Guide to Using

Combined Heat and Power

for Enhancing Reliability & Resiliency in Buildings

1 PDH / 1 CE Hour / 1 AIA LU/HSW

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U.S. Environmental Protection Agency

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Combined Heat and Power Final Exam

1. **During and after Hurricane Sandy, combined heat and power (CHP) enabled a number of critical infrastructure and other facilities to continue their operations when:**
   a. gas lines were destroyed
   b. the electric grid went down
   c. fuel storage tanks were damaged
   d. propane supplies were depleted

2. **Considering *Support for CHP in the Region*, in early 2013, New York Governor Andrew Cuomo announced that a ___________ investment will be made towards clean energy projects (including CHP), specifically those aimed at providing continuous power and heat during grid outages.**
   a. $20 million
   b. $10 million
   c. $100 million
   d. $50 million

3. **With regards to *Prioritizing CHP Applications*, a first step in considering how to incorporate CHP is to review the ____________________________ _______, which provides emergency planners with a variety of assessment tools.**
   a. Federal EPA's Guide to Emergency Energy Systems (GEES)
   b. Department of Energy's Resources for Atomic Free Power (RAFP)
   c. Government Accounting Office's Emergency Budget Plan (EBP)
   d. Department of Homeland Security's National Infrastructure and Protection Plan (NIPP)

4. **CHP is also known as:**
   a. balanced energy
   b. cogeneration
   c. back-up power
   d. autonomous power

5. **According to *Figure 1*, CHP operates at _______ efficiency.**
   a. 45%
   b. 50%
   c. 75%
   d. 90%

6. **According to *Figure 1*, a traditional system operates at _______ efficiency.**
   a. 45%
   b. 50%
   c. 75%
   d. 90%

7. **Considering *Table 1*, the Net Annual Operating Cost of a New Natural Gas CHP system sized appropriately to meet the needs of a medium-to-large-sized institutional facility is:**
   a. $4,555,889
   b. $500,000
   c. $54, 138,850
   d. $2,890,269

8. **In reference to *Comparing CHP to Back-up Generators*, many facilities utilize ______________ to provide power during grid outages.**
   a. back-up diesel generators
   b. gasoline generators
   c. natural gas generators
   d. battery packs

9. **From *Table 2*, CHP provides __________ than Backup Generators.**
   a. higher emissions
   b. poorer reliability
   c. lower system efficiencies
   d. lower emissions

10. **According to the *Appendix*, the CHCC CHP system for the Christian Health Care Center ran independently of the grid for:**
    a. 2 weeks
    b. 97 hours
    c. 8 days
    d. 12 hours

Using Combined Heat and Power for Enhancing Reliability and Resiliency in Buildings

AIA CES Course Number: AIAPDH131

Course Description:

During and after Hurricane Sandy, combined heat and power (CHP) enabled a number of critical infrastructure and other facilities to continue their operations when the electric grid went down. Time and again, CHP has proved its value as an alternative source of power and thermal energy (heating and cooling) during emergencies, and demonstrated how it can be a sound choice in making energy infrastructure more resilient in the face of extreme weather events. This course on CHP provides both an overview of CHP and examples of how this technology can help improve the resiliency and reliability of key infrastructure. It provides practical information on CHP, including what factors must be considered when configuring a CHP system to operate independently of the electricity grid, and what steps are involved in a typical CHP project development process.

Learning Units:

1.0 LU/HSW

Learning Objective 1:

Upon completion of this course, the student will be aware of the opportunities for CHP to contribute to reliability.

Learning Objective 2:

The student will learn CHP basics and benefits.

Learning Objective 3:

The student will understand many of the factors for determining whether CHP is an appropriate choice for multifamily housing and critical facilities as well as steps in the CHP project development process.

Learning Objective 4:

The student will know of options for financing CHP.

Guide to Using Combined Heat and Power for Enhancing Reliability and Resiliency in Buildings

September 2013

Acknowledgments

To assist State and local officials and others involved in the Hurricane Sandy rebuilding process, the U.S. Department of Energy (DOE), the U.S Department of Housing and Urban Development (HUD), and the U.S. Environmental Protection Agency (EPA) developed the *Guide to Using Combined Heat and Power for Enhancing Reliability and Resiliency in Buildings*. The following staff from these federal agencies provided input on this Guidance document - Katrina Pielli and Rima Oueid, DOE; Susan Wickwire, Neeharika Naik-Dhungel, and Charles Imohiosen, EPA; and Michael Freedberg, and Robert Groberg (ret.), HUD.

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INTRODUCTION

During and after Hurricane Sandy, combined heat and power (CHP) enabled a number of critical infrastructure[i] and other facilities to continue their operations when the electric grid went down. Time and again, CHP has proved its value as an alternative source of power and thermal energy (heating and cooling) during emergencies, and demonstrated how it can be a sound choice in making energy infrastructure[ii] more resilient in the face of extreme weather events.

To assist State and local officials and others involved in the rebuilding process, the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) developed this guidance on CHP with the U.S. Department of Housing and Urban Development (HUD). Its purpose is to provide practical information on CHP, including what factors must be considered when configuring a CHP system to operate independently of the electricity grid, and what steps are involved in a typical CHP project development process.

This guidance is divided into seven sections that discuss:

1. The policy context for CHP, including in the aftermath of Hurricane Sandy;
2. CHP in State and local resiliency planning efforts;
3. CHP basics and benefits;
4. The opportunities for CHP to contribute to reliability;
5. Factors for determining whether CHP is an appropriate choice for multifamily housing and critical facilities and steps in the CHP project development process;
6. Options for financing CHP; and
7. Additional resources that provide more detailed information.

i 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. See, Patriot Act of 2001 Section 1016 (e).

ii Energy infrastructure means assets such as electric generation plants, boilers, the electric grid, distribution and substations; however, this term often refers to oil and gas infrastructure as well.

1. THE CONTEXT FOR CHP IN SANDY REBUILDING EFFORTS

This guidance document on CHP supports the *August 2013 Hurricane Sandy Rebuilding Strategy* by providing an overview of CHP and examples of how this technology can help improve the resiliency and reliability of key infrastructure.

Hurricane Sandy Rebuilding Task Force Report

In response to Executive Order 13632, in August 2013, the Federal Hurricane Sandy Rebuilding Task Force published a *Hurricane Sandy Rebuilding Strategy* that describes how CHP played a successful role in keeping a number of college campuses, multifamily housing, critical medical facilities, sewage treatment plants and other facilities running during the storm and its aftermath.[1,2] The strategy offers two recommendations to bolster CHP, district energy and other forms of clean distributed generation, including "ensuring that Sandy recovery energy investments in critical infrastructure are resilient" (Recommendation 12), and also "encourage Federal and State cooperation to improve electric grid policies and standards" (Recommendation 14).

Support for CHP in the Region: In the effort by States to enhance emergency preparedness and resilient infrastructure, CHP and its role in these efforts have been recognized. As examples, New York State, New York City and New Jersey recently initiated programs to promote CHP.

- In early 2013, New York Governor Andrew Cuomo announced that a $20 million investment will be made towards clean energy projects (including CHP), specifically those aimed at providing continuous power and heat during grid outages.[3] This investment is based on recommendations made by NYS 2100, one of the three commissions Governor Cuomo created in the aftermath of Hurricane Sandy to improve the State's emergency preparedness and response to natural disasters.
- More recently, New York City issued "A Stronger, More Resilient New York," building on the original 2007 PLANYC, which is a comprehensive plan that contains recommendations for rebuilding the communities impacted by Sandy and increasing the resilience of infrastructure and buildings citywide.[4] The Plan discusses CHP, including the city's plan to improve building and other codes to enable increased use of CHP for emergency power.
- New Jersey is attempting to improve its energy resilience through the New Jersey Energy Master Plan.[5] As a part of this plan, the New Jersey Economic Development Authority and Board of Public Utilities, under Governor Chris Christie, issued funding to assist in improving grid reliability in the State through CHP.[6]

2. CHP IN STATE AND LOCAL RESILIENCY PLANNING

CHP can effectively contribute to State and local planning efforts to build resiliency for both critical infrastructure and other facilities, including multifamily housing. CHP systems allow facilities to remain functional in the event of a disaster, and for non-critical loads to resume functionality as quickly as possible (e.g. CHP systems with back start capability and that meet other technical requirements, can ensure seamless operation during a grid outage). Key facilities across sectors can be protected from disruptions to the electricity grid through the use of CHP and other forms of distributed energy.

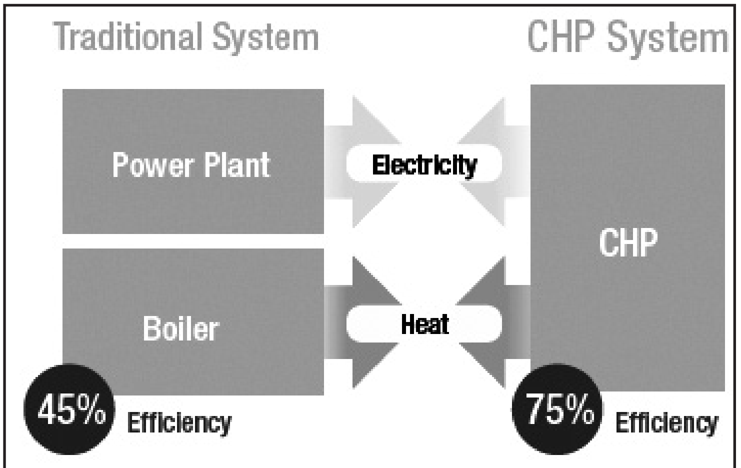
Prioritizing CHP Applications: A first step in considering how to incorporate CHP is to review the Department of Homeland Security's National Infrastructure and Protection Plan (NIPP), which provides emergency planners with a variety of assessment tools. This tool has been used in reviewing critical infrastructure assets and can potentially be used for other facilities including multifamily housing. In 2009, the New York State Energy Research and Development Authority (NYSERDA) conducted an assessment with the assistance of the NIPP, and found that the most appropriate focus and prioritization of CHP should be at hospitals and water treatment/sanitary facilities, followed by nursing homes, prisons, and places of refuge.[7,8] NYSERDA, in a current funding solicitation specified a preference for CHP systems that can run during grid outages to provide electric power to the site's priority loads for all facilities, and not just critical facilities.[9]

The Need for Coordination: To ensure continued progress towards addressing grid and 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.

Incorporating CHP in Critical Infrastructure Planning: Some State and local governments have developed, or are in the process of developing, policies to include CHP and other forms of clean distributed generation in critical infrastructure planning, to ensure the energy security and reliability of emergency facilities[iii] (e.g., hospitals, fire stations, and emergency shelters).[iv] For example, the damage caused by hurricanes along the Texas and Louisiana Gulf Coasts in the past several years acted as a catalyst to propel the adoption of critical infrastructure policies in Texas and Louisiana. These States have both adopted laws stating that all critical government buildings must evaluate installing CHP in new buildings or during major retrofits of existing buildings.[10]

3. CHP BASICS AND BENEFITS

CHP, also known as cogeneration, is the simultaneous production of electricity and heat from a single fuel source, such as natural gas, biomass, biogas, coal, waste heat, or oil.[11] Instead of purchasing electricity from the grid and burning fuel in an on-site furnace or boiler to produce thermal energy (for heating, cooling, dehumidification, or process needs), facilities can use CHP to provide both energy services – electric power and thermal energy – in one energy-efficient step.[12]



Source: EPA CHP Partnership

Figure 1: CHP Efficiency Comparison

CHP can improve a facility's operation by increasing both the efficiency and reliability of its energy supply, therefore providing economic and environmental benefits.

Benefits of CHP: Figure 1 illustrates the efficiency benefits of a CHP system compared to a separate heat and power system. CHP provides numerous benefits, including the following:[13,14]

- Reduces energy costs for the user
- Reduces risk of electric grid disruptions and enhances energy reliability for the user

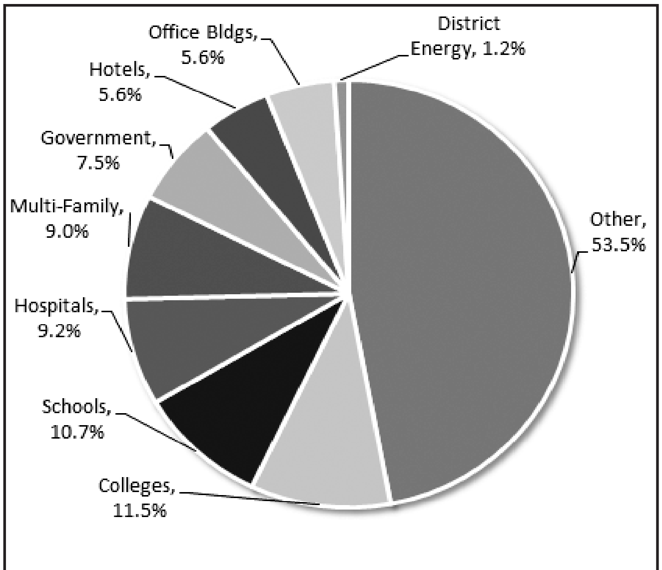
iii Critical facilities as defined by FEMA include hospitals, fire stations, police stations, storage of critical records, and similar facilities.

iv When designing a CHP system for an emergency facility, a critical infrastructure application, it is important that the system can operate independently from the grid ("islanding") and that it includes black start capability.

- Provides stability for the user in the face of uncertain electricity prices
- Offers a low-cost approach to new electricity generation capacity
- Provides an immediate path to lower greenhouse gas emissions through increased energy efficiency
- Lessens the need for new transmission and distribution (T&D) infrastructure and enhances power grid security

Current Use: CHP currently provides over 82 gigawatts (GW) of generation capacity at more than 4,100 facilities.[15] It is best used in applications that have coincident power and thermal loads, i.e. where the demand for electrical power and heat occur at the same time.

Thirteen percent of existing CHP capacity is in commercial and institutional applications, providing power, heating and cooling to multifamily housing, hospitals, schools, university campuses, hotels, nursing homes, and office buildings (Figure 2).



Source: ICF CHP Installation Database 2013

Figure 2: Commercial Sector CHP Sites

The remaining eight-seven percent of CHP capacity is primarily in industrial applications providing power and steam to energy intensive industries such as chemicals, paper, refining, food processing, and metals manufacturing.

Of the 2,300 commercial CHP sites, over half are at various commercial, institutional and multifamily properties, as shown in Figure 2. The largest amount of existing commercial CHP capacity in the Northeast is at municipal district energy sites followed by universities, hospitals, and multifamily buildings.

CHP in Multifamily Residential Buildings: Approximately 200 multifamily housing sites nationwide currently use CHP, representing nine percent of existing commercial CHP systems. Twenty-six of these sites are public housing developments. A table in the Appendix, at the end of this document, shows several multifamily facilities as well as assisted living and other critical facilities with CHP systems that remained operational during Hurricane Sandy.

CHP in Critical Facilities: Critical facilities as defined by FEMA include hospitals, fire stations, police stations, storage of critical records, and similar facilities; according to FEMA these facilities should be given special consideration when formulating regulatory alternatives and floodplain management plans.[16] A 2013 DOE report discusses how CHP can enable resilient energy infrastructure for critical facilities. The report showcases several examples of how CHP systems in New York and across the country continued to run and provide their host sites with electricity and thermal

Brevoort Co-op, Greenwich Village, New York

During Hurricane Sandy, the Brevoort Co-op was the only building on lower Fifth Avenue able to provide energy and full service to its residents thanks to its 400 kilowatt (kW) CHP system. The building has 277 units, and typically houses 720 residents. However, those numbers swelled to 1,500 after the storm as Brevoort residents took in friends and family members without power.

Salem Community College, Carney's Point, New Jersey:

During Hurricane Sandy, the 300 kW CHP system operated continuously for almost 48 hours. The American Red Cross opened a disaster relief shelter in Davidow Hall, one of the main campus buildings. The CHP system was the only source of power for Davidow Hall during the storm, and operations ran flawlessly, providing shelter to 85 people.

needs during extreme weather and emergency events including examples of universities, health care centers, hospitals, data centers, multi-family housing and local municipal utilities.[17]

District Energy, Microgrids, and CHP

Overview: Microgrids typically integrate small-scale distributed energy resources into low-voltage electricity systems within clearly defined electrical boundaries that act as a single controllable entity with respect to the grid. District Energy (DE) systems typically distribute thermal energy such as, steam, hot water, or chilled water, from a central plant to a number of facilities connected through a piped distribution system.[18]

Where feasible, both DE systems and microgrids can be operated with CHP, and provide an attractive option for meeting the power and thermal energy needs of multiple facilities located in close proximity that can benefit from a centralized supply of energy.

Benefits: Microgrids and DE systems can be designed to connect and disconnect from the grid to enable it to operate in both grid-connected or in an island-mode.[19] They can save the end-users, such as office and multifamily buildings, significant space in their buildings since these users do not now need to operate their own separate boilers or chillers. They can use a mix of fuels, and most DE systems can operate at a reliability of “five nines” (99.999 percent).[20]

Example Projects and Programs: Due to their resiliency and reliability benefits, many universities and cities are interested in DE systems with CHP or microgrids that incorporate CHP. DE CHP systems in cities and university campuses currently represent 5 GW of installed CHP.[21] Many city and local planning departments have recently begun to require the consideration of CHP in any new mixed-use developments.[22] For example, the City of San Francisco is moving forward on a large redevelopment project—termed the Transit Center District Plan. The Transit Center District Plan identifies CHP and DE as priorities in this new dense mixed use development. In addition, the Obama Administration is working closely with New Jersey on a range of new approaches to improve the resiliency of the grid, with a focus on microgrids and CHP. New Jersey Governor Chris Christie and Energy Secretary Ernest Moniz recently announced an agreement to develop a microgrid that would help ensure continued operation of the NJ Transit rail system after a major disaster such as Hurricane Sandy.[23] In addition, Connecticut established the nation’s first Statewide microgrid pilot program, and recently awarded a total of $18 million to nine microgrid projects that will keep critical building powered during grid outages.[24]

4. CHP SYSTEM REQUIREMENTS FOR RELIABILITY

Properly sized and configured CHP systems can effectively insulate facilities from a grid failure. In so doing they provide continuity of critical services, and free up power restoration efforts to be focused on other facilities. The design elements necessary so that a CHP system can be isolated from the grid – i.e. operate in “island” mode – are system-specific and include additional controls and switchgear.[25] For an example of a CHP system running in island mode, see the box on Greenwich Hospital.[26] In order to operate during a utility system outage, the CHP system must have the following features:

1. **Black start capability:** 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 or backup generator located on-site to allow it to start operating when the grid experiences an outage. 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” to begin operating.

2. **CHP electric generator capable of operating independently of the utility grid:** CHP systems use either synchronous or induction generators. Synchronous generators do not need to be connected to an external power grid to operate, and are the only option for “island” mode. However, they need additional safeguards to ensure 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. This external power typically comes from the local grid. High frequency generators (microturbines) or DC generators (fuel cells) also need to have inverter technology to ensure they can operate independently of the grid.

3. **Ample carrying capacity:** The size of the CHP system must be matched to the critical loads in the facility. During the design phase of the project, a decision will need to be made on whether to a) size the system for optimal energy and economic efficiency, and designate critical loads that will 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.

4. **Parallel utility interconnection and switchgear control:** When a CHP system disconnects from the utility grid in an outage, appropriate switchgear and controls are required to transition to serve critical loads without overloading the generator capacity. These critical loads must be isolated from the rest

of the facility's 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). The ability to seamlessly transfer from being grid interconnected to operating in an uninterrupted or island mode can add another 5% to 10% to the system capital costs, or more depending on the size and complexity of the system.[27]

5. DETERMINING IF CHP IS A GOOD FIT

Buildings or facilities that are considering whether CHP makes sense for them should examine the following items:

Financial Considerations:

- The up-front capital investment required to install CHP or replace an existing boiler (may also include the additional features that enable islanding and black start capability).
- Anticipated operations and maintenance (O&M) costs.
- The monetary savings that result from not paying for grid-provided electricity and separate thermal energy.
- The monetary and other benefits that result from maintaining critical operations during grid disruptions (e.g., data servers, research and development activities, caring for hospital patients, wastewater treatment).
- Meeting organizational financial targets (e.g., rate-of-return, return-on-investment).
- Availability of State, local, utility or Federal financial incentives for CHP.

Environmental and Compliance Considerations:

- Compliance with air quality requirements (through permitting).
- Compliance with local ordinances (e.g., building codes, fire regulations).
- Achievement of organizational sustainability/climate change goals.
- State policies and requirements governing utility actions that impact CHP system operation (e.g., interconnection standards, standby charges).

CHP Project Development: There are a variety of items that are important to successful development of CHP projects, including engaging with a knowledgeable developer who has dealt with installation challenges and has extensive experience in assessing the various factors that should be taken into account, as well as engaging early on with the local utility.

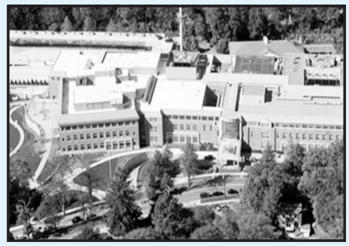
The development of a CHP project generally follows five phases:

- Site qualification;
- Level 1 feasibility analysis; Level 2 investment grade analysis;
- Financing,
- Permitting, and procurement; and
- Developing an operation and maintenance plan.

Please consult EPA's CHP Partnership Project Development Handbook[28] for details on these phases as well as tips for managing the development

Greenwich Hospital, Greenwich, Connecticut:

The area surrounding Greenwich Hospital lost power due to Hurricane Sandy for seven days. The transition from using grid power to operating solely on the 2.5 MW CHP system went smoothly. The entire process took about 5 minutes for the system to shut down and restart in island mode, while power was supplied to the hospital by backup generators. The CHP system allowed the hospital to continue normal operations throughout the storm and admit additional patients that could not be seen at other facilities.



process. The DOE Technical Assistance Partnerships (TAPs)[29] can also provide technical assistance throughout the project development process, including project screenings, feasibility analyses, and third-party review.

Available Assessment Tools: EPA, DOE and HUD have developed tools and resources and offer technical assistance to aid in the CHP decision-making process.

- EPA's CHP Partnership program offers a Spark Spread Estimator that calculates the difference between the delivered electricity price and the total cost to generate power with a prospective CHP system, providing an initial indication of its potential economic feasibility. The Partnership also offers a Project Development Handbook that provides information and tools for developing a CHP project.[30]
- DOE's Advanced Manufacturing Office provides CHP screenings, feasibility analysis, and third-party review of request for proposals and CHP project development proposals, through its regional CHP Technical Assistance Partnerships (CHP TAPs).[31]
- HUD also provides a CHP Screening Tool developed for multifamily housing.[32]

The Economics of CHP: Table 1 presents an economic comparison of a sample CHP system to the installation of new natural gas boilers. The CHP system consists of a combustion turbine that produces electrical power and a heat recovery steam generator. The assessment is based on a CHP system that is sized appropriately to meet the steam needs of a medium-to-large-sized institutional facility.[v]

Table 1: Comparative Economics between CHP and Natural Gas Boilers[33]

	New Natural Gas Boilers	New Natural Gas CHP	Comparison
Peak Boiler Capacity, MMBtu/hr input	120	120	
Peak Steam Capacity, MMBtu/hr	96	96	
Avg Steam Demand, MMBtu/hr	76.8	76.8	
Boiler Efficiency	80%	NA	
CHP Capacity, MW	NA	14	
CHP Electric Efficiency	NA	31%	
CHP Total Efficiency	NA	74%	
Annual Steam Use, MMBtu	614,400	614,400	0
Annual Steam Use, MMlbs	558.6	558.6	0
Annual Power Generation, kWh	NA	106,400,000	106,400,000
Fuel Use, MMBtu/year	768,000	1,317,786	549,786
Annual Fuel Cost	$4,608,000	$7,906,719	$3,298,719
Annual O&M Cost	$729,600	$1,687,200	$957,600
Annual Electric Savings	0	($6,703,200)	($6,703,200)
Net Annual Operating Costs	$5,337,600	$2,890,269	($2,447,331)
Steam Costs, $/MMBtu	$9.56	$5.18	($4.38)
Capital Costs	$4,200,000	$21,000,000	$16,800,000
10 Year Net Cash Flow (output)	**$65,389,602**	**$54,138,850**	($11,250,752)
Incremental CHP Payback			6.9 years
10 Year IRR - CHP vs. Gas Boiler			10%
10 Year NPV – CHP vs. Gas Boiler			$2,411,765

Source: ICF International

Notes: Based on 8,000 hours of operation, 7 cents per kWh electricity price, and $6/MMBtu natural gas price. CHP system cost of $1,500/kWh, O&M costs of $0.009/kWh and 31 percent electrical efficiency. CHP availability of 95 percent and portion of electric price avoided by on-site generation of 90 percent are assumed values. Natural gas boiler estimated cost of $35/MBtu input was provided by Worley Parsons. Net cash flow is based on a sum of 10-year operating costs, escalated at 3 percent annually, including capital cost as a Year 1 cost. All efficiency values and natural gas prices are expressed as higher heating values.

v A medium-to-large-sized institutional facility is typically a facility that could use a 10 to 20 MW CHP system with an average steam demand of at least 50 MMBtu/hr.

In this example, a CHP system is installed at a cost of $21 million compared to the cost of a standard gas boiler costing $4.2 million.[34] However, the overall economics show that the incremental cost more than pays for itself in terms of electricity savings resulting from the CHP system. As shown in Table 1, both the new boiler and the CHP system would serve the same steam demand (76.8 million BTU/hr) and provide the same thermal output during the year (614,400 million BTUs annually). However, the CHP system also provides power generation (106.4 million KWh annually).

Since the CHP system provides both heat and electricity from natural gas, the CHP system consumes significantly more natural gas than the boiler alone (1.31 million vs. 768,000 million BTUs/year). As a result, fuel costs for CHP in this example are almost double that of the boiler ($7.9 million vs. $4.6 million); there is also an additional $957,000 in operating and maintenance (O&M) costs. These additional fuel and O&M costs are more than offset by the electricity savings of $6.7 million, which yields a net savings of over $2.4 million/year. If all operating costs are attributed to the steam production, including the annual electric savings, steam costs decrease from $9.56/MMBtu to $5.18/MMBtu with the CHP system.

The cost of installing a CHP system in this example is, significantly higher than the cost of installing a gas boiler. However, as a result of the significant savings from the CHP system's electricity production, the incremental investment of $16.8 million for the CHP system provides an annual net savings of $2.4 million. In addition, the additional investment offers an internal rate of return of 10 percent and a payback period of less than 7 years, and an internal rate of return (IRR) of 10 percent.

Comparing CHP to Back-up Generators: Many facilities utilize back-up diesel generators to provide power during grid outages. These provide power and keep critical systems operational. Another option for facilities installing a diesel backup generator to provide outage protection, is to design that capability into a CHP system.[vi] In this type of configuration, the CHP system would be sized to meet both 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.[vii]

To assess the comparative benefits of CHP systems over backup generators, facilities need to carefully evaluate their year-round energy needs, as well as their backup power needs, and determine whether these needs can be met economically and strategically with either a CHP system or a backup generator. Table 2 provides a comparison between CHP and backup generators on several important metrics.

Table 2: Comparison between CHP and Backup Generators

	CHP	Backup Generators
System Performance	• Designed and maintained to run continuously • High performance reliability	• Only used during emergencies
Fuel Supply	• Natural gas infrastructure typically not impacted by severe weather	• Limited by on-site storage
Transition from Grid Power	• May be configured for "flicker-free" transfer from grid connection to "island mode"	• Lag time may impact critical system performance
Energy Outputs	• Electricity • Thermal (heating, cooling, hot/chilled water)	• Electricity
Emissions	• Typically natural gas fueled • Achieve greater system efficiencies (80%) • Lower emissions	• Commonly burn diesel fuel

vi Some health care facilities cannot forgo a backup generator. During the CHP development process, ensure all legal requirements relative to backup generators are considered.

vii The ability to seamlessly transfer from being grid interconnected to operating in an uninterrupted or island mode can add another 5% to 10% to the system capital costs, or more depending on the size and complexity of the system.

6. OPTIONS FOR FINANCING CHP

For companies or communities deciding whether or not to invest in CHP, there are a number of private, public, and public-private financing options available to help spread risk and overcome capital constraints.

Private Sector: Private financing options for CHP systems range from power purchase agreements[35] and other third-party financing options, to lease financing[36] and debt financing.[37]

Public Sector: Public financing options include revolving loan funds,[38] grant or rebate programs, State tax incentives, loan guarantees, State bonds, renewable/thermal energy credit (RECs) markets, and property assessed clean energy (PACE) financing[viii] Some examples of Federal and State financing programs that are either focused on Hurricane Sandy relief efforts or focused on energy efficiency projects such as CHP are cited below.[39]

- **FEMA.** The Federal Emergency Management Agency (FEMA) has two programs available under which CHP systems could potentially qualify – the FEMA Public Assistance Program,[40] and the FEMA Hazard Mitigation Program.[41]
- **New York State.** In New York State, the Community Reconstruction Zone (CRZ) Program was recently launched to help communities develop comprehensive local rebuilding plans funded by the State and federal government.[42] CHP could be part of the strategy for this CRZ effort. New York recently established the CHP Acceleration Program administered by NYSERDA.[43]
- **New Jersey.** In New Jersey, the Economic Development Authority (EDA) provides grants for the installation of CHP or fuel cells.[44]
- **Connecticut.** In Connecticut, the Clean Energy Finance and Investment Authority currently has $5 million in financing available for grants, loans, loan enhancements, and power purchase incentives for CHP projects.[45]

7. RESOURCES FOR MORE INFORMATION

There are a number of resources available to help determine if CHP is a good option for Sandy rebuilding efforts. The EPA CHP Partnership, U.S. Department of Energy, and the U.S. Department of Housing and Urban Development provide a number of CHP screening tools which provide information on CHP technology options, estimated costs of installing CHP, financing opportunities, along with projected benefits from such installations.

General CHP Information

- Department of Energy, CHP Deployment Program, http://www1.eere.energy.gov/manufacturing/distributedenergy/
- EPA CHP Partnership, http://www.epa.gov/chp/index.html
- SEE Action – Guide to the Successful Implementation of State Combined Heat and Power Policies, http://www1.eere.energy.gov/seeaction/pdfs/see_action_chp_policies_guide.pdf
- DOE and EPA, Combined Heat and Power: A Clean Energy Solution, http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf

CHP for Reliability/Resiliency

- CHP: Enabling Resilient Energy Infrastructure for Critical Facilities, http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_critical_facilities.pdf
- Environmental and Energy Study Institute, Energy Efficient Infrastructure for More Resilient Local Economies: The Role of District Energy, CHP, and Microgrids, http://www.eesi.org/050813idea
- NYSERDA, The Contribution of CHP to Infrastructure Resiliency in New York State, http://www.energetics.com/resourcecenter/products/studies/Pages/CHP-Contribution-Infrastructure-NY.aspx

Project Development Process

- CHP Project Development Handbook, http://www.epa.gov/chp/project-development/index.html
- HUD CHP Screening Tools,46 http://portal.hud.gov/hudportal/HUD?src=/program_offices/comm_planning/library/energy
- DOE Clean Energy Application Centers / CHP Technical Assistance Partnerships, http://www1.eere.energy.gov/manufacturing/distributedenergy

Availability of Incentives

- EPA CHP Partnership CHPP incentive database http://www.epa.gov/chp/policies/database.html
- Database of State Incentives for Renewables and Efficiency http://www.dsireusa.org/
- Federal Finance Facilities Available for Energy Efficiency Upgrades and Clean Energy Deployment, A Guide for State, Local & Tribal Leaders and their

viii Commercial property assessed clean energy (PACE) programs allow building owners to receive full financing for eligible energy saving measures (which can include CHP), repaid as a property tax assessment for up to 20 years.

Partners http://energy.gov/sites/prod/files/2013/08/f2/Federal%20Finance%20Facilities%20Available%20for%20Energy%20Efficiency%20Upgrades%20and%20Clean%20Energy%20Deployment.pdf

Other

- HUD Hurricane Sandy Rebuilding Task Force http://portal.hud.gov/hudportal/HUD?src=/sandyrebuilding

APPENDIX

Table: Snapshot of 11 Facilities with CHP and their Operation during Hurricane Sandy

Name of Facility	Type	Size	CHP Capacity	Location	Operational during Sandy
MULTIFAMILY BUILDINGS					
Co-op City	Multifamily	15,372 units	40,000 kW	Bronx, NY	The CHP plant at Co-op City provided the 60,000-plus residents with power and heating throughout the storm and its aftermath.
Seaside Apartments	Multifamily	275 units	100 kW	Staten Island, NY	Yes
Heritage House	Assisted Living	56 units	75 kW	Falmouth, MA	The CHP system was operational during Sandy, providing standby capabilities to the facility.
Schwab House	Multifamily	654 units	300 kW	New York, NY	Yes
Toren Condominiums	Multifamily	240 units	500 kW	Brooklyn, NY	Yes
CRITICAL FACILITIES – HEALTHCARE					
St Joachims and Ann Nursing & Rehab	Nursing	200 beds	300 kW	Brooklyn, NY	The Center stayed open and continued to provide 24-hour care to more than 200 residents.
South Oaks Hospital	Hospital	245 beds	1,250 kW	Amityville, NY	South Oaks was able to provide critical services for two weeks relying solely on its CHP system.
Christian Health Care Center	Hospital	300 beds	260 kW	Wyckoff, NJ	The CHCC CHP system ran independently of the grid for 97 hours, meeting all of its residents' power, heat, and hot water needs.
CRITICAL FACILITIES – COLLEGES & UNIVERSITIES					
The College of New Jersey	College	39 major buildings	5,200 kW	Ewing, NJ	The campus CHP system stayed in island mode for about a week because of severe utility infrastructure problems, providing more than 40% of the campus' electricity needs.
Princeton University	University	180 on-campus buildings	15,000 kW	Princeton, NJ	The CHP system provided the university with power, heating, and cooling throughout the storm and its aftermath. 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.
CRITICAL FACILITIES – PUBLIC INFRASTRUCTURE					
Bergen County Utilities Wastewater Plant	Water Treatment	Serves 47 communities	2,800 kW	Little Ferry, NJ	The CHP system operated seamlessly for 24 hours without support from the local utility, and was praised by the adjacent power plant for being able to provide treated cooling water throughout the storm event.

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29 DOE. http://www1.eere.energy.gov/manufacturing/distributedenergy/ceacs.html.

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31 DOE Technical Assistance Partnerships. http://www1.eere.energy.gov/manufacturing/distributedenergy. Through September 30, 2013, the CHP Technical Assistance Partnerships (CHP TAPs) are known as Clean Energy Application Centers (CEACs).

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33 EPA CHP Partnership. Fact Sheet: CHP as a Boiler Replacement Opportunity. http://www.epa.gov/chp/documents/boiler_opportunity.pdf.

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35 An arrangement whereby a third-party developer owns, operates, and maintains the CHP system, and a host customer agrees to purchase the system's electric and thermal outputs. This financial arrangement allows the host customer to receive stable, and sometimes lower cost electricity, while the CHP provider acquires valuable financial benefits such as tax credits and income generated from the sale of electricity to the host customer. DOE information on renewable PPA's and sample documents can be accessed at: https://www1.eere.energy.gov/femp/financing/power_purchase_agreements.html.

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37 Debt financing means borrowing money on credit with a promise to pay the amount borrowed, plus interest. Debt financing programs, such as low-interest loan programs, are designed to improve the availability and affordability of capital for CHP development. For small businesses, the Small Business Administration (SBA) can guarantee bank loans up to $750,000 for energy efficiency projects. The SBA guarantee could improve a borrower's ability to secure a loan.

38 A loan program that provides low-cost financing to eligible entities within state/tribal lands for specific projects.

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