out; however, the automatic switch system transferred the data center load to a UPS (uninterruptible power supply) system while the CHP system was transferring into stand-alone mode. The whole transition took about one minute and was done automatically. Even though the areas surrounding the building were out of power, employees of PINS were able to come into the office and resume their normal functions. In addition to keeping the power and cooling operational for the data center, the CHP system was also able to provide the building landlord with power to continue to run their computer and security systems.

Site CHP Perspectives

Public Interest Network Services decided to install a CHP system because the company was growing and they needed more telecommunications equipment, which would generate more heat. After the 2003 blackout which showed the vulnerability of the electric grid, it was imperative to ensure that customers of PINS would have uninterrupted service. Since some of their customers are environmental groups, such as the Natural Resources Defense Council, it was deemed appropriate to try something different. "We were willing to make the investment not only for financial reasons, but also because we thought it was the right thing to do," said David Birnbaum, the president of the company.[37]

[37] http://www.nytimes.com/2007/09/15/nyregion/15green.html?_r=0

Co-op City

Facility: Co-op City
Location: The Bronx, NY
Utility: Consolidated Edison

CHP System Description

Co-op City, one of the largest cooperative housing developments in the country, is spread out over 330 acres in the Bronx, NY. The development includes 14,000 apartments, 35 high-rises, seven clusters of townhouses, eight parking garages, three shopping centers, one high school, two middle schools and three grade schools. Serving the residents of Co-op City is a 40 MW natural gas-fired combined cycle CHP plant, installed in 2011. The system provides about 95% of the electric and thermal needs of the community. Since Co-op City only needs 24 MW of power at peak usage periods, the extra capacity provides redundancy in case of equipment failure, as well as the ability to sell the excess capacity providing an additional income stream. The CHP system is connected to Consolidated Edison, the local electric utility, which allows it to run parallel to the grid system, and also buy and sell electricity as needed.[38] The thermal energy from the system (200,000 lbs per hour of steam) is used to provide hot water, space heating and cooling, and steam to the community.

Operation During Superstorm Sandy

During Superstorm Sandy the area surrounding Co-op City was heavily impacted with trees blown over and power outages. However, the CHP plant provided the 60,000-plus residents of the development with power and heating throughout the storm and its aftermath.

Site CHP Perspectives

"We decided to invest in an onsite cogeneration plant because we wanted to save money by producing our own electricity and capturing the waste heat to provide our residents with hot water and space cooling," said Herb Freedman, a principal of Marion Real Estate, Inc., which manages Co-op City for the Riverbay Corporation. "We have certainly saved money, but we are also really happy to provide our residents with the added benefit of independence from the power grid." [39] The energy savings that have been achieved through the CHP system have provided many benefits to the Co-op City community because this money is reinvested in capital projects including window replacements and façade repairs. According to New York City government estimates, the system also saves residents at least $15 million a year, and emits 40% less pollutants than the previous CHP system that served the community.[40]

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[38] http://www.greateasternenergy.com/2010/10/energy-savings-from-cogeneration-continues-to-increase/
[39] http://www.dgardiner.com/doc/Combined%20Heat%20and%20Power%20and%20Electric%20Reliability%20rev11.15.12.pdf
[40] http://digitaleditions.sheridan.com/display_article.php?id=1311622

Twentynine Palms

Facility: Twentynine Palms Marine Corps Air Ground Combat Center
Location: Twentynine Palms, CA
Utility: Southern California Edison

Project Description

The Marine Corps Air Ground Combat Center, Marine Air Ground Task Force Training Command Twentynine Palms (MCAGCC) is located on more than 998 square miles of high desert in southern California. Its mission is to provide live fire arms training to troops prior to deployment. The Public Works department provides facilities, services and support to 28,441 military and civilian personnel. The installation has 1,685 buildings totaling over 7.6 million square feet.

Military installations are integral to national security and require secure and reliable electricity and thermal energy to perform this function. The Department of Defense has transformed the electric infrastructure and expanded the district energy system at Twentynine Palms to meet this objective and demonstrate the capability of CHP to serve as the backbone of microgrids.[41] In February 2003, MCAGCC started operating a 7.2 MW dual-fueled combustion turbine system to meet these demands. The turbine exhaust is captured in a heat recovery generator which supplies a high-temperature hot water system, used directly for heating and domestic hot water. It also drives a 200-ton absorption chiller for cooling and air-conditioning. The system has dual-fuel capability to enable the base to make a seamless switch between gas and diesel if there is a failure in the natural gas fuel supply. The $16 million CHP project, including more than three miles of high-pressure gas lines, and then design, construction, and financing costs, paid for itself in less than four years. The system also provides mission critical energy for the base with N+1 reliability.[42] By avoiding an estimated 19,700 metric tons per year of carbon equivalent emissions - equal to the emissions of electricity used by more than 2,400 homes - this system earned MCAGCC the 2012 Energy Star CHP Award.

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[41] U.S. Department of Defense Annual Energy Management Report for FY2011, September 2012; available at http://www.acq.osd.mil/ie/energy/energymgmt_report/main.shtml
[42] Presentation by Twentynine Palms Public Works, "Mission Critical CHP Meets Energy Needs of Marine Corps Base Expansion," at International District Energy Association's Campus Energy Conference, February 2013; available at http://www.districtenergy.org/assets/pdfs/2013CampConference/Thursday/Track-B/5B.3FINALIDEA-2013-Mission-Critical-CHP-29-Palms-Final.pdf

Operation During Grid Outages

In the case of an electric grid outage, which occurs frequently since the base is at the end of an electricity distribution line, the plant can operate in "island mode" — independently from the grid — and supply power to four critical load circuits on the base. The CHP system has “black start” capability through a diesel generator that provides power to start the turbine in the absence of grid power. Since the installation of the CHP system, the base has had to enter island mode a number of times due to curtailment by Southern California Edison, demonstrating the energy security capability that will be enhanced once the new CHP project is complete.

Site CHP Perspectives

Based on the success of this installation, a new CHP plant is being constructed to serve a large base expansion, with planned completion by May 2013. This new plant will have two 4.6 MW recuperated gas combustion turbines, bringing the total CHP capacity at Twentynine Palms to 16.4 MW. The recuperated design of the turbines delivers an electrical efficiency of 40%, while as much as 32% of the heat is expected to be recovered for a total efficiency of 72%. Coupled with the new gas turbines will be two 650 ton absorption chillers and one 650 ton electric chiller that will deliver chilled water through the expanded district energy system. The new CHP system will also have black start capability.

In addition to the 16.4 MW of electrical power provided by the CHP systems, the base has 0.5 MW of solar photovoltaic power and 1.0 MW of fuel cells. With the new CHP system project, a second natural gas line is being developed, which along with propane storage sufficient for seven days will give the installation an excellent degree of fuel supply redundancy. “Strategic energy planning is a key component of our master plan,” says Commander Rob Tye, head of the facilities management division at Twentynine Palms. “[the CHP system] is helping us treat energy as a resource rather than as an expense.”[43]

[43] http://www.greenerfacilities.org/admin/data/case_studies/29PalmsMCAA.pdf

Louisiana State University

Facility: Louisiana State University
Location: Baton Rouge, LA
Utility: Entergy

Project Description

Located in Baton Rouge, Louisiana State University (LSU) is spread over a main campus of 2,000 acres and 250 buildings, serving 26,000 students. The LSU campus has two CHP systems. The first was installed in 1993 and is a 3.7 MW aeroderivative gas turbine with a heat recovery steam generator (HRSG). The CHP unit produces chilled water and steam for campus needs and is typically brought on during the summer peak. A second gas turbine CHP unit was installed in 2005 and has a 20 MW capacity. It operates 24 hours a day, seven days a week. This plant provides 65% of the electric demand of the campus, approximately 40% of the peak load during the summer, and provides 98% of the thermal load. The turbine system connects to a 23 MVA generator and also drives three 2,000-ton steam turbine centrifugal chillers. The HRSG includes a duct firing burner at 150,000 lb/hr capacity and normal capacity at 85,000 to 90,000 lb/hr. The steam is mainly used for the three steam chillers, lab processes – auto claves and sterilizers, and domestic hot water uses.

Operation During Grid Outages

With the larger 20 MW CHP plant, the university is able to keep much of the campus on-line in the event of severe weather or grid power failure. The advantage of the CHP system is that it produces power on-site and is not reliant on transmission lines that are often damaged during hurricanes due to storm surges or trees falling on the lines. The transmission lines at LSU are underground. There are two examples in which the CHP system kept the campus powered during and after a hurricane.

For four days during Hurricane Gustav in 2008, the CHP system provided electricity to critical sections of the campus. According to Dave Maharrey, Associate Executive Director Facility and Utility Operations at LSU, "This cogeneration plant provides assurance that the critical needs of the LSU campus will be met during an extended blackout." The second natural disaster that tested the CHP system was Hurricane Katrina. Hurricane Katrina struck Louisiana in 2005 and caused over $81 billion in property damage. During this time, LSU stayed on-line and never lost power, which allowed the school to continue to operate and allow administrative offices of the University of New Orleans and the LSU Medical School to relocate to the main LSU campus. Further, the Lod Cook Conference Center and Hotel, located on campus, housed many of the LSU employees displaced by the Hurricane.

Nassau Energy Corporation

Facility: Nassau Energy Corporation CHP Facility
Location: Garden City, NY
Utility: Long Island Power Authority (LIPA)

CHP System Description

The Nassau Energy Corporation district energy CHP system is a 57 MW combined cycle system that is natural gas-fired and was installed in 1991. The district heating loop was first installed in 1972. The CHP system produces 42 MW from a combustion turbine and 15 MW from a steam turbine. The district energy (DE) CHP system produces 90,000 lbs/hr of steam and 8,000 tons/hr of chilled water and is run by 27 staff members of Nassau Energy Corporation. The CHP system sells its power to the Long Island Power Authority (LIPA). The main customer for steam and chilled water from the CHP system is the Nassau University Medical Center (NUMC), a 530 bed trauma hospital. Additionally, the CHP system provides steam and chilled water services to most of Nassau Community College's campus. The Community College also serves as an American Red Cross evacuation center for Nassau County.[44] Additionally, the CHP system provides hot and chilled water to the Nassau Veterans Memorial Coliseum, the Long Island Marriott Hotel, and a museum complex including an Aviation museum, a Firefighter's museum, and a Children's museum.

Operation During Superstorm Sandy

During Superstorm Sandy, the CHP system was able to continue supplying power to LIPA, and also maintained the supply of thermal energy to the Nassau University Medical Center, Nassau Community College, and all other end-use customers. The CHP system ran through the entire storm and had no operational issues of any kind.

In preparation for the storm, Long Beach Medical Center and a number of Long Beach nursing homes moved patients to NUMC. In 2011, during Hurricane Irene, NUMC had taken Long Beach Medical Center patients and learned from that experience according to Janice Pateres, director of nursing for med/surg services. "We did preliminary registrations for patients and set up transport teams this time," she said. "Once patients were assessed and their destinations were determined, we were able to transport them more quickly. This allowed us to get 20 psych patients settled in about an hour."[45]

Nassau Community College served as an emergency shelter during Superstorm Sandy and provided services to over 1,000 people displaced by the storm for about a month and a half. A representative from the Community College said that the College has never experienced any disruptions in service from the district energy CHP system.

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[44] Nassau Community College Life Sciences Building, Garden City, NY, Technical Report Three, November 29, 2010, http://www.engr.psu.edu/ae/thesis/portfolios/2011/mwr5047/tech3.pdf
[45] Boyd, Tracy, *From Evacuations for Power Outages to Floods, Nurses Brave Sandy*, November 9, 2012, http://news.nurse.com/article/20121109/NY01/111120005.

Site CHP Perspectives

Nassau County has enjoyed significant benefits from the use of the CHP system. The County estimates that the CHP system will yield $100 million in energy savings over the life of the project. Additionally, the Nassau Energy Corporation is able to receive financial incentives for the project in the way of environmental offset credits for NOx emissions. Other benefits of the district energy CHP system include the increase in useful space for its customers since they don't have onsite boilers and other equipment, additionally the district energy system reduces the amount of staff that would otherwise be necessary for onsite heat and cooling services at NMUC, Nassau Community College, and other customers of the system.

Bergen County Utilities

Facility: Bergen County Utilities Wastewater Treatment Plant
Location: Little Ferry, NJ
Utility: Public Service Electric and Gas

CHP System Description

The Bergen County Utilities Wastewater Treatment Plant uses a 2.8 MW reciprocating engine CHP system that was installed in 2008. The facility runs off of biogas and processes sewage for 47 communities. The facility typically runs at 95% capacity and treats around 80 million gallons per day of water. The development of the CHP system began after an energy study done in 2005 determined that it would be beneficial for the Bergen County Utilities Authority (BCUA) and its municipalities to install a CHP system. The BCUA entered into an agreement with a local CHP developer in 2006 to build the CHP system. The system was completed in June 2008 a little under the project budget of $12 million. The project was originally operated by the project developer, and is located in Little Ferry, New Jersey adjacent to an existing BCUA building. The BCUA took over operation of the CHP facility in 2010. The energy produced by the CHP system is consumed entirely by the BCUA Water Pollution Control Facility (WPCF).

The CHP plant uses two biogas fueled reciprocating engine generator sets with emission control and heat recovery equipment. Natural gas is used as a backup source of fuel. Thermal generation is used to heat the building and also for sludge digester heating purposes. The CHP system is operated in parallel with the Public Service Electric and Gas Co. (PSE&G) electrical distribution system. The engines supply approximately 85% of the electric needs of the BCUA facility, and are capable of adjusting to the instantaneous electrical load of the facility. Treated water from the BCUA facility is supplied as cooling water to an adjacent power plant.

Operation During Superstorm Sandy

The CHP system was able to remain up and running during Superstorm Sandy. There was a momentary controlled blackout when PSE&G service went down, which caused power quality from the CHP system to suffer, and required the WPCF's control system to be reset. The BCUA facility has a backup power system that is comprised of three kerosene-powered emergency generators that are able to run auxiliary systems and helped keep the CHP system in operation. The CHP system operated seamlessly for 24 hours without PSE&G and was praised by the adjacent power plant for being able to provide treated cooling water throughout the storm event.

The current CHP system is not equipped with black start capability since the plant already has an independent backup power system in place. However, the backup power system requires a lot of annual maintenance so the BCUA facility is planning on retiring the standby power system within the next ten years, and will then install black start capabilities.

Site CHP Perspectives

The CHP system results in a number of environmental and economic benefits for the BCUA. By capturing and using the biogas from the anaerobic digestion process to produce power and thermal energy instead of flaring the gas, the BCUA realizes significant reductions in GHG emissions. The elimination of flaring also reduces criteria pollutants, which helps prevent smog formation and other air quality issues.

Additionally, electricity is the largest operating cost for the BCUA WPCF. The BCUA consumes 29 million kWh of electricity per year and the CHP engines have generated about 29.96 million kWh of power annually while using 284.2 mm cubic ft. of biogas. This results in annual energy cost savings of $3,462,289 and has helped save $10 million dollars to date. The BCUA has also been able to generate renewable energy credits (RECs) to help meet the state's Renewable Portfolio Standard (RPS) targets. To date, the BCUA has received $100,000 for its RECs. It is estimated that the project will pay for itself after 6.35 years. The CHP project has also allowed the BCUA to participate in PJM's Demand Response Program, and BCUA had received $43,787 as of the end of 2009 for demand reduction.

The BCUA CHP facility was a winner of the 2009 New Jersey Governor's Environmental Excellence Award. The BCUA facility also recently won an award in March 2013 from the Association of Environmental Authorities of New Jersey (AEA)[46] for its ability to remain operational during Superstorm Sandy, and also for its other environmental attributes. The BCUA CHP system has served as a model for other water authorities that are considering the use of CHP. Staff from other city, and municipal water authorities, have visited the BCUA site to help determine if CHP is a right fit for them.

[46] The Association of Environmental Authorities of New Jersey, http://www.aeanj.org/index.php?option=com_content&view=frontpage&Itemid=1.

New York University

Facility: NYU Washington Square Campus CHP System
Location: New York City, NY
Utility: Consolidated Edison

CHP System Description

NYU is a private institution located in Greenwich Village in Manhattan with 38,000 students and 21,000 faculty members. The University has on campus housing capacity for over 12,000 students. Most of NYU's main buildings surround Washington Square Park, which is also the location of the University's CHP system. The NYU Washington Square Campus facilities are served by a 14.4 MW combined cycle CHP system, which was installed in 2010. The system runs off of natural gas, with the option of using ultra low-sulfur diesel for limited periods, and replaced an existing engine-driven CHP facility that began operation in 1980. The CHP system includes two combustion turbines, two heat recovery steam generators, and a steam turbine and generates up to 90,000 pounds of steam per hour. The electricity generated supplies 22 campus buildings. The steam is used to produce hot water for 37 campus buildings and meets 100% of their space heating, space cooling, and hot water needs. When campus electrical demand is low, the excess electricity is sold to Con Edison. The CHP has a total operating efficiency of almost 75%.

Operation During Superstorm Sandy

NYU's core campus maintained both power and heat during Superstorm Sandy because of its CHP system. The CHP system went into island mode when the local grid went down, isolating itself from Con Edison's network. The system provided uninterrupted electricity, heating, and cooling to the campus, and also enabled NYU and New York City officials to set up a command post on the campus as well as serve area residents forced to evacuate their homes in the wake of the storm. The CHP system does not cover the NYU Langone Medical Center which was criticized when its backup generator failed and it had to evacuate its patients to nearby hospitals.[47]

Site CHP Perspectives

NYU installed the new CHP system in 2010 in order to save money and reduce the University's carbon footprint. However, the CHP system has led to a number of other benefits for the University such as allowing for energy independence from the utility, increased reliability, reduced load for Con Edison, reduced energy costs and air emissions. The CHP system also serves as one of the main components of the University's sustainability initiatives and the University's Green Action Plan. The system reduces the

[47] NY Times, How N.Y.U. Stayed (Partly) Warm and Lighted, November 5, 2012, http://green.blogs.nytimes.com/2012/11/05/how-n-y-u-stayed-partly-warm-and-lighted/.

University's energy costs by over $5 million annually. The CHP system uses approximately 27% less fuel than supplying electricity from the grid and producing steam with onsite boilers. The system also prevents emissions of air pollutants, including an estimated 43,400 tons per year of CO_2 emissions, equal to that from the electricity used by more than 4,900 homes. The NYU facility recently won a 2013 EPA Energy STAR CHP Award for its performance.[48]

[48] U.S. EPA, Winners of the 2013 ENERGY STAR CHP Award, http://www.epa.gov/chp/partnership/current_winners.html.

Sikorsky Aircraft Corporation

Facility: Sikorsky Aircraft Corporation CHP System
Location: Stratford, CT
Utility: Consolidated Edison

CHP System Description

Sikorsky Aircraft, a unit of United Technologies Corporation (UTC) installed a CHP system at its two-million-square-foot production facility in Stratford, Connecticut, in October 2011. This helicopter manufacturing facility has approximately 6,650 full time employees working in engineering, assembly, and test flight operations. The CHP system is composed of a 10.7 MW natural gas-fired combustion turbine. The system supplies 84% of the two million square foot facility's power needs. Additionally, the CHP system provides 85% of the facility's steam heating needs. The system uses the recovered thermal energy to operate absorption chillers, provide space heating in winter, and power a steam-turbine air-compressor system. As a money saving option, the CHP system is connected to the grid, which allows the facility to purchase electricity based on the cost of natural gas.

Operation During Superstorm Sandy

The facility's CHP system did not experience any disruptions during Superstorm Sandy. Sikorsky also offered free helicopter transport services for disaster relief personnel in New Jersey, New York and Connecticut after the storm. The helicopters ferried water, snacks, diapers, flashlights and other necessities to Staten Island University Hospital in New York.

Site CHP Perspectives

The CHP system has a number of benefits. The system reduces CO_2 emissions by an estimated 8,900 metric tons annually – equivalent to the greenhouse gas emissions produced by 1,600 passenger vehicles a year.[49] The project cost around $26 million to install but has less than a four year payback. The project was also able to receive a $4.66 million incentive grant from the State. Sikorsky President Jeffrey P. Pino said at the commissioning ceremony for the CHP system, "Today Sikorsky takes another big step in our commitment to operate as an environmentally friendly and sustainable business."[50]

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[49] http://www.cospp.com/articles/2011/10/sikorsky-powers-up-chp-system-in-connecticut.html
[50] Ibid.

Policies Promoting CHP in Critical Infrastructure

During and after a natural or man-made disaster, CHP can play a vital role in ensuring that the appropriate emergency response services are available and critical infrastructure remains operational. These recent natural disasters have spurred greater focus by state and local policymakers and planners on the role of CHP. For example, the damage caused by hurricanes along the Texas and Louisiana Gulf Coast in the past several years acted as a focusing event, which propelled the adoption of critical infrastructure policies in these two states.[51] Additionally, due in part to the Northeast Blackout in 2003, storm events, security threats and other concerns, New York State has also been a strong proponent of CHP at critical infrastructure facilities.

Texas and Louisiana are leaders in the deployment of CHP because of the large industrial base in the region. Although a significant portion of CHP has been implemented in this region, its use has been largely limited to industry and has been deployed primarily for economic purposes. The damage caused by the previous hurricanes made it apparent to policy makers that critical infrastructure needs to be re-enforced with reliable sources of power, and reliability and survivability improved, during natural disasters. The result was the passage of critical infrastructure policies in Texas and Louisiana.

Texas bills HB 1831 and HB 4409[52] and Louisiana resolution No. 171, passed in 2009 and 2012, respectively, require that 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 situation.
- Prior to constructing or making extensive renovations to a critical governmental facility, the entity in control of the facility must obtain a feasibility study to consider the technical opportunities and economic value of implementing CHP.

The State Energy Conservation Office in Texas and the Department of Natural Resources and the Louisiana Public Services Commission are tasked to establish guidelines to evaluate CHP feasibility in critical government facilities. This legislation was enacted because of several major natural disasters (hurricanes Katrina, Rita, and Ike) that showed the vulnerability of the state's critical infrastructure. It was found that these natural disasters could knock out portions of the electric grid for weeks and backup generators were not necessarily reliable. Texas and Louisiana have found that the high pressure pipeline system that supplies natural gas throughout the state has provided highly reliable service throughout recent hurricanes. Underground natural gas pipelines provide a secure source of energy to

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[51] One must keep in mind that the power outage does not even have to be a major natural disaster to cause significant societal and economic disruption. For example, the Northeast Blackout of 2003, putting 55 million people without power, was largely caused by tree branches tripping a wire. The outage affected water supply, communication and transportation, as well as industry. The event that caused the blackout was hundreds of miles from much of the population that was affected. CHP can help prevent the wide-spread outages and minimize the effect.

[52] http://www.txsecurepower.org/

on-site CHP systems, which can then deliver electricity, steam, and chilled water securely throughout the facility.

In both states, a government building or facility is deemed "critical," if it meets the following criteria:

- Is owned by the state or a political subdivision of the state;
- Is expected to continue serving a critical public health or safety function throughout a natural disaster or other emergency situation, even when a widespread power outage may exist for days or weeks;
- Is continuously occupied and maintains operations for at least 6,000 hours each year; and
- Has a peak electricity demand exceeding 500 kilowatts.

Examples of government buildings and facilities that may meet the "critical" definition include hospitals, nursing homes, command and control centers, shelters, prisons and jails, police and fire stations, communications and data centers, water or wastewater facilities, research facilities, food preparation or food storage facilities, hazardous waste storage facilities, and similar operations.

For both states, CHP may be deemed feasible if it can provide a facility with 100% of its critical electricity needs, can sustain emergency operations for at least 14 days, and meets a minimum efficiency of 60%. The energy savings must also exceed installation, operating and maintenance costs over a 20-year period.[53]

New York - The New York State Energy Research and Development Authority (NYSERDA) has been a strong supporter of CHP technology development and implementation for over 10 years. NYSERDA created a strategic partnership 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 facilities and places of refuge. The purpose of this partnership was to provide the "connecting links" between national homeland security efforts and regional/state infrastructure resiliency activities. The partnership produced a report[54] in 2009 detailing the CHP potential in critical infrastructure applications in New York. The partnership provided outreach information to these sectors (e.g., hospitals, water treatment plants, places of refuge etc.) by scheduling presentations at their meetings or other gatherings to present the benefits of CHP to infrastructure resiliency.

On February 14, 2013, New York Governor Andrew Cuomo announced that a $20 million investment will be made towards clean energy projects, specifically those aimed at providing continuous power and heat during power outages.[55] This investment is based on recommendations made by NYS 2100, one of the three commissions Governor Cuomo created in the aftermath of Superstorm Sandy to improve the State's emergency preparedness and response to natural disasters. The program will be administered by

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[53] http://files.harc.edu/sites/gulfcoastchp/newsletters/Newsletter_20120626.pdf
[54] http://www.nyserda.ny.gov/en/Publications/Research-and-Development/~/media/Files/Publications/Research/Other%20Technical%20Reports/nyserda-chp-final-report-optimized.ashx
[55] http://www.governor.ny.gov/press/02142013-20million-for-combined-heat-and-power

NYSERDA. NYSERDA will only fund those CHP systems that can continue operations during grid outages. Additionally, all fund applicants in flood zones must meet a "high and dry" requirement, meaning they must install CHP systems that would be above the flood plain in a worst-case flood scenario. Incentives will be paid up to $1.5 million per project for projects 50 kW to 1.3 MW in capacity. Funding is available on a first-come, first-serve basis through December 31, 2016, or until funds are exhausted. Only CHP systems installed at sites that pay the System Benefits Charge are eligible for funding.[56]

New Jersey is attempting to improve its energy resilience through the New Jersey Energy Master Plan[57]. As a part of this plan, the New Jersey Economic Development Authority and Board of Public Utilities, under Governor Chris Christie, issued another round of funding to assist in improving grid reliability in the state through CHP. On January 17, 2013, the state issued a second round of the Large Scale Combined Heat and Power/Fuel Cell Program. This is a $25 million rolling grant program that will provide incentives to projects greater than 1 MW in size. The maximum incentive for the project is $3 million or 30% of total project costs, whichever is greater. Any New Jersey based governmental, commercial, institutional or industrial entity is eligible to participate.[58]

Emergency Planning and Risk Mitigation with CHP

Some state and other local governments have developed, or are in the process of developing, policies to include CHP in critical infrastructure planning, to ensure the energy security and reliability of emergency facilities. A focus of infrastructure resilience is investing in resources that allow for as much of the relevant critical infrastructure system as possible to remain functional in the event of an attack or disaster, and for compromised parts of the system to resume functionality as quickly as possible. In this context, the value of CHP to infrastructure resilience becomes clear; critical assets across sectors can be insulated from disruptions to the electricity grid through the use of CHP and other forms of distributed energy.[59] For successful implementation of critical infrastructure policies there must be considerable interaction between the utility, government emergency planners, and facility operators. A first step in identifying and prioritizing critical infrastructure assets, and how to incorporate CHP, is to review the Department of Homeland Security's National Infrastructure and Protection Plan (NIPP).[60] The NIPP helps emergency planners determine how to prioritize its critical infrastructure assets through a variety of assessment tools.

The first assessment recommended by the NIPP is to determine which facilities and services are most important for the safety and recovery of the community, and then rank these facilities in order of their importance. The assessment will help determine the problems a community may face if a specific facility

[56] All Investor Owned Utilities in New York pay the Systems Benefits Charge (Consolidated Edison, Orange & Rockland, Rochester Gas & Electric, Central Hudson Gas & Electric, Niagara Mohawk, New York State Electric and Gas).
[57] State of New Jersey, Energy Master Plan. http://nj.gov/emp/
[58] http://www.njeda.com/web/pdf/LargeScaleCHPFuelCellsSolicitation.pdf
[59] When designing a CHP system for a critical infrastructure application it is important that the system can operate independently from the grid. The system must be designed to be "islanded," meaning that the system is self-contained and can operate separate from the grid.
[60] http://www.dhs.gov/xlibrary/assets/NIPP_Plan.pdf

or piece of infrastructure is not operational by looking first at the human impact, followed by the economic impact, the impact to public confidence, and the impact on government continuity. This impact analysis also helps pinpoint the best sites for CHP development.

NYSERDA has conducted an assessment with the assistance of the NIPP, and found that the most appropriate focus and prioritization of CHP review should be at hospitals and water treatment/sanitary facilities, followed by nursing homes, prisons, and places of refuge.[61] To ensure continued progress towards addressing grid and critical infrastructure resilience through technologies such as CHP, improved coordination between government emergency planners and the electricity sector must occur. State utility regulators can facilitate that coordination and help reduce regulatory barriers to CHP so that these systems can be safely and more easily installed in critical infrastructure applications. Having specific resolutions or policies in place facilitates the deployment of CHP and can help promote the development of this resource and ensure its inclusion in the emergency planning process.

There are other barriers to the development of CHP at CI facilities besides technical and economic feasibility that should also be addressed. Education about the benefits of CHP systems to CI facilities is necessary. One of the main challenges is to move beyond standard back-up generation implementation. The practice of continuing to install diesel or natural gas back-up generation is largely a result of institutional inertia; however, it can also be due to state mandates. Certain critical facilities such as hospitals with life-safety needs are required to install backup generators for their critical loads. CHP systems can serve this function and may be able to be substituted for backup generators if designed appropriately. Backup generator systems are known and familiar to emergency planners and facility operators, typically have lower up-front costs than CHP, and are easier to install and get online than a CHP system. The result is that standard back-up generation is the default choice in most instances, but with greater information and understanding, CI facilities may choose to invest in CHP.

Conclusions

CHP may be a good investment for critical infrastructure facilities due to its opportunity to improve resiliency, mitigate the impacts of a disaster, provide energy cost savings, greater efficiencies, and reduced overall emissions, all while providing reliability during grid outages. There are numerous examples of CI facilities with CHP that operated during disasters, including Superstorm Sandy. Successful application of CHP in critical infrastructure applications requires engaging decision-makers who build, manage, and operate these facilities, as well as emergency management professionals and state and local policy makers.

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[61] The Contribution of CHP to Infrastructure Resiliency in New York State, Final Report, April 2009, New York State Energy Research and Development Authority.
http://www.energetics.com/resourcecenter/products/studies/Pages/CHP-Contribution-Infrastructure-NY.aspx

Resources for Further Information

For more information about CHP and opportunities for technical assistance, visit the DOE Advanced Manufacturing Office industrial distributed energy website at: http://www1.eere.energy.gov/manufacturing/distributedenergy/

Appendix A: CHP Design for Power Reliability

The requirements for a CHP system to be used for power reliability are fairly straightforward, but they may add some costs to the system. In order to operate during a utility system outage, the CHP must have the following features:

Black Start Capability

Electric generation equipment cannot be started without an electrical signal. In most cases, when starting a CHP system after a shutdown, the electric grid can be used as the source of this electrical signal. However, if both the grid and the CHP system are down and not supplying power at the same time, then the CHP system will need to be outfitted with "black start capability" so that it can begin operation. Similar to the way a car battery is used to start the engine of a car, a CHP system needs an electrical signal from a battery located on-site to allow it to start operation when the grid is experiencing an outage.

Generator Capable of Operating Independently of the Utility Grid

CHP systems that utilize reciprocating engines, gas turbines, or steam turbines as their prime mover technologies convert the mechanical shaft power to electricity through the use of an electric generator. There are two types of generators used in CHP systems: synchronous and induction.

Synchronous generators are internally (self) excited generators that do not need the external power grid to provide the source of excitation. They are preferred by CHP owners because the CHP system has the potential to continue to produce power through grid brownouts and blackouts. It is more complex and costly to safely interconnect this type of generator to the grid, as the facility must ensure that when the grid is de-energized, the CHP system cannot export power to the "downed" grid, which could injure utility personnel or repair equipment.

Induction generators require an external source of power to operate, i.e., they need the external power grid to provide the source of excitation. Induction generators are preferred by utilities because the CHP system cannot operate if the grid is de-energized. This ensures that no power can be fed into a "downed" grid ensuring the safety and integrity of the grid and utility service personnel. The downside to the customer is that this configuration does not enhance electrical power reliability to the customer, because if the grid is de-energized, the CHP system shuts down. The advantage is that is that it is simpler and less costly to safely connect to the grid.

Ample Carrying Capacity

The traditional optimal sizing strategy for CHP is to meet as much as possible of the 24/7 electric loads without having to cycle or export power, and without delivering more thermal energy than is needed to meet the building cooling loads. Typically, CHP does not replace the grid-supplied power entirely but rather reduces the amount of purchased power by making electricity on-site. The thermal energy recovered from CHP may be used for space heating or cooling, process heating, or dehumidification. A CHP system should be the correct size to meet onsite thermal needs and electric power requirements, providing the highest CHP system efficiency. Power from the local utility is usually needed to supplement the CHP system during those times when heating or cooling needs are reduced and the CHP system is generating less electrical power, or if the CHP system does not provide all of the site's electricity needs.

Rather than install a diesel backup generator to provide outage protection, a facility can design that capability into a CHP system that provides electric and thermal energy to the site on a continuous basis, resulting in daily operating cost savings. In this type of configuration, the CHP system would be sized to meet the base load thermal and electricity needs of the facility. Supplemental power from the grid would serve the facility's peak power needs on a normal basis and would provide the entire facility's power when the CHP system is down for planned or unplanned maintenance. However, the CHP system would also need to be sized large enough to maintain critical facility loads in the event of an extended grid outage.

During the design phase of a CHP system, the proper amount of electrical capacity would need to be determined based on the day-to-day electrical needs of the site and the importance of having the system provide for all the power needs of a facility during a grid outage. Using traditional system sizing methods, most commercial or institutional CHP applications which are highlighted in this report would have CHP systems that provide for most, but not all, of the electrical requirements of the site. The decision must be made during the design phase of the project whether to a) size the system for optimal energy and economic efficiency, and designate critical loads to be supplied during a grid outage, or b) size the system for all of the site electrical requirements and arrange to export power to the grid or operate at partial load on typical days.

Parallel Utility Interconnection and Switchgear Controls

During normal CHP operation, both the traditional electric grid and the CHP system supply electricity directly to the facility, and there is typically no service interruption in switching from one source to the other. This operation mode is referred to as operating in "parallel" with the utility. When connecting an on-site generator to a utility grid, the major concerns include the safety of the customers, line workers, and general public; integrity of the power grid; protection of connected equipment; and the ability of the utility to retain system control. Proper interconnection equipment and design is critical to address these concerns. An on-site generator is not allowed to feed power back onto a de-energized grid, so utilities require interconnect designs that ensure CHP systems are disconnected from their grid automatically when they sense a grid outage. In addition, many utilities require that a separate external disconnect switch be installed that is accessible by utility personnel to disconnect and lock out the CHP system from the grid.[62] Any CHP installation must be reviewed with the local utility to ensure that the utility's ability to manage grid operations is not compromised.

After a CHP system disconnects from the utility grid due to an outage, appropriate switchgear and controls are required to isolate and serve critical loads without overloading the generator capacity. These critical loads must be isolated from the rest of the facility non critical loads which must be shut down during a system outage through the installed switchgear and control logic. The switching capability can be designed for manual transfer (providing emergency power within several minutes), automatic transfer (providing emergency power in a few cycles to a few seconds), or a static transfer system (which provides seamless transfer from the grid to the CHP system in a stand-alone mode).

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[62] http://www.dsireusa.org

Typically, the switchgear and circuiting costs are roughly comparable to what the facility would install for a diesel standby system meeting a portion of the facility load; therefore, the incremental cost for the CHP system for switchgear, control, and circuiting is included in the estimate of the installed diesel gen-set cost. However, a facility considering CHP that would not otherwise install back-up generation, might want to include that function by investing in the appropriate switchgear and controls. Typically, such a customer (i.e., one with low to moderate outage costs below the threshold of investment for backup), would require only a basic system.

The additional costs for switchgear and controls for a CHP system depend on the level of control and the speed with which the facility needs to have the CHP system pick up the critical loads in the case of a utility power outage. **Table A-1** describes three levels of protection—manual, automatic, and seamless—and site-specific costs for reconfiguring the site wiring and control panels to isolate and serve the critical load. The level of backup capability and control chosen for a CHP system will be directly tied to the value of reliability and risk of outages for the customer.

Table A-1. Control Costs for Generator Backup Capability[63]

Control Level	Time to Pick up Load	Equipment Required	Capital Cost
Manual	Up to an hour	· Engine start · Manual transfer switch · Distribution switchgear	\$20–\$60 per kW
Automatic	5 to 10 cycles when running	· Engine start · Open transition automatic transfer switch · Distribution switchgear	\$25–\$105 per kW
Seamless	¼ to ½ cycle when running	· Engine start · Closed transition automatic transfer switch with bypass isolation · Distribution switchgear	\$45–\$170 per kW
Reconfiguring for Load Shedding	Not applicable	As needed by the site: · Design · Engineering · Rewiring · Added electrical panels, breakers, controls	\$100–\$500 per kW

Note: Cost range figures represent estimates for a 500 kW CHP system at the high end and a 3,000 kW CHP system at the low end. Cost estimates do not include re-circuiting costs, which depend on site needs.

[63] Adapted from: K. Darrow and M. Koplow, *Dual Fuel Retrofit Market Assessment*, Onsite Energy Corporation for Gas Research Institute, 1998. (Costs escalated at 3% per year for equipment and 6% per year for labor.)

Manual control requires an operator to isolate the generator to the emergency circuits using manual transfer switches. An *automatic* transfer switch eliminates the need for operator intervention. The generator is switched to the emergency circuit automatically, a process in which the circuit is open for only a fraction of a second (5-10 cycles.) *Seamless* transfer—most often integrated with a full UPS—utilizes a more costly, closed transition, automatic transfer switch with bypass isolation. This switch is a "make-before-break" design that momentarily parallels the two circuits before switching. An isolation bypass switch allows removal of the automatic switching mechanism in the case of failure with the ability to then manually switch the load.

Table A-2 provides an economic comparison of a hypothetical 1500 kW natural gas-fueled CHP system with and without the capability to provide backup power to a site during grid power outages. The impact of enhanced reliability is calculated two different ways. The first method is based on a customer's specific calculations for the value of service and expected number of hours per year of facility disruption that could be avoided with a CHP system that includes backup capability. The second approach, based on willingness to pay, is simply to take a capital cost credit for avoiding the cost of a diesel backup generator. A capital credit is taken for the backup generator, controls, and switchgear that would not need to be installed at the site because backup capability is integrated into the CHP system (note that the CHP system includes an additional capital cost for this capability, but the incremental capital cost is more than offset by credit from the displaced backup generator). With the second method, the simple payback for the CHP system is reduced from 6.8 to 5.3 years and the internal rate of return is increased to 16.9%.

Table A-2. CHP Value Comparison With and Without Backup Power Capability[64]

CHP System Components	Standard CHP (no off-grid reliability benefit)	CHP With Backup Capabilities – Direct Cost Measure	CHP With Backup Capabilities – Avoided Diesel Generator Measure
Generator Capacity (kW)	1500	1500	1500
CHP System Installed Cost, ($/kW)	$1,800	$1,800	$1,800
Added Controls and Switchgear Cost, ($/kW)	N/A	$175	$175
Typical Backup Gen-Set, Controls, and Switchgear, ($/Kw)	N/A	Not valued directly	($550)
Total CHP System Capital Cost, ($/kW)	$1,800	$1,975	$1,425
Total CHP System Capital Cost, ($)	$2,700,000	$2,962,500	$2,137,500
Net Annual Energy Savings, ($)	$400,000	$400,000	$400,000
Total Annual Savings	$400,000	$568,750	$400,000
Payback	6.8 Years	5.2 Years	5.3 Years
Internal Rate of Return	12.20%	17.50%	16.90%
Net Present Value (at 10% discount)	$311,302	$1,239,507	$822,665

[64] Adapted from *The Role of Distributed Generation in Power Quality and Reliability*, Energy and Environmental Analysis, Inc. for New York State Energy Research & Development Administration. June 2004.