NRDC ISSUE PAPER

APRIL 2013
IP:13-04-B

Combined Heat and Power Systems:
Improving the Energy Efficiency of Our Manufacturing Plants, Buildings, and Other Facilities

AUTHORS
Vignesh Gowrishankar
Christina Angelides
Hannah Druckenmiller

Acknowledgments

The authors would like to acknowledge John Cuttica and Clifford Haefke at the Midwest Clean Energy Application Center, Katrina Pielli at the U.S. Department of Energy, and Dylan Sullivan at NRDC for valuable feedback and comments.

About NRDC

The Natural Resources Defense Council (NRDC) is an international nonprofit environmental organization with more than 1.4 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in New York City, Washington, D.C., Los Angeles, San Francisco, Chicago, Livingston, and Beijing. Visit us at www.nrdc.org.

NRDC's policy publications aim to inform and influence solutions to the world's most pressing environmental and public health issues. For additional policy content, visit our online policy portal at www.nrdc.org/policy.

NRDC Director of Communications: Edwin Chen
NRDC Deputy Director of Communications: Lisa Goffredi
NRDC Policy Publications Director: Alex Kennaugh
Lead Editor: Carlita Salazar
Design and Production: www.suerossi.com

Cover images: Reciprocating engine © Finley Buttes; Gas turbine at University of Illinois at Chicago © Vignesh Gowrishankar; CHP at BMW manufacturing plant © BMW Manufacturing Co.

EXECUTIVE SUMMARY

Improving the energy efficiency of our manufacturing facilities, buildings, and homes can help us meet our energy challenges affordably. It can save consumers money on their energy bills, drive business competitiveness and economic growth and jobs, enhance grid reliability and flexibility, and help protect public health and the environment. Combined heat and power (CHP) systems are strong examples of how energy-efficiency technologies can help achieve these significant benefits for end-user facilities, utilities, and communities. As the case studies featured in this report illustrate, CHP systems are extremely versatile and can be used in a spectrum of industries—advanced manufacturing, food processing, health care, chemical and primary metal production—and facilities including data centers, hotels, multifamily housing, district energy, landfills, and farms.

CHP technology has vastly improved in recent years, and current market drivers are becoming more favorable. When designed and operated properly, CHP systems can be economical and can generate considerable net savings. Currently, 82 gigawatts (GW) of installed CHP generation capacity (9 percent of U.S. energy-generation capacity) are in use at more than 4,100 sites across every state in the nation. But at least 50 GW, and up to almost 200 GW of additional CHP potential, remain to be tapped.

This issue paper illuminates the great potential and versatility of CHP technologies to generate useful energy more efficiently, describing how these systems work; the benefits they can provide; their application and use in the industrial, commercial, institutional, agricultural, and residential sectors; and their economics. Central to this paper are 30 case studies that demonstrate how various facilities have taken advantage of CHP to better control their energy use, boost their bottom lines, and reduce pollution and reap other benefits. Table 1 on the following page indexes the featured case studies and sectors, and summarizes the mix of benefits seen at these facilities, as described later in the report.

© Sikorsky

Sikorsky manufacturing plant.

Table 1: Summary and Index of Featured Case Studies and Their Benefits

Sector	Subsector	Case studies (in report)	State	Page	Energy efficiency	Reduced energy costs	Supply power to grid	Other revenue streams	Energy reliability	Power quality	Easier capacity expansion	Industry-specific benefit	Meeting standards	Reduced emissions	Job creation	Renewables integration
					Key system attributes seen in case studies											
INDUSTRIAL	Advanced manufacturing	**1. Sikorsky Aircraft Corp.**	CT	5	Y	Y			Y					Y		
INDUSTRIAL	Automotive	**2. BMW Manufacturing Co.**	SC	6	Y	Y			Y					Y		
INDUSTRIAL	Chemicals, plastics, rubber	**3. Dow Chemical Co.**	LA	6	Y	Y								Y		
INDUSTRIAL	Chemicals, plastics, rubber	**4. Harbec Plastics**	NY	8	Y	Y			Y	Y	Y			Y		
INDUSTRIAL	Ethanol	**5. POET Biorefining – Macon**	MO	8	Y	Y	Y		Y				Y			
INDUSTRIAL	Food processing	**6. Frito-Lay**	CT	9	Y	Y			Y					Y		
INDUSTRIAL	Food processing	**7. Gills Onions**	CA	10	Y	Y		Y				Y	Y	Y		Y
INDUSTRIAL	Forest products	**8. Brattleboro Kiln Dry Co.**	VT	11	Y	Y										
INDUSTRIAL	Pharmaceuticals	**9. Johnson & Johnson Transform Pharmaceuticals**	MA	13	Y	Y								Y		Y
INDUSTRIAL	Power generation	**10. Linden Cogeneration Plant**	NJ	13	Y									Y	Y	
INDUSTRIAL	Primary metals	**11. ArcelorMittal Indiana Harbor**	IN	14	Y	Y			Y					Y	Y	
INDUSTRIAL	Primary metals	**12. SunCoke Energy**	OH	14	Y	Y	Y	Y				Y		Y		
INDUSTRIAL	Pulp and paper	**13. Seaman Paper Co.**	MA	15	Y	Y								Y		
INDUSTRIAL	Refineries	**14. Ergon**	MS	16	Y	Y			Y	Y					Y	
COMMERCIAL	Data centers	**15. BP Helios Plaza**	TX	16	Y	Y			Y					Y		
COMMERCIAL	Hotels, resorts	**16. Snowbird Ski & Summer Resort**	UT	18	Y	Y			Y		Y					
COMMERCIAL	Hotels, resorts	**17. Hilton New York**	NY	20	Y											
COMMERCIAL	Laundries	**18. Arrow Linen Supply Co.**	NY	20	Y	Y			Y					Y		
COMMERCIAL	Multifamily housing	**19. Co-Op City**	NY	23	Y		Y									
COMMERCIAL	Office buildings	**20. Transamerica Pyramid Bldg.**	CA	24	Y	Y			Y				Y			
COMMERCIAL	Retail center	**21. Roger's Gardens**	CA	24	Y	Y			Y					Y		
INSTITUTIONAL	District energy	**22. TECO**	TX	25	Y	Y			Y					Y		
INSTITUTIONAL	Health care	**23. Baptist Medical Center**	MS	26	Y	Y			Y							
INSTITUTIONAL	Health care	**24. Beloit Memorial Hospital**	WI	27	Y	Y	Y		Y	Y	Y					
INSTITUTIONAL	Landfills	**25. Finley Buttes Regional Landfill**	OR	28	Y	Y	Y	Y				Y		Y		Y
INSTITUTIONAL	Military	**26. Naval Station Great Lakes**	IL	28	Y	Y			Y					Y		
INSTITUTIONAL	Universities, colleges	**27. Cornell University**	NY	29	Y	Y			Y					Y		
INSTITUTIONAL	Wastewater treatment	**28. Rochester Wastewater Reclamation Plant**	MN	29	Y	Y			Y			Y		Y		Y
AGRICULTURAL	Dairies	**29. Crave Brothers Farmstead Cheese**	WI	30	Y	Y	Y	Y			Y	Y		Y		Y
AGRICULTURAL	Greenhouses	**30. Houweling's Tomatoes**	CA	30	Y	Y	Y	Y				Y	Y	Y		

COMBINED HEAT AND POWER: A ROBUST TOOL TO IMPROVE ENERGY EFFICIENCY ACROSS SECTORS

Improving the energy efficiency of our manufacturing facilities, buildings, and homes can help us meet our energy challenges affordably. However, seizing greater energy-efficiency opportunities in these sectors will require diverse strategies to meet national and state energy, environmental, and economic goals, including the deployment of better-performing energy-efficient technologies and systems. Combined heat and power (CHP)—an integrated system that simultaneously generates electricity and useful thermal energy (e.g., steam) from a single fuel—is a versatile technology that can generate useful energy more efficiently, and thereby significantly and economically improve energy efficiency and deliver substantial benefits for end-user facilities, utilities, and communities.

Currently, 82 GW of installed CHP generation capacity—the equivalent of more than 130 coal plants on average, or 9 percent of our nation's total energy-generation capacity—is in use at more than 4,100 sites across every state in the nation.[1] While the vast majority of CHP systems (by capacity) are used in manufacturing facilities, a growing number of commercial, agricultural, and residential sites, such as supermarkets, hotels, and multifamily housing complexes, are considering the use of such systems.[2]

There exists significant potential for much greater CHP deployment throughout the U.S. economy—at least 50 GW and up to almost 200 GW more. CHP has markedly advanced over the years and is more reliable and cost-effective than ever before. Also, the price of natural gas, the most common fuel used in CHP applications, has dropped, and future prices are projected to be conducive to CHP expansion over the next few years. Another factor driving increased deployment of CHP systems has been growth in state and utility incentives for CHP in various forms.

In a conventional CHP system (known simply as CHP, or topping-cycle CHP), fuel is burned solely to generate electricity and useful thermal energy. In a variation on the conventional system, called waste energy recovery (WER, or bottoming-cycle CHP), a fuel is burned to serve an industrial process (e.g., steel production), and any unused (or "waste") energy (e.g., process gases, in the case of steel production) is then captured to generate electricity and, in some cases, additional useful thermal energy. Waste energy recovery can also include the productive utilization of pressure drops or gaseous exhaust with partial-fuel content. (Please note: In this document, unless otherwise specified, CHP refers to both conventional CHP and WER systems.)

The electricity from CHP systems can be used on-site or sold back to the grid if agreements and protocols with the local utility can be arranged. The thermal energy can be used, typically on-site, for a variety of purposes such as steam production, refrigeration, and space heating or cooling. In fact, the most efficient CHP systems are those that are able to productively utilize, with minimal waste, the available thermal energy.

As outlined in subsequent sections, CHP systems employ a variety of technologies on a wide range of scales, use different fuels, and can be implemented across many industries and applications. While a full discussion of the necessary drivers to promote CHP deployment is beyond the scope of this report, enhanced awareness of and education about CHP's versatility and potential, coupled with strong commitment from businesses, suitable facilitation from utilities, and conducive policies and regulations from all levels of government, are needed to drive these technologies in the marketplace.

1 **Sikorsky Aircraft Corp.** Stratford, CT

OVERVIEW: Sikorsky's 10-MW CHP plant, which provides 84 percent of the facility's electricity needs and 85 percent of its steam-heating needs, began operation in 2011. As part of the company's larger push toward environmental responsibility—which included the installation of 450 solar panels—the CHP plant reduces carbon dioxide (CO_2) emissions by 8,900 tons per year. With energy savings of more than $6.5 million per year, Sikorsky's almost $26 million investment is expected to pay back in less than four years. The CHP system can run on multiple fuels (e.g., natural gas and oil), so the facility is insulated from fuel-price volatility and supply risks. During and after Hurricane Sandy, the CHP system provided backup power for the facility to remain open and minimize operational disruption. Moreover, the facility was able to service its 9,000 employees with food and amenities, even while many local communities were without power. Based on the overall success of this CHP system, Sikorsky is considering other clean-energy solutions in more of its facilities worldwide.

FINANCING AND INCENTIVES:

- $26 million capital investment by Sikorsky Aircraft Corp.
- $4.66 million State Cogeneration Incentive Grant

SECTOR: Advanced manufacturing

OPERATION START: 2011

TECHNOLOGY: Gas turbine

FUEL: Natural gas

MANUFACTURER: Carrier (UTC)

CAPACITY: 10 MW

INSTALLED COST: $30.6 million

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: > $6.5 million/year

REPORTED PAYBACK: <4 years

OTHER BENEFITS:

- Reduces emissions: 8,900 tons CO_2/year

Source: Pangea Digital Media, "Sikorsky Aircraft Breaks Ground for Co-generation Project," World of Cogeneration, October 12, 2009, available at http://www.worldofcogeneration.com/cogen_plants/combined_cycle_news/3211-Sikorsky-Aircraft-Breaks-Ground-for--generation-Project.html.

2 **BMW Manufacturing Co.** Spartanburg, SC

OVERVIEW: In 2009, two high-efficiency gas-fired combustion turbines were installed at the BMW manufacturing plant in Spartanburg, South Carolina. The facility imports landfill gas from Waste Management's Palmetto Landfill through a 9.5-mile pipeline to fuel the 11-MW CHP system. In addition, the exhaust heat is recovered and used to generate steam for the facility's industrial processes. The CHP meets 30 percent of the plant's electrical needs and about 50 percent of its thermal needs. In addition to providing reliable power on-site, the installation has resulted in annual energy savings of between \$5 million and \$7 million and reduced CO_2 emissions by 92,000 tons per year.

SECTOR: Automotive

OPERATION START: 2009

TECHNOLOGY: Gas turbine

FUEL: Landfill gas

MANUFACTURER: N/A

CAPACITY: 11 MW

INSTALLED COST: N/A

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: \$5 million to \$7 million/year

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reduces emissions: 92,000 tons CO_2/year

Source: U.S. Department of Energy, Southeast Clean Energy Application Center, *BMW Manufacturing Co.*, Project Profile, October 2009, available at http://www.southeastcleanenergy.org/profiles/se_profiles/BMW_Case_Study.pdf.

3 **Dow Chemical Co.** Plaquemine, LA

OVERVIEW: Dow's 1,500-acre integrated-manufacturing facility near Plaquemine and brine operations in Grand Bayou comprise one of Louisiana's largest petrochemical facilities, with more than 3,000 employees and contract employees. It is home to 23 production units that manufacture more than 50 different intermediate and specialty chemical products, such as chlorine and polyethylene, that are used to produce cosmetics, detergents, solvents, pharmaceuticals, adhesives, and plastics for a variety of packaging, automotive parts, electronics components, and more. Dow currently owns and operates the Plaquemine cogeneration plant, which consists of four GE natural gas fired, 170-MW combustion turbines and a 200-MW steam turbine. For increased flexibility, the system is capable of firing multiple fuels, including pure natural gas, pure hydrogen-gas stream, or a mixture. This plant allows Dow to generate power and steam via more energy-efficient assets, decrease the use of older, less efficient equipment over time, and reduce energy costs. Power and steam are used at the Plaquemine and other Dow manufacturing facilities. The system reduces CO_2 emissions up to 0.94 million metric tons per year, and mono-nitrogen oxide (NO_X) emissions are less than one-quarter of those at a typical power plant.

Dow is an extensive user of CHP, with more than 90 percent of its energy requirements served by CHP (either self-owned or third-party operated). Typical efficiencies of Dow's CHP systems exceed 80 percent, while emission-control equipment helps reduce emissions.

SECTOR: Chemicals, plastics, rubber

OPERATION START: 2004

TECHNOLOGY: Gas turbine, steam turbine

FUEL: Natural gas

MANUFACTURERS: GE (gas turbine), Alstom (steam turbine), NEM (heat recovery steam generator)

CAPACITY: 880 MW

INSTALLED COST: \$550 million

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: >\$80 million/year

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reduced CO_2 emissions
- Reduced NO_x emissions
- Fuel flexibility

Source: "Dow Chemical Completes Purchase Of Plaquemine Cogeneration Facility from AEP," Chemical Online, December 2006, available at http://www.chemicalonline.com/doc.mvc/Dow-Chemical-Completes-Purchase-Of-Plaquemine-0001; U.S. Environmental Protection Agency, Letter to Dow Plaquemine Cogeneration Facility, July 2011, available at http://www.epa.gov/airmarkets/emissions/petitions/2011/R20110713_55419.pdf; Dow Chemical Company, "Congress Must Continue Incentives for Combined Heat and Power: The Dow Chemical Company's Perspective," available at http://lobby.la.psu.edu/_107th/128_PURPA/Organizational_Statements/North_East_Mid_West_Institute/congress_must_continue_incentives.pdf(accessed March 2013).

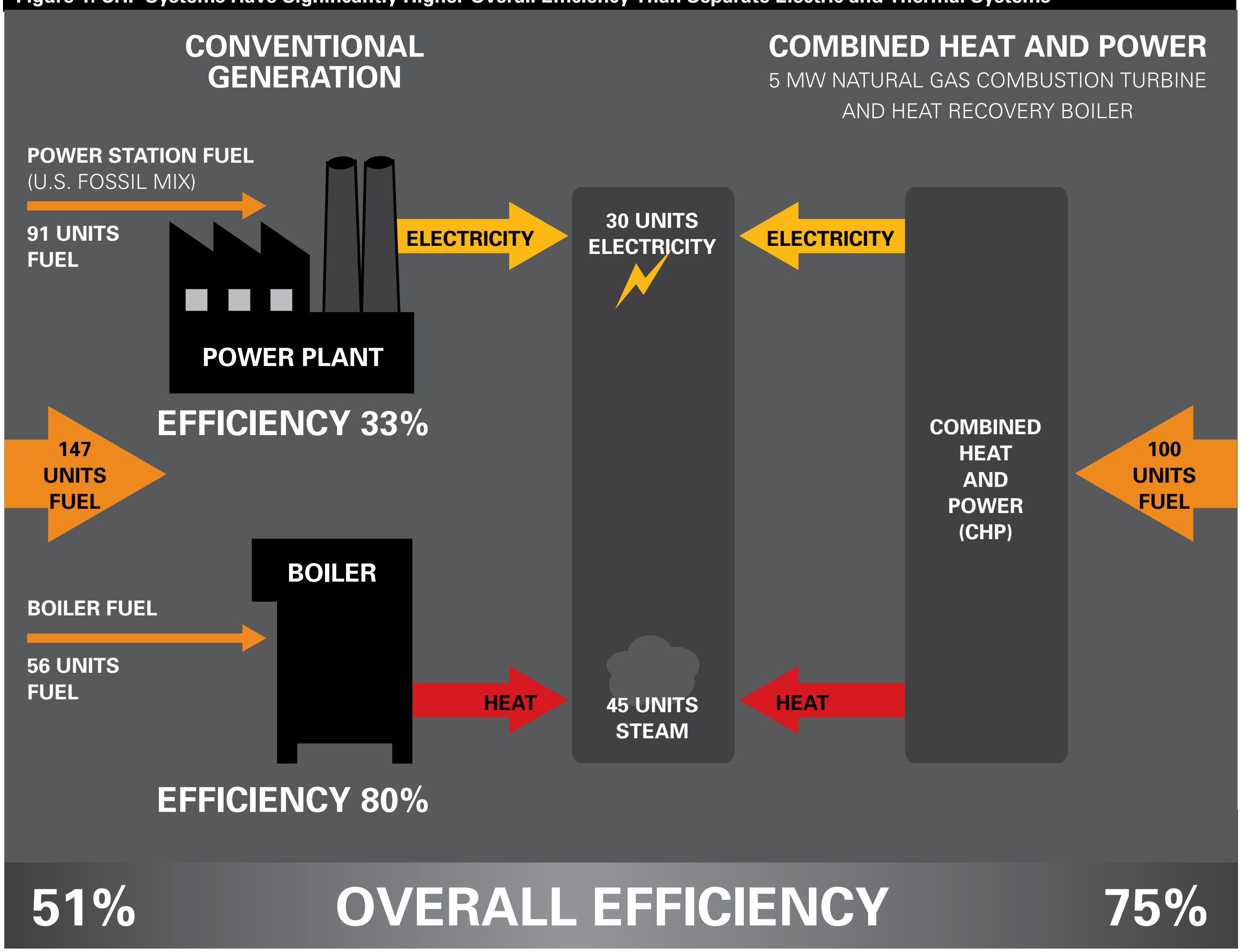
THE MYRIAD BENEFITS OF COMBINED HEAT AND POWER SYSTEMS

Before considering the use of CHP, facilities must make certain that all existing electrical and thermal loads and processes are as efficient as possible. This will ensure that CHP systems are optimally sized.

CHP systems can then facilitate much more efficient generation and use of energy than systems that generate electricity and thermal energy separately (e.g., electricity purchased from a utility and thermal energy generated by a boiler). Conventional power stations (e.g., coal plants, combined-cycle natural gas plants) discard, on average, close to two-thirds of a fuel's intrinsic energy as wasted heat, typically resulting in energy efficiency levels below 40 percent. Boilers that generate thermal energy alone are more efficient, achieving efficiencies of around 80 percent or higher. However, to meet the total electrical and thermal energy needs of a given facility, power stations and boilers working independently achieve overall energy efficiencies of only about 50 percent (see figure 1). In contrast, CHP technologies are able to put the thermal energy that would be wasted by conventional power systems to productive use and can routinely achieve overall average efficiency levels of 75 percent or higher.[3] Furthermore, because electricity is generated and used on-site, there are fewer transmission and distribution losses compared with electricity obtained from distant power plants.

Stemming from this core advantage of greater energy efficiency and complemented by other features, CHP systems offer myriad benefits for end-user facilities (e.g., manufacturing plants and commercial buildings), utilities, and communities. These benefits are discussed in the following section.

Figure 1: CHP Systems Have Significantly Higher Overall Efficiency Than Separate Electric and Thermal Systems[a]



a U.S. EPA, *Combined Heat and Power Partnership, Efficiency Benefits*, available at http://www.epa.gov/chp/basic/efficiency.html (accessed March 2013).

© Harbec Plastics

4 Harbec Plastics Ontario, NY

OVERVIEW: In 2001, Harbec Plastics, a custom-injection molder located in Ontario, New York, installed 25 30-kW microturbines. The CHP system provides electricity for manufacturing processes and thermal energy to heat and cool the facility. The microturbines, which run on natural gas, can be dispatched in 30-kW increments, making the CHP system an ideal fit for a facility currently with a load range of 80 kW to 450 kW; when a 30-kW increase is needed, an additional unit is turned on, and when a 30-kW decrease is expected, a unit can be turned off. With an overall efficiency of 70 percent, the CHP results in a 36 percent energy savings and reduces the facility's CO_2 emissions by 1,800 tons per year. In the past, the CHP system's high-quality, reliable power allowed Harbec Plastics to circumvent as much as $15,000 per month in damaged equipment and lost product. Today, Harbec operates its CHP under thermal priority, which means the plant's thermal requirements, for heating and air conditioning, dictate the number of turbines operating at any time. In this mode, Harbec's CHP system is always ensuring maximum overall energy efficiency and thus maximum economic and environmental opportunity.

SECTOR: Chemicals, plastics, rubber

OPERATION START: 2001

TECHNOLOGY: Microturbine

FUEL: Natural gas

MANUFACTURER: Capstone

CAPACITY: 750 kW

INSTALLED COST: N/A

OVERALL EFFICIENCY: 70%

ENERGY SAVINGS: 36% net cost reduction per year

REPORTED PAYBACK: 2.5 years

OTHER BENEFITS:

- Reliability
- Avoided cost of damaged equipment
- Reduced emissions by 1,800 tons CO_2/year

Source: U.S. Department of Energy, Northeast CHP Application Center, *Harbec Plastics*, Project Profile, available at http://www.northeastcleanenergy.org/profiles/documents/Harbec-CHPProjectProfile_final.pdf (accessed March 2013).

© POET Biorefining - Macon

5 Northeast Missouri Grain, LLC, doing business as POET Biorefining – Macon Macon, MO

OVERVIEW: In a joint venture with the City of Macon, Missouri, POET Biorefining – Macon installed a 10-MW Solar Mars 100 Gas Turbine in April 2003. (The CHP system is operated by the City of Macon; the turbine generator is maintained by the City of Macon; and the heat recovery steam generator is maintained by POET Biorefining – Macon.) The CHP system provides the 45-million-gallon-per-year ethanol plant with 100 percent of its electrical needs (as a backup to its on-site sub-stations) and approximately 60 percent of its steam needs. As a result, POET Biorefining – Macon has seen an approximate 20 percent reduction in steam production costs and has successfully maintained operations through two to four power outages per year since the system was put online.

FINANCING AND INCENTIVES: Built on-site at the ethanol plant, the CHP system was purchased entirely by the City of Macon, which has benefited from a 50 percent decrease in fuel costs and has received renewable-energy credits from the State of Missouri.

SECTOR: Ethanol

OPERATION START: 2003

TECHNOLOGY: Gas turbine

FUEL: Natural gas

MANUFACTURERS: Solar Turbines, Deltek

CAPACITY: 10 MW

INSTALLED COST: N/A

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: Approximately 20% cost savings on steam production per year

REPORTED PAYBACK: 13 years

OTHER BENEFITS:

- Reliability

Source: U.S. Department of Energy, Midwest CHP Application Center, *Northeast Missouri Grain, LLC & City of Macon, Missouri*, Project Profile, available at http://www.midwestcleanenergy.org/profiles/ProjectProfiles/NortheastMissouriGrain.pdf (accessed March 2013).

COMBINED HEAT AND POWER SYSTEM BENEFITS TO THE END USER

Reduced energy costs: CHP's greater overall efficiency reduces fuel costs. By generating on-site power and thermal energy, it is possible to displace as much as one-third to one-half of the overall energy expenditures at a facility, especially in regions where purchased power from utilities is relatively expensive.[4] As such, CHP systems generate significant annual operational cost savings. This is what enables CHP systems to pay back the initial investment, and the savings continue beyond the payback period for the remainder of the system's useful life. Energy-intensive industries (e.g., steel, refining, chemicals) may especially benefit from cost savings related to electrical power and thermal energy.

New revenue streams: CHP systems can also offer new sources of income. For example, excess electricity can be sold to a utility if agreements and protocols can be arranged. CHP systems can also provide saleable steam and heat or other industry-specific products. While these markets are emerging, additional revenue streams for CHP could include certain types of clean energy credits as well as payments for providing demand response and capacity reserves.

Increased competitiveness: Energy bill savings and additional revenue streams provided by CHP systems can be reinvested in facilities (or companies at large) to support facility expansion and other capital projects, to hire or retain workers, or in other initiatives that enhance competitiveness. CHP systems can also earn Leadership in Energy and Environmental Design (LEED) recognition and Energy Star CHP awards. Companies could use this recognition to differentiate themselves in the marketplace and help fulfill corporate social responsibility goals.

Increased energy reliability: CHP systems produce both electricity and thermal energy on-site; accordingly, they reduce the risk of electric grid disruptions and enhance energy reliability.[5] CHP systems have the ability to provide utility-quality backup power capable of running even when there is a power outage in the grid (often referred to as running in "island" mode; a small amount of increased capital investment may be required to enable this benefit).[6] Power outages can be very costly for companies—for example, a one-hour outage at an industrial manufacturing plant can cost a company more than $50,000 in losses.[7] And sometimes more than money is at stake when the power goes out. The increased reliability that CHP systems provide is especially important for facilities where power is mission-critical, such as hospitals, data centers, and 24/7 industrial facilities.

In fact, during Hurricane Katrina in August 2005 and Hurricane Sandy in October 2012, facilities with CHP had uninterrupted access to reliable and essential power and thermal amenities. These sites included the Baptist Medical Center in Jackson, Mississippi (see case study 23); Co-Op City in the Bronx, New York (case study 19); Sikorsky Corporation in Stratford, CT (see case study 1); the South Oaks Hospital in Amityville, NY; the Greenwich Hospital in Greenwich, CT; Princeton University in Princeton, NJ; The College of New Jersey in Ewing, NJ; the Public Interest Data Center in New York City; and New York University's Washington Square campus. For New York University, the critical benefits of CHP were starkly apparent: While the Washington Square campus had power, its Langone Medical Center lost grid and backup power and had to evacuate all of its patients.[8]

Furthermore, to insulate facilities from fuel-price volatility and possible supply risks, CHP systems can be configured to run on multiple fuels. And as another facet of energy reliability, CHP systems can offer superior power quality (i.e., a more regular and predictable voltage and current profile).[9] They can achieve this when isolated from or even when connected to the grid.

6 **Frito-Lay** Killingly, CT

OVERVIEW: Pepsi's Frito-Lay plant in Killingly, Connecticut, is a 275,000-square-foot facility with more than 400 employees. In 2009, Frito-Lay installed a Solar Turbines Centaur 50 gas turbine and a heat recovery steam generator (HRSG) from Rentech Boiler Systems. The CHP system meets 90 percent of the facility's electrical needs, and the HRSG uses the exhaust heat from the gas turbine to produce 48,000 pounds of steam per hour to heat the oil in two chip fryers. In addition, the exhaust heat from the fryers is recovered and used for space heating. As a 24/7 facility, reliability was a large driver in Frito-Lay's decision to install a CHP system; the plant can be run in "island" mode should the grid go down. Together, the low-emissions gas turbine and HRSG with selective catalytic reduction have reduced the facility's NO_X emissions to 2.5 parts per million.

SECTOR: Food processing

OPERATION START: 2009

TECHNOLOGY: Gas turbine

FUEL: Natural gas

MANUFACTURERS: Solar Turbines, Rentech Boiler Systems

CAPACITY: 4.5 MW

INSTALLED COST: N/A

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: N/A

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reliability
- Reduced NO_x emissions

Source: U.S. Department of Energy, Northeast Clean Energy Application Center, *Frito-Lay Killingly*, Project Profile, 2010, available at http://www.northeastcleanenergy.org/profiles/documents/FritoLayCaseStudy.pdf.

Easier energy capacity expansion: CHP systems are typically scalable according to a facility's eletrical and thermal needs. CHP systems can sometimes also be installed more quickly than a utility can extend the required high-voltage transmission and distribution. CHP systems can typically be installed within one-half to three years, whereas transmission build-outs can take 10 years or longer.[10]

Industry- or product-specific benefits: CHP systems can often offer industry- or product-specific benefits, such as

- Production of higher-quality metallurgical coke (see case study 12, SunCoke Energy)
- Utilization of carbon-dioxide emissions as fertilizer and reduction of water usage (see case study 30, Houweling's Tomatoes)

In addition, CHP systems can help promote the sustainable use of otherwise wasted products and can simplify waste management. Some examples are

- Improved waste management and production of animal feed (see case study 7, Gills Onions)
- Waste reduction (see case study 29, Crave Brothers Farmstead Cheese)
- Productive use of landfill waste (see case study 25, Finley Buttes Regional Landfill)
- Improved waste management (see case study 28, Rochester Wastewater Reclamation Plant)

COMBINED HEAT AND POWER SYSTEM BENEFITS TO UTILITIES

Meeting standards: CHP systems can potentially help facilities and utilities meet their compliance obligations under local, state, and federal emissions standards, such as the recently announced air toxin standards for boilers and power plants. While these systems on their own may not bring facilities into compliance, they can potentially help reduce the cost of meeting those standards and reduce the emission of CO_2 and other pollutants.

CHP and WER systems also qualify for clean energy portfolio standards (e.g., energy efficiency resource standard, alternative energy portfolio standard, renewable portfolio standard) in 24 states that specifically include them as eligible resources in some form.[11]

Greater flexibility in the electrical grid and deferment of investments in new fossil-fuel power plants: As demand for energy rises because of increased industrial and commercial activity and a growing population, and as our energy mix shifts to cleaner sources—including energy efficiency and an increasing penetration of renewables—our transmission system and infrastructure will need to be enhanced to provide the flexibility necessary to accommodate a changing suite of resources while maintaining reliability and avoiding congestion.[12]

7 Gills Onions Oxnard, CA

OVERVIEW: Gills Onions, the nation's largest family-owned grower and processor of onions, installed an Advanced Energy Recovery System (AERS) comprising two 300-kW molten carbonate fuel cells in 2009, to take advantage of biogas from the approximately 1.5 million pounds of onion waste produced at the company's processing facility each week. Prior to installing the system, Gills Onions disposed of onion-peel waste through traditional land applications at the company's agricultural fields. This had numerous adverse impacts, including noxious odors, growth impairment of the fields, potential groundwater contamination, and the operating costs of intensive labor involved in waste disposal. The company's AERS helped solve these problems by diverting the previously discarded waste to meet the facility's energy needs, saving the company money and reducing pollution. The fuel cells provide 100 percent of the processing facility's base-load energy demand and savings of approximately $700,000 per year on the company's energy bills. The company also saves $400,000 in avoided waste-disposal costs annually, including truck trips to haul waste to the fields. In addition, it now has an additional stream of revenue from the sale of any remaining solid-onion waste as cattle feed. Gills' award-winning system also reduces greenhouse gas emissions and waste discharge from the facility. With an installation cost of $10.8 million, the company expects to recover the cost of the system within six years.

FINANCING AND INCENTIVES:

- $2.7 million grant from Sempra Energy's Self-Generation Incentive Program
- $3.2 million from the American Recovery and Reinvestment Act

SECTOR: Food processing

OPERATION START: 2009

TECHNOLOGY: Fuel cell

FUEL: Biogas

MANUFACTURER: FuelCell Energy

CAPACITY: 600 kW

INSTALLED COST: $10.8 million

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: $700,000/year ($1.1 million/year, including avoided waste disposal costs)

REPORTED PAYBACK: 6 years (on Gills Onions' investment)

OTHER BENEFITS:

- Waste reduction
- Reduced emissions
- Sale of coproduct

Source: U.S. Department of Energy, Pacific Clean Energy Application Center, *Gills Onions*, Project Profile, December 2011, available at http://www.pacificcleanenergy.org/PROJECTPROFILES/pdf/Gills%20Onion.pdf; updated information provided by Gills Onions in email correspondence with NRDC, October 2012.

"Non-wires" alternatives, including demand response, distributed generation systems such as CHP, and other energy-efficiency solutions, can offer a far less capital-intensive route than building new fossil-fuel power plants to meet this growing demand; accordingly, they provide greater flexibility in transmission and distribution planning.[13] These benefits could save consumers money on their energy bills and allow regions to more cost effectively plan new generation and transmission infrastructure.[14] In particular, CHP systems may reduce the need to invest in transmission infrastructure as power is generated close to where it is needed. CHP systems may also assist in the integration of renewables. Furthermore, as they generate power with greater overall efficiency, CHP systems may also reduce the need to build more power-generation capacity.

In July 2011, the Federal Energy Regulatory Commission (FERC) issued a new order—Order 1000—that could help CHP systems play a greater role in transmission and distribution planning.[15] Among other requirements, the order requires regional transmission planners to consider non-wire alternatives, such as CHP systems and energy efficiency, in their planning processes to facilitate meeting existing public policy goals, such as state energy-efficiency and renewable-energy standards. As the order was only recently implemented, its full effects remain to be seen.

Additionally, to the extent that CHP systems could provide for demand response, FERC's Order 745 lays out guidelines for appropriate compensation in applicable markets.[16]

COMBINED HEAT AND POWER SYSTEM BENEFITS TO COMMUNITIES

Reduced emissions: CHP systems reduce emissions of CO_2 and other pollutants, including nitrogen oxides, sulfur dioxide, particulates, and other greenhouse gases. (CO_2 is a global warming pollutant, while other industrial pollutants can cause ground-level smog, acid rain, and human health impacts such as asthma, heart disease, cancer, and premature death.) For example, a 5-MW gas-turbine CHP unit with an overall efficiency of 75 percent reduces annual CO_2 emissions by about 50 percent, as compared with an 80-percent-efficient, on-site natural gas boiler and an average fossil fuel–based electricity generator.[17] On average, making a similar comparison, a CHP system can be expected to reduce emissions of CO_2 by about 4,000 metric tons per MW of installed capacity.[18]

Job creation: The use of CHP systems creates direct jobs in manufacturing, engineering, installation, ongoing operation and maintenance, and many other areas. In addition, CHP projects create indirect jobs in the CHP industry's supply chain and other supporting industries. Workers employed as a result of these direct and indirect jobs can spend their received income on other goods and services, and businesses and consumers can reinvest the energy-bill savings they receive from CHP systems into other projects, goods, and services. All this activity creates and retains jobs and induces economic growth in local communities.[19] Preliminary work suggests that each GW of installed CHP capacity may be reasonably expected on net to create and maintain between 2,000 and 3,000 full-time equivalent jobs throughout the lifetime of the system. These jobs would include direct jobs in manufacturing, construction, operation and maintenance, as well as other indirect and induced jobs (net of losses in other sectors), both from redirection of industrial energy expenditures and re-spending of commercial and household energy-bill savings.

8 **Brattleboro Kiln Dry Co.** Brattleboro, VT

OVERVIEW: The largest custom wood-drying company in New England, Brattleboro Kiln Dry Co., uses 16 kilns (heated by boilers) to dry and process lumber for sawmills, lumber wholesalers, furniture manufacturers, and construction companies. Years ago, as pressure dropped during the drying process, energy in the steam was lost. In 1989, the facility installed a 380-kW Turbosteam back-pressure steam-turbine generator. This WER system captures the steam energy that would be lost when high-pressure steam is distributed into low-pressure steam for heating purposes, and uses it to generate electricity. The system had an installation cost of $140,000 and reduces annual energy expenditures by $50,000.

SECTOR: Forest products
OPERATION START: 1989
TECHNOLOGY: Steam turbine
FUEL: Waste energy
MANUFACTURER: Turbosteam
CAPACITY: 380 kW
INSTALLED COST: $140,000
OVERALL EFFICIENCY: N/A
ENERGY SAVINGS: $50,000/year
REPORTED PAYBACK: < 3 years
OTHER BENEFITS: N/A

Source: Turbosteam, *Brattleboro Dry Kiln Company*, Case Study, document provided by company in August 2012.

Direct jobs in the CHP industry, like many energy-efficiency industries, are often more labor-intensive than these in other sectors of the economy are locally bound, and cannot be outsourced.[20] For instance, engineering, installation, operation, and maintenance must be done on-site. In addition, a number of CHP manufacturers and service providers—including GE, Solar Turbines, Capstone, Carrier, Turbosteam, ClearEdge Power, and 2G-CENERGY—have operations in the United States.

The Manufacture, Installation, and Use of CHP Systems Create Many Direct and Indirect Jobs

Greater deployment of CHP is driving job growth. Here are examples of new and retained jobs at manufacturing facilities:

- ArcelorMittal created approximately 360 manufacturing and construction jobs from the installation of a 38-MW CHP system at the company's Indiana Harbor facility in East Chicago, Indiana. The project is also expected to help retain 6,000 employees at the facility by lowering the company's steel production costs by $5 per ton and ultimately making the plant more competitive.[21]
- The Linden Cogeneration facility in Linden, New Jersey, created 60 full-time jobs in operation and maintenance at the plant.[22]
- Ethan Allen's furniture factory in Vermont was able to stay in business and retain 550 employees because of reduced energy costs from the installation of a CHP system.[23]

Here are examples of new and retained jobs within the CHP industry:

- GE employs approximately 1,000 worldwide as part of its CHP business, including workers at its Houston, Texas, and Waukesha, Wisconsin, facilities.[24]
- 2G-CENERGY, a manufacturer of biogas, natural gas, syngas, and other CHP systems, announced in 2012 that it is establishing an operation in St. Augustine, Florida, to produce advanced CHP systems. It plans to hire 125 workers.[25]
- Recycled Energy Development, a CHP and waste energy recovery company headquartered just outside Chicago, in the last few years has created or retained more than 250 jobs within the company across the United States.[26]

Integration of renewable energy: Renewable energy use is rapidly expanding in the United States. However, at present, some renewable sources can be intermittent. CHP systems, especially those running on natural gas, can provide additional flexibility and reliability when used in conjunction with potentially variable renewable energy systems by supplying standby power, able to kick in when there is, for example, cloud cover or a drop in wind speed. In fact, with increasing penetration of renewable energy, CHP developers are exploring opportunities to use their systems to support renewable energy deployment.

Additionally, CHP systems are typically quite flexible and can use a variety of fuels. As such, CHP systems could be used to promote the use of renewable fuels, such as sustainably sourced biomass and biogas. Among the sites offering such opportunities are landfills (see case study 25, Finley Buttes Regional Landfill), wastewater treatment facilities (see case study 28, Rochester Wastewater Reclamation Plant), and even farms (see case study 7, Gills Onions; case study 29, Crave Brothers Farmstead Cheese.)

Reduced rates for all customers: CHP systems have financial benefits that spread beyond the facilities where they are deployed. For instance, well-designed and well-operated CHP systems can reduce the need to build additional power plants that are more expensive. Accordingly, such CHP systems significantly reduce the cost of the overall power system.[27] These savings accrue to a given utility's entire customer base, benefiting consumers, businesses, and the community at large.

9 Johnson & Johnson's Transform Pharmaceuticals Lexington, MA

OVERVIEW: Johnson & Johnson acquired Transform Pharmaceuticals located in Lexington, Massachusetts, in 2005. In 2008, the company installed a 250-kW solar-assisted CHP system to reduce costs and greenhouse gas emissions to comply with a corporate sustainability mandate. Designed and installed by Dresser-Rand, the tri-generation system provides reliable electricity, heating, and cooling to the manufacturing plant. The CHP system can produce up to 1.3 million British thermal units (Btus) of 180°F hot water or 75 tons of chilled water, so on a typical day it can deliver approximately 38 percent of the site's hot water and 29 percent of its cooling needs. Together with the facility's renewable solar thermal generation, the CHP system results in annual energy savings of $220,000 and annual carbon footprint reduction of nearly 1,000 tons.

SECTOR: Pharmaceuticals

OPERATION START: 2008

TECHNOLOGY: Gas turbine

FUEL: Natural gas

MANUFACTURER: Dresser-Rand

CAPACITY: 250 kW

INSTALLED COST: N/A

OVERALL EFFICIENCY: Approximately 80%

ENERGY SAVINGS: $220,000/year (including solar generation)

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reduced greenhouse gas emissions

Source: "CHP System Helping Pharmaceutical Company Exceed Goals to Reduce Energy Costs and Greenhouse Emissions," *Solar Thermal Magazine*, available at http://www.solarthermalmagazine.com/2009/10/29/chp-system-helping-pharmaceutical-company-exceed-goals-to-reduce-energy-costs-and-greenhouse-emissions/ (accessed March 2013).

10 Linden Cogeneration Plant Linden, NJ

OVERVIEW: In 1992, Linden Cogeneration Plant began operation of a 900-MW CHP system consisting of five gas turbines. Owned by GE, the facility sells its electricity to Consolidated Edison in New York and to the electrical grids in New Jersey, Pennsylvania, and Maryland. The steam is sold to the Bayway Refinery. The plant includes three variable-frequency transformers and new smart-grid technology, which allows operators to control power flow between grids. Linden Cogeneration Plant has created 60 full-time jobs in operation and maintenance.

FINANCING AND INCENTIVES: Linden Cogeneration Plant contributed to the rapid expansion of CHP in New Jersey. This helped fulfill the 1978 Federal Public Utilities Policy Act, which required states to encourage CHP by requiring utility monopolies to purchase power from independent generators. New Jersey CHP facilities increased in capacity 40-fold from 1986 to 1996.

SECTOR: Power generation

OPERATION START: 1992

TECHNOLOGY: Gas turbine

FUEL: Natural gas

MANUFACTURER: N/A

CAPACITY: 900 MW

INSTALLED COST: N/A

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: N/A

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reduced emissions
- Creation of 60 full-time jobs

Source: Pew Environment Group, *Combined Heat and Power: Energy Efficiency to Repower U.S. Manufacturing*, Fact Sheet, May 2011, available at http://www.pewenvironment.org/uploadedFiles/PEG/Publications/Fact_Sheet/CHP%20NEW%20JERSEY%20HI-RES%2012.6.11.pdf.

11 **ArcelorMittal Indiana Harbor** East Chicago, IN

OVERVIEW: The largest steelmaking facility in North America, the ArcelorMittal Indiana Harbor complex operates five blast furnaces at full capacity with a steelmaking capability of 9.5 million tons per year. In fall 2012, the company completed the installation of a 38-MW CHP system to utilize previously wasted blast furnace gas (BFG), a by-product of the iron making process, to produce electricity on-site. The new $63.2 million waste energy recovery system captures approximately 46 billion cubic feet of BFG from the facility's No. 7 blast furnace and uses it to produce steam to generate electricity. The installation is expected to lower the facility's annual energy costs by nearly $20 million and reduce annual CO_2 emissions by 340,000 tons. In addition, the project created approximately 360 manufacturing and construction jobs and is expected to help retain 6,000 employees at the facility by lowering the production costs of steel by $5 per ton.

FINANCING AND INCENTIVES: $31.6 million matching grant from the U.S. Department of Energy under the American Recovery and Reinvestment Act.

SECTOR: Primary metals

OPERATION START: 2012

TECHNOLOGY: Steam turbine

FUEL: Waste energy

MANUFACTURER: N/A

CAPACITY: 38 MW

INSTALLED COST: $63.2 million

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: $20 million/year

REPORTED PAYBACK: 1.6 years (on ArcelorMittal's investment)

OTHER BENEFITS:

- Reduced emissions
- Reliability
- Job creation

Source: ArcelorMittal, *ArcelorMittal Indiana Harbor (East Chicago, Ind.) Energy Recovery & Reuse – 504 Boiler Project*, Case Study, 2012, (document provided by company in September 2012).

12 **SunCoke Energy** Middletown, OH

OVERVIEW: SunCoke Energy, the largest producer of metallurgical coke in the Americas, uses an advanced heat recovery coke-making process that yields a higher quality product, generates energy from waste heat, and helps reduce emissions. SunCoke Energy's ovens produce solid state carbon (coke) from coal, while thermally destroying volatile matter. Their superior coke exhibits a high average size and high coke strength after reaction values, enhancing iron, and steel-making economics. SunCoke Energy's coke-making process uses waste heat recovery technologies to generate steam and electricity, which can be used within the facility or sold to the utility.

SECTOR: Primary metals

OPERATION START: 2011

TECHNOLOGY: Steam turbine

FUEL: Waste heat

MANUFACTURER: N/A

CAPACITY: 45 MW

INSTALLED COST: ($410 million for entire plant)

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: N/A

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Production of higher quality metallurgical coke
- Additional revenue stream of electricity sales
- Reduced emissions

Source: SunCoke Energy, Our Innovation, available at http://www.suncoke.com/our-innovation/suncoke-way.php (accessed March 2013); SunCoke Energy, "SunCoke Energy: The High Degree" presentation at the Combined Heat and Power Workshop, Columbus, OH, June 20, 2012, available at http://www.puc.ohio.gov/emplibrary/files/media/CMSFiles/WebcastRelated/155/SunCoke%20Energy%20-%20Skipworth.pptx.

DEPLOYMENT POTENTIAL FOR COMBINED HEAT AND POWER TECHNOLOGY

While 87 percent of the 82 GW of CHP capacity is in manufacturing plants around the country, a growing number of facilities in the commercial, agricultural, and residential sectors are considering its use.[28] As explained earlier in this paper, CHP expansion is very plausible in upcoming years for several reasons: CHP is more reliable and cost-effective than ever before; the price of natural gas, the most common fuel in CHP applications, has dropped; and there are expanding state and utility incentives available for CHP in various forms.

Table 1 shows the spectrum of industries in which CHP can be used. This is not an exhaustive list, and CHP can be used elsewhere, too. Table 1 also indexes and highlights the case studies discussed in this report, selected across a number of industries and from nearly 20 states nationwide, along with the key benefits that the systems provide. Figure 2 shows the geographic distribution of these case studies. A larger compilation of such studies has been compiled by the U.S. Department of Energy (DOE).[29]

There is tremendous potential for even greater deployment of CHP. A 2009 study by McKinsey & Company estimated that 50 GW of CHP in industrial and large commercial/institutional applications could be deployed at reasonable returns with equipment and energy prices available at that time.[30] Going beyond the currently installed capacity, the remaining technical potential of CHP systems (where they are technically feasible and favorable to deploy) in the industrial and commercial/institutional sectors is roughly 65 GW each.[31] A breakdown of this technical potential in key sectors is given in figure 3. However, the 65 GW of remaining industrial technical potential accounts only for systems with sizes constrained such that they do not have excess power to export to the grid. But if systems can be sized to enable export of power to the grid, then the remaining industrial technical potential doubles, to 130 GW.

In August 2012, President Obama issued an executive order announcing a national goal of deploying 40 GW of new, cost-effective CHP in the industrial sector by the end of 2020.[32] As part of this federally facilitated effort, the State and Local Energy Efficiency Action Network (SEE Action), coordinated by the DOE and the U.S. Environmental Protection Agency, released the *Guide to the Successful Implementation of State Combined Heat and Power Policies*.[33] Furthermore, as noted previously, many states have encouraged CHP technologies in some manner through clean energy standards and other incentives.

13 **Seaman Paper Co.** Otter River, MA

OVERVIEW: Seaman Paper Company of Otter River, Massachusetts, is a 24/7 industrial mill that produces 75 tons of flat tissue paper per day. In 2009, the company completed the installation of a 283-kW CHP system to achieve cost savings and reduce emissions. The facility operates a back-pressure turbine, which generates steam at a higher temperature and pressure than is required for Seaman's processes, and then flows the exhaust steam through a turbine to generate 1,450 MWh of electricity each year. Prior to installation, the mill was using approximately 1.7 million gallons of No. 6 fuel oil and 24,000 MWh of electricity per year. In contrast, now the facility's CHP system is fueled by 27,000 tons of wood, and the mill uses only 21,000 MWh of electricity per year. The improvements have reduced Seaman Paper's fuel usage to less than 70,000 gallons of fuel oil per year and generated annual energy savings of $1.5 million. In addition, the CHP system has reduced CO_2 emissions by 99 percent and NO_X emissions by 30 percent.

SECTOR: Pulp and paper

OPERATION START: 2009

TECHNOLOGY: Back-pressure steam turbine

FUEL: Biomass

MANUFACTURERS: Turbosteam, Hurst

CAPACITY: 283 kW

INSTALLED COST: N/A

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: $1.5 million/year

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reduces CO_2 and NO_X emissions

Source: U.S. Department of Energy, Northeast Clean Energy Application Center, *Seaman Paper*, Project Profile, August 2010, available at http://www.northeastcleanenergy.org/profiles/documents/Seamanpaper.pdf.

14 **Ergon, Inc.** Vicksburg, MS

OVERVIEW: Ergon, in Vicksburg, Mississippi, is a crude-oil processor and manufacturer of asphalt products. In 1994, the company installed a 4.72-MW CHP system to supply reliable electricity and make use of the heat to create steam for the refinery. All of the electricity generated is used to power processes at the facility. The steam produced is delivered to the refinery at a pressure of 650 pounds per square inch (psi), and the facility can produce 50,000 pounds per hour at this pressure. Low-pressure steam from the CHP system is used by facility processes as well. The entire CHP system is governed by demand, which requires an operator to monitor closely the use of the CHP system; as the need for electricity or steam fluctuates, so does the use of the CHP system (and a separate duct burner, which provides enough flexibility to supply sufficient steam). While the production of the electricity is more expensive than buying it from the utility provider, the steam production saves Ergon an estimated $1.7 million per year.

SECTOR: Refineries (crude-oil processor)

OPERATION START: 1994

TECHNOLOGY: Gas turbine

FUEL: Natural gas

MANUFACTURER: Solar Turbines

CAPACITY: 4.72 MW

INSTALLED COST: N/A

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: $1.7 million/year

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reliability (stable source of power)

Source: U.S. Department of Energy, Southeast Clean Energy Application Center, *Ergon, Inc.*, Project Profile, 2011, available at http://www.southeastcleanenergy.org/profiles/se_profiles/Ergon_Project_Profile.pdf.

15 **BP Helios Plaza** Houston, TX

OVERVIEW: BP Helios Plaza is a 355,000-square-foot office building and data center that houses BP's North America Gas and Power business and Upstream Learning Centre. Since energy, security, and reliability are essential for such a facility, a CHP system was installed in 2009. The plant consists of a 4.6-MW gas turbine, manufactured by Solar Turbines, including a heat recovery system utilizing an absorption chiller and selective catalytic reduction technology for emissions reduction. The CHP system is capable of meeting all of the facility's energy needs and helped BP achieve LEED Platinum certification. When rolling blackouts hit Houston in February 2011, the facility's on-site, clean-burning power plant remained in operation, ensuring that business continued 24/7 without interruption.

SECTOR: Data centers, office building

OPERATION START: 2009

TECHNOLOGY: Gas turbine

FUEL: Natural gas

MANUFACTURER: Solar Turbines

CAPACITY: 4.6 MW

INSTALLED COST: N/A

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: 34% cost savings per year

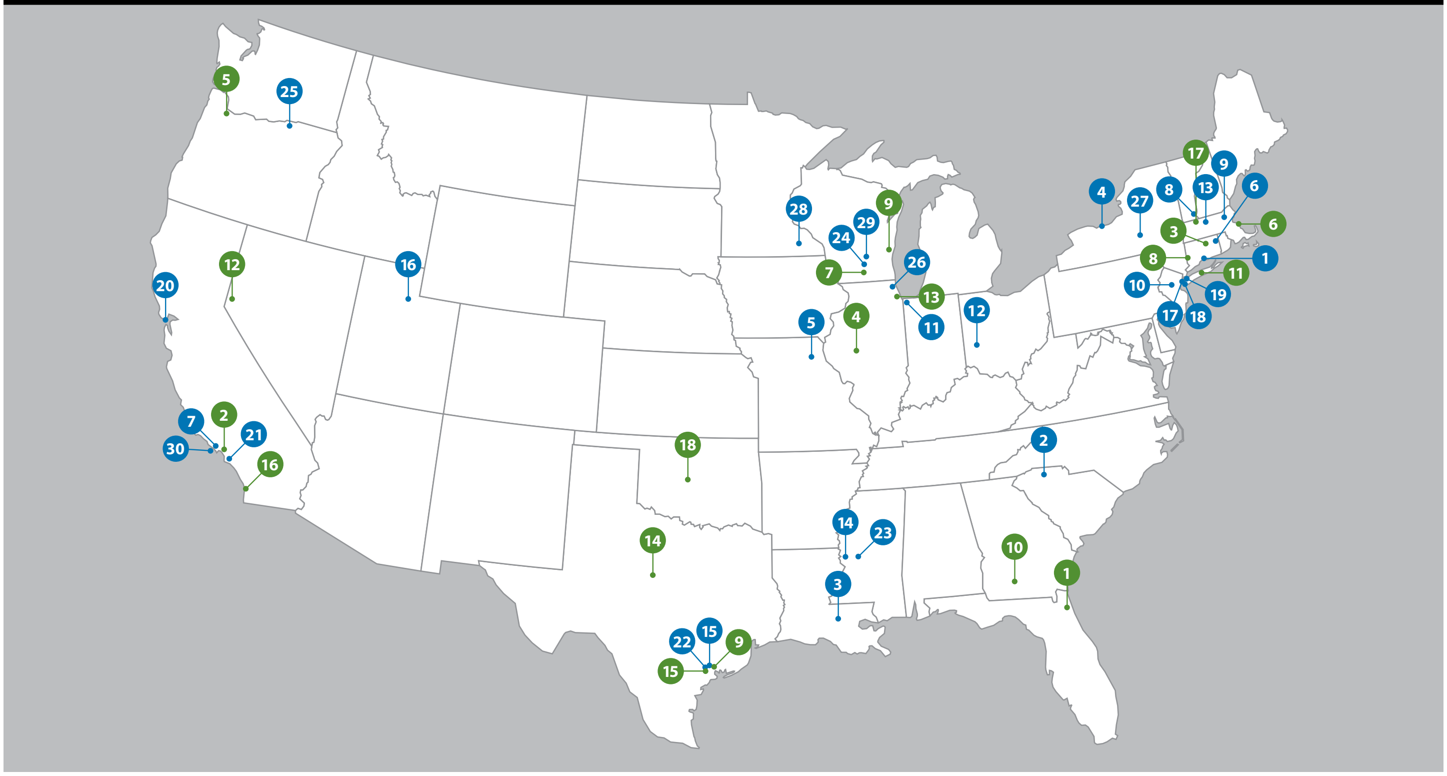
REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reliability (provides power in absence of grid)
- Environmental sustainability
- Additional backup through Uninterruptible Power System

Source: U.S. Department of Energy, Gulf Coast Clean Energy Application Center, *BP Helios Plaza*, Project Profile, 2011, available at http://files.harc.edu/sites/gulfcoastchp/CaseStudies/BP-Helios.pdf.

Figure 2: Location of Featured Case Studies from Companies with CHP-Related Operations
Eighty-two GW of CHP capacity is distributed over more than 4,100 sites across every state in the United States.



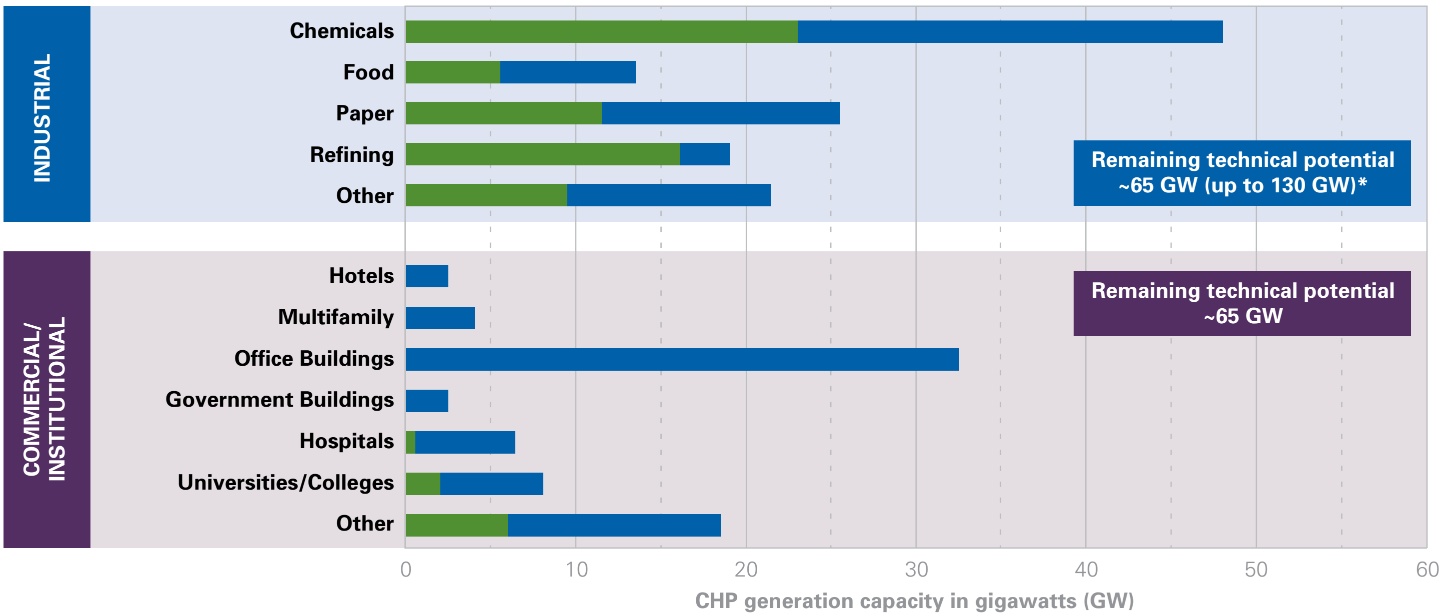
CASE STUDIES

1. **Sikorsky Aircraft Corp.**
   Stratford, CT
2. **BMW Manufacturing Co.**
   Spartanburg, SC
3. **Dow Chemical Co.**
   Plaquemine, LA
4. **Harbec Plastics**
   Ontario, NY
5. **Northeast Missouri Grain, LLC (dba) POET Biorefining – Macon**
   Macon, MO
6. **Frito-Lay**
   Killingly, CT
7. **Gills Onions**
   Oxnard, CA
8. **Brattleboro Kiln Dry Co.**
   Brattleboro, VT
9. **Johnson & Johnson's Transform Pharmaceuticals**
   Lexington, MA
10. **Linden Cogeneration Plant**
    Linden, NJ
11. **ArcelorMittal Indiana Harbor**
    East Chicago, IN
12. **SunCoke Energy**
    Middletown, OH
13. **Seaman Paper Co.**
    Otter River, MA
14. **Ergon**
    Vicksburg, MS
15. **BP Helios Plaza**
    Houston, TX
16. **Snowbird Ski and Summer Resort**
    Snowbird, UT
17. **Hilton New York**
    New York, NY
18. **Arrow Linen Supply Co.**
    Brooklyn, NY
19. **Co-Op City**
    Bronx, NY
20. **Transamerica Pyramid Building**
    San Francisco, CA
21. **Roger's Gardens**
    Corona Del Mar, CA
22. **Thermal Energy Corporation (TECO)**
    Houston, TX
23. **Baptist Medical Center**
    Jackson, MS
24. **Beloit Memorial Hospital**
    Beloit, WI
25. **Finley Buttes Regional Landfill**
    Boardman, OR
26. **Naval Station Great Lakes**
    Great Lakes, IL
27. **Cornell University**
    Ithaca, NY
28. **Rochester Wastewater Reclamation Plant**
    Rochester, MN
29. **Crave Brothers Farmstead Cheese**
    Waterloo, WI
30. **Houweling's Tomatoes**
    Camarillo, CA

MANUFACTURERS AND DEVELOPERS

1. **2G CENERGY**
   St. Augustine, FL
2. **Capstone**
   Chatsworth, CA
3. **Carrier**
   Farmington, CT
4. **Caterpillar**
   Peoria, IL
5. **ClearEdge Power**
   Hillsboro, OR
6. **Dresser-Rand CHP Solutions**
   Cohasset, MA
7. **Fairbanks Morse Engine**
   Beloit, WI
8. **Fuel Cell Energy**
   Danbury, CT
9. **GE Energy**
   Houston, TX
   Waukesha, WI
10. **Hurst Boiler & Welding Co.**
    Coolidge, GA
11. **Intelligen Power Systems**
    Old Bethpage, NY
12. **Ormat Technologies**
    Reno, NV
13. **Recycled Energy Development**
    Westmont, IL
14. **Rentech**
    Abilene, TX
15. **Siemens Energy**
    Houston, TX
16. **Solar Turbines**
    San Diego, CA
17. **Turbosteam**
    Turner Falls, MA
18. **York Unitary Products Group**
    Norman, OK

Figure 3: Remaining Technical Potential for CHP—Industrial: ~65 to 130 GW; Commercial/Institutional: ~65 GW



- Existing CHP
- Potential CHP

*The 65 GW of remaining industrial technical potential (with breakdown shown above) accounts only for systems with sizes constrained such that they do not have excess power to export to the grid, but if systems can be sized so as to enable export of power to the grid, the remaining industrial technical potential doubles to 130 GW.

16 **Snowbird Ski and Summer Resort** Snowbird, UT


© Wikimedia

OVERVIEW:
Snowbird Ski and Summer Resort sprawls across 2,500 acres in Snowbird, Utah. In 1987, the growing resort became too large for the utility's 25-kilovolt (kV) power line that runs up the mountain. Instead of paying for a line upgrade, the company decided to turn to on-site power generation and installed a 2-MW CHP system at a cost of $3.5 million. An additional $2.2 million was required to build a natural gas pipeline to the facility. With an overall efficiency of 75 percent, the CHP results in energy savings of $815,000 per year and ensures a reliable source of power for the facility. In the winter, heat from the CHP system is used for space and pool heating and melting snow on walkways. In the summer, some of the heat is still used for space and pool heating, but the rest runs a Carrier absorption chiller for the lodge's air conditioning.

SECTOR: Hotels, resorts
OPERATION START: 1987
TECHNOLOGY: Reciprocating engine
FUEL: Natural gas
MANUFACTURERS: Caterpillar, Carrier
CAPACITY: 2 MW
INSTALLED COST: $5.7 million
OVERALL EFFICIENCY: 75%
ENERGY SAVINGS: $815,000/year
REPORTED PAYBACK: 7 years
OTHER BENEFITS:
- Reliability

Source: U.S. Department of Energy, Intermountain Clean Energy Application Center, *Snowbird Ski and Summer Resort*, Project Profile, 2011, available at http://www.intermountaincleanenergy.org/profiles/Snowbird-Project_Profile.pdf.

THE FIVE KEY TECHNOLOGIES DEPLOYED IN COMBINED HEAT POWER SYSTEMS

Five main technologies are used in typical CHP systems.[34] These technologies, sometimes referred to as "prime movers," are:

- **Gas turbines (or combustion turbines).** Such turbines revolutionized airplane propulsion in the 1940s. Since the 1990s they have become a popular choice for power-generation systems, including CHP. In this technology, air is taken in, compressed, burned with a fuel (usually natural gas), and then ejected to drive a turbine that generates power. Heat can be recovered from the exhaust and put to use for heating, cooling, or industrial processes.
- **Steam turbines (or back-pressure steam turbines).** These are used in a majority of power plants across the United States. In these turbines, water is pressurized, heated by a burning fuel, and converted to steam, which is then used to drive a turbine that generates power. The steam turbine was the earliest prime mover used in large-scale power generation, dating back to the late 1800s. In a CHP system, any exhaust steam left after the power-generation step can be put to productive use, as described above.
- **Reciprocating engines.** Such engines are used in most motor vehicles, and the technology has significantly improved in electrical efficiencies over the past few decades. The engines have a combustion chamber in which fuel is burned. The combustion pushes a piston that drives a crankshaft to generate power. Heat can be recovered from the exhaust and jacket water and put to use.
- **Fuel cells.** Fuel cells electrochemically convert fuel to generate electricity. Typically this involves the combining of hydrogen and oxygen. A fossil fuel, such as natural gas, can be chemically reformed to produce hydrogen. Heat generated during the fuel cell's electrochemical reaction can be recovered for certain uses, such as heating water.
- **Microturbines.** These are essentially small gas turbines that employ modified processes and structures to generate power and heat.

© Vignesh Gowrishankar

CHP system—gas turbine (center), with hot gases heading to heat recovery steam generator (right).

17 **Hilton New York** New York, NY

OVERVIEW: The Hilton New York is the largest hotel in New York City. The 46-story building houses about 2,000 guest rooms plus other facilities and halls. The electrical demand averages more than 3 MW along with significant thermal heat loads. In the summer of 2007, a 200-kW phosphoric-acid fuel cell CHP system was installed, which provides about 6 percent of the electricity and 8 percent of the heating needs. A fuel cell system was found to be attractive in this urban setting because it does not create vibrations, noise, or visible exhaust. The hotel anticipates reducing its annual carbon footprint by about 800 tons a year, in addition to NO_X emissions reductions of nearly 3 tons per year. As energy can account for more than 6 percent of a hotel's operating costs, the CHP system contributes to more than $80,000 in annual savings. In addition, the system confers valuable reliability as it can operate independently of the grid in emergencies.

SECTOR: Hotels, resorts
OPERATION START: 2007
TECHNOLOGY: Fuel cell
FUEL: Natural gas
MANUFACTURER: UTC Power (now ClearEdge Power)
CAPACITY: 200 kW
INSTALLED COST: N/A
OVERALL EFFICIENCY: > 50%
ENERGY SAVINGS: $80,000/year
REPORTED PAYBACK: N/A
OTHER BENEFITS:

- Reduced emissions
- Reliability

Source: New York State Energy Research and Development Authority, *Hilton New York – Fuel Cell Provides Electricity and DHW*, available at http://cdhnrgy1.user.openhosting.com/Fact%20Sheets/Hilton%20New%20York%20Fact%20Sheet.pdf (accessed March 2013).

18 **Arrow Linen Supply Co.** Brooklyn, NY

OVERVIEW: Arrow Linen, an industrial laundry facility in Brooklyn, New York, installed two 150-kW reciprocating engines in 2003 to reduce energy expenditures. Like other laundries, Arrow Linen's high demand for electricity and hot water make it an ideal fit for CHP. In fact, the facility uses approximately 100,000 gallons of water heated to 160°F every day. With an overall efficiency reaching more than 80 percent, the CHP has resulted in annual energy savings of $120,000. In addition, the on-site generation has increased the facility's energy security, allowing it to remain in operation 14 hours a day, 6 days a week.

SECTOR: Laundries
OPERATION START: 2003
TECHNOLOGY: Reciprocating engine
FUEL: Natural gas
MANUFACTURER: Coast Intelligen
CAPACITY: 300 kW
INSTALLED COST: N/A
OVERALL EFFICIENCY: > 50%
ENERGY SAVINGS: $120,000/year
REPORTED PAYBACK: < 3 years
OTHER BENEFITS:

- Reliability

Source: CDH Energy Corp., *Arrow Linen*, Project Profile, 2010, available at http://cdhnrgy1.user.openhosting.com/Fact%20Sheets/Arrow%20Linen%20CHP%20Site%20Fact%20Sheet.pdf

Newer prime-mover technologies are finding greater use in the marketplace as well. One of these is the Organic Rankine Cycle engine, which works on a principle similar to that of a steam turbine but usually uses a fluid other than water. It is often used in waste-energy recovery systems where low-grade heat, such as low-pressure steam, is available. Another emerging CHP technology is the Stirling engine.[35]

Prime movers form the core of a CHP system. Auxiliary technologies that are typically used include heat recovery steam generators to capture heat and use it beneficially, absorption chillers that utilize thermal energy to provide cooling, and desiccant dehumidification systems.[36] Other technology can also be added on, such as selective catalytic reduction to reduce NO_X emissions (by up to 90 percent from gas turbine exhaust), but this may reduce efficiencies.

A variety of fuels can be used in CHP systems, including natural gas, biogas, landfill gas, coal, biomass, waste products, and exhaust gas.

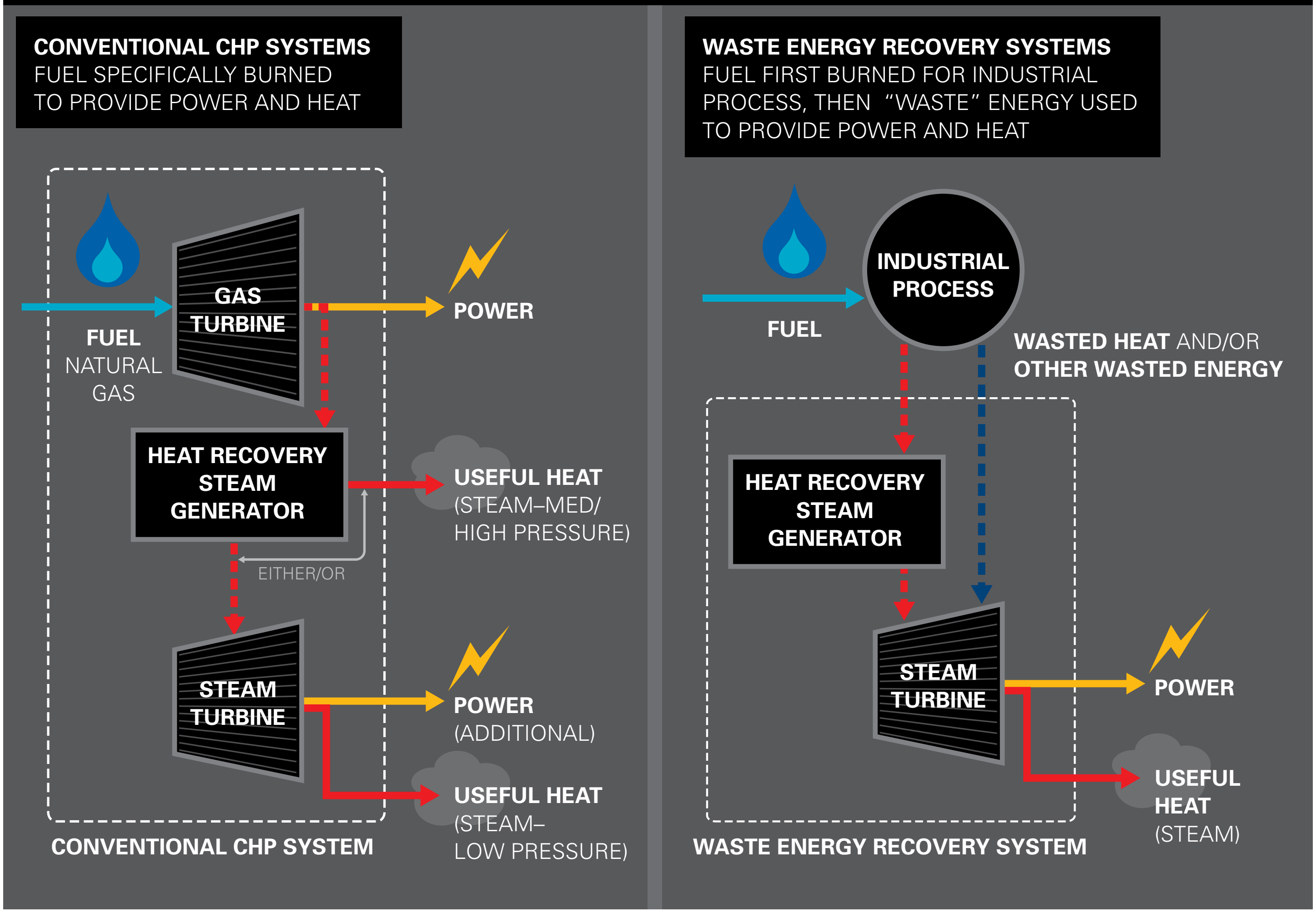
A summary of the key CHP technologies along with their advantages, constraints, industry suitability, and economics, is given in table 2.[37]

Schematics of how some of these prime-mover and auxiliary technologies can be configured are shown in figure 4.

Table 2: Prime Mover Technologies and Their Characteristics

		Advantages	Constraints	Suitable industries	Cost Capital cost ($/kW) + O&M cost ($/kWh)	Overall efficiency
LARGE-SCALE	**Gas turbine** (500 kW to 350 MW)	• Low emissions • High reliability • No cooling required • High-grade heat available	• Poor efficiency at low loads • Output falls as ambient temperature rises • Requires high-pressure gas or in-house gas compressor	• Chemicals • District energy • Food processing • Oil recovery • Paper/pulp • Refining • Universities • Waste treatment	$1,000 to $1,300 /kW + 0.5 to 1 cent/kWh	75% to 85%
LARGE-SCALE	**Steam turbine** (500 kW to 350 MW)	• High overall efficiency • High reliability • Flexible fuel usage • Long working life • Variable power-heat ratio • Can meet more than one heat-grade requirement	• Slow start up • Cannot attain high power-heat ratio	• Agriculture • Ethanol plants • Lumber mills • Paper/pulp • Primary metals • Refining	$400 to $1,100 /kW + < 0.5 cent/kWh	85% to 90%
LARGE-SCALE	**Reciprocating engine** (100 kW to 5 MW)	• Low investment cost • High power efficiency • Good load following capability • Fast start-up • Easy maintenance	• High maintenance costs • Relatively high emissions • Cooling required • Limited to lower-temperature applications • Loud (low-pitch) noise	• Chemical processing • Dairy farms • Data centers • Food processing • Health care • Office buildings • Universities • Water treatment	$1,100 to $2,200 /kW + 1 to 2 cents/kWh	75% to 90%
SMALL-SCALE	**Fuel cell** (1 kW to 1,200 kW)	• Low emissions • High efficiency • Low noise • Modular design	• High costs • Fuels require processing • Low durability • Low power density	• Backup/portable power • Distributed generation • Material handling • Residential • Transportation	$5,000 to $6,500 /kW + 3 to 4 cents/kWh	60% to 90%
SMALL-SCALE	**Microturbine** (30 kW to 400 kW)	• Low emissions • No cooling required • Compact size	• High costs • Relatively low efficiency • Limited to lower-temperature applications	• Education • Health care • Lodging • Office buildings • Residential • Warehousing	$2,400 to $3,000 /kW + 1 to 2.5 cents/kWh	70% to 85%

Figure 4: Schematic of CHP Systems



© Finley Buttes Regional Landfill

Reciprocating engine prime mover.

19 **Co-Op City** Bronx, NY

© Wikimedia

OVERVIEW: Co-Op City is one of the largest housing cooperatives in the world and the largest residential development in the United States. It is located in the Bronx (northeastern New York City) and covers 330 acres. Were it to be considered a separate municipality, it would rank as the tenth-largest "city" in New York State. It boasts more than 14,000 apartment units, 35 high-rise buildings, seven clusters of town houses, eight parking garages, three shopping centers, a high school, two middle schools, and three grade schools. Co-Op City is powered by a 40-MW CHP system that utilizes both gas turbines and steam turbines. The CHP system provides Co-Op City's entire residential electricity needs and a portion of its space-heating needs. Excess power can be exported to Consolidated Edison's grid. The CHP system enabled millions of dollars of energy cost savings, some of which were applied to façade and window upgrades. The system is also central to Co-Op City's power reliability. In fact, after Hurricane Sandy battered the East Coast region in late October 2012, Co-Op City's lights did not blink.

SECTOR: Multifamily housing

OPERATION START: 2011

TECHNOLOGY: Gas turbine, steam turbine

FUEL: Natural gas

MANUFACTURER: Siemens

CAPACITY: 40 MW

INSTALLED COST: N/A

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: Many millions of dollars per year

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reliability (provides power in absence of grid)

Source: "Lessons From Where The Lights Stayed On During Sandy," *Forbes,* October 2012, available at http://www.forbes.com/sites/williampentland/2012/10/31/where-the-lights-stayed-on-during-hurricane-sandy/; New York State Energy Research Development Authority, "DG/CHP Integrated Data System," available at http://chp.nyserda.org/facilities/fulldetails.cfm?Facility=167 (accessed March 2013).

© Transamerica Pyramid Building

20 **Transamerica Pyramid Building** San Francisco, CA

OVERVIEW: In 2007, the owners of the iconic Transamerica Pyramid Building in San Francisco installed two 500-kW natural gas-fired reciprocating engines. CHP provides the 48-story building, which houses office and retail space, with 100 percent of its steam demand, and 71 percent of its electrical demand. The vast majority of thermal energy produced is used to power the massive 320-ton capacity York chiller. At an installed cost of $3.4 million, the project had a reported payback of less than five years.

FINANCING AND INCENTIVES: The California Public Utility Commission's Self-Generating Incentives Program paid for 13 percent of the capital cost.

SECTOR: Office buildings

OPERATION START: 2007

TECHNOLOGY: Reciprocating engine

FUEL: Natural gas

MANUFACTURERS: GE, York

CAPACITY: 1 MW

INSTALLED COST: $3.4 million

OVERALL EFFICIENCY: 50%

ENERGY SAVINGS: N/A

REPORTED PAYBACK: < 5 years

OTHER BENEFITS:

- Reduced reliance on the grid

Source: U.S. Department of Energy, Pacific Clean Energy Application Center, *Transamerica Pyramid Building*, Project Profile, November 2010, available at http://www.pacificcleanenergy.org/PROJECTPROFILES/pdf/Pyramid%20Building.pdf.

21 **Roger's Gardens** Corona Del Mar, CA

OVERVIEW: Driven by its energy efficiency and sustainability goals, Roger's Gardens, a destination home and garden store in Orange County, California, installed three fuel-cell CHP systems to provide 15 kW of power for the facility, in June 2012. The installation was the result of collaboration between the retail center and ClearEdge Power, a manufacturer of scalable fuel-cell systems for on-site power generation. The CHP system provides heat and electrical power to the seven-acre facility plus many other benefits, including more than $6,500 in net project energy-bill savings per year, greater control over the facility's energy use, and increased reliability. In addition, the system has reduced the center's annual greenhouse gas emissions by 41 percent and fuel consumption by 38 percent.

FINANCING AND INCENTIVES: The installation of the system was part of a project supported by the U.S. DOE's Office of Energy Efficiency and Renewable Energy to accelerate the use of fuel-cell technologies in a variety of industries. The DOE's Pacific Northwest National Laboratory will also be analyzing the system's performance to ensure the projected benefits are achieved.

SECTOR: Retail center

OPERATION START: 2012

TECHNOLOGY: Fuel-cell

FUEL: Natural gas

MANUFACTURER: ClearEdge Power

CAPACITY: 15 kW

INSTALLED COST: N/A

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: $6,500/year

REPORTED PAYBACK: 3.4 years

OTHER BENEFITS:

- Reduced emissions

Source: ClearEdge Power, "Roger's Gardens Partners with ClearEdge Power to Support Environmentally Sustainable Business Practices," *Business Wire*, June 7, 2012, available at http://www.marketwatch.com/story/rogers-gardens-partners-with-clearedge-power-to-support-environmentally-sustainable-business-practices-2012-06-07; updated information provided by ClearEdge Power in email correspondence with NRDC, March 2013.

ECONOMIC ANALYSIS OF COMBINED HEAT AND POWER TECHNOLOGIES[38]

As alluded to previously in the report, before considering the use of CHP systems, facilities must make certain that all existing electrical and thermal loads and processes are as efficient as possible. This will ensure that CHP systems are not larger and more expensive than necessary.

While an up-front investment is required to install a CHP system, energy cost savings provided by the system can pay back the investment over time. The economics of a CHP system depend on site-specific conditions and can vary widely. However, where site conditions are conducive and when configured and operated optimally, CHP systems can provide significant energy and cost savings, along with other benefits as discussed previously.

OVERALL OPERATIONAL EFFICIENCY DETERMINES THE ECONOMICS OF A CHP SYSTEM

Before a discussion of financial details, one should be aware of several attributes that are essential for efficient and cost-effective CHP systems:

- **Complementary thermal and electric needs.** As CHP systems generate power and thermal energy simultaneously, a facility (or group of facilities or a small region) with a roughly stable mix of coincident electricity and thermal needs, daily and seasonally, could capitalize on a CHP system's unique advantages to the largest extent.

22 Thermal Energy Corporation (TECO) Houston, TX

© Thermal Energy Corporation

OVERVIEW: As a district energy system, TECO provides thermal energy (chilled water and steam) for air-conditioning, heating, and process needs to the institutions in the Texas Medical Center—the largest medical center in the world. Starting operation in 2010, TECO's 48-MW CHP plant was designed to meet the medical center's growing needs with increased reliability, environmental responsibility, and energy efficiency. Despite record electric demands, TECO has been able to meet 100 percent of its peak electricity needs and 100 percent of TECO customers' peak chilled-water and steam loads. The CHP system can also provide uninterrupted emergency power to run the entire facility in the event of a prolonged grid outage. The project improved the plant's overall efficiency from 42 percent to more than 80 percent. It is projected to reduce fossil-fuel consumption by 60 percent and to save the Texas Medical Center more than $200 million during the next 15 years. In addition, the CHP system has reduced CO_2 emissions by more than 300,000 tons per year and NO_X emissions by more than 300 tons annually.

FINANCING AND INCENTIVES:

- $10 million in U.S. DOE funding from the American Recovery and Reinvestment Act of 2009
- $325 million in tax exempt bonds

SECTOR: District energy

OPERATION START: 2010

TECHNOLOGY: Gas turbine

FUEL: Natural gas

MANUFACTURER: GE

CAPACITY: 48 MW

INSTALLED COST: $377 million

OVERALL EFFICIENCY: > 80%

ENERGY SAVINGS: $200 million over 15 years

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reliability (48 MW in backup emergency power)
- Reduces emissions

Source: Thermal Energy Corporation, Combined Heat and Power in the Texas Medical Center, (presentation), Combined Heat and Power Workshop, Columbus, OH, June 20, 2012, available at http://www.puc.ohio.gov/emplibrary/files/media/CMSFiles/WebcastRelated/155/TECO%20CHP%20-%20swinson.ppt; U.S. DOE, Energy Efficiency and Renewable Energy, Advanced Manufacturing Office, *Thermal Energy Corporation Combined Heat and Power Project*, 2010, available at http://www1.eere.energy.gov/industry/distributedenergy/pdfs/teco_chp.pdf.

- **Sizing according to thermal needs.** As produced thermal energy is most efficiently used at the facility or locally, it is best to size and configure a CHP system to meet the thermal needs of a facility. Systems sized larger than that can result in wasted thermal energy that detracts from overall efficiency and energy bill savings. The electricity generated can be either used at the facility or sold to the grid.
- **Long operating hours.** As with most projects requiring up-front investment, a CHP system that can run for longer hours (daily and seasonally) and at high efficiency will be most economic. To facilitate this, CHP systems should be maintained well and operated in tune with the facility's needs.
- **Comparison with retail electricity rates, or "spark spread."** Spark spread refers to the difference between the retail price of electricity and the cost of fuel—most commonly natural gas—used by the CHP system. If the retail price of electricity is high but the cost of the fuel and other services needed to generate electricity using the CHP system is comparatively low, the economics for CHP systems will be more favorable.

The detailed financials will depend on site-specific factors, such as system size, CHP technology, add-on equipment, type and price of fuel used, environmental compliance, and maintenance and operations. A typical range of the financial details are shown below:[39]

- Capital cost per kilowatt (kW) of installed capacity: $1,000 to $3,000. But costs can be higher for smaller systems, up to $10,000 per kW. Approximately $50 per kW to 150 per kW in additional investments may be required to enable a CHP system to perform independently of the grid.
- Cost per kWh of generated electricity: $0.05 to $0.10. Usually, more than half of this figure comes from fuel and operational costs; hence fuel-price volatility has a strong bearing on the cost of power produced by CHP. The rest reflects the capital cost, which is also an important factor, and a thermal credit, which is explained later.
- Payback period: three to seven years. This depends mainly on the capital cost per kW, overall efficiency of the system, and hours of operation. CHP projects can come on line within one-half to three years, and the lifetime of a CHP system can exceed 20 years.[40]

Some financial details, organized according to technology, are shown in table 2.

Figure 5 shows how CHP systems can be cost-effective compared with other forms of power generation and average retail electricity rates.[41] As CHP systems generate useful electricity and thermal energy, one justifiable and reasonable way to account for these dual benefits is to apply the value of the useful thermal energy to lower the effective cost of electricity generated. Figure 5 illustrates this by the application of a "thermal credit" to the cost of delivered electricity. By doing so, large CHP systems in Ohio, for example, can compete even with the low retail prices for power available to large users.

Similarly, medium-size CHP systems can be cost-effective for certain commercial users. Smaller CHP systems may not be directly cost-effective in all cases but could have other benefits that still make them attractive in particular instances. In New Jersey, where electricity rates are higher, the economics are even more favorable for CHP.[42]

23 **Baptist Medical Center** Jackson, MS

OVERVIEW: Baptist Medical Center is an urban hospital with approximately 620 beds and more than 3,000 employees. In 1991, the hospital installed a 4.3-MW natural gas turbine. Since the center's recent expansion, the CHP system is capable of meeting 60 percent of the facility's electrical needs, 80 percent of its steam needs, and 30 percent of its cooling needs. The CHP system has generated average energy savings of $800,000 per year, resulting in a simple payback period of 6.3 years on the $4.2 million installed cost. (Savings have been lower during periods of lower natural gas prices.) In addition, the CHP system serves as backup emergency power for the medical center. In fact, when Hurricane Katrina caused the grid to go down for 52 hours beginning on August 29, 2005, the medical center remained fully operational.

SECTOR: Health care

OPERATION START: 1991

TECHNOLOGY: Gas turbine

FUEL: Natural gas

MANUFACTURERS: Solar Turbines, York, Trane

CAPACITY: 4.3 MW

INSTALLED COST: $4.2 million

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: $800,000/year (depends on natural gas prices)

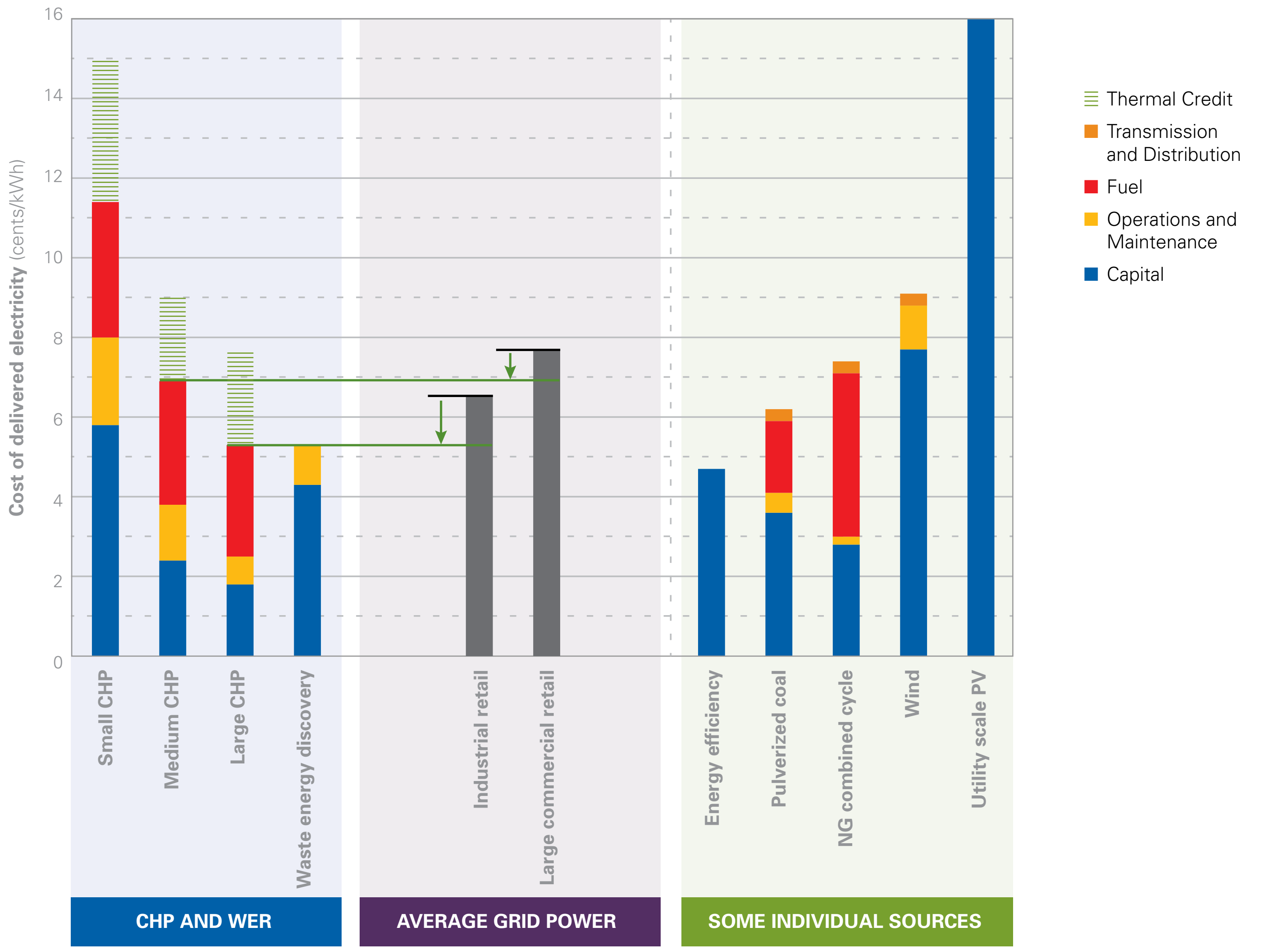
REPORTED PAYBACK: 6.3 years

OTHER BENEFITS:

- Reliability (backup emergency power)

Source: B.K. Hodge and L. Chamra, "CHP (Cooling, Heating, and Power) at the Mississippi Baptist Medical Center, Southeast CHP Application Center," 2007, available at http://gulfcoastcleanenergy.org/Portals/24/Events/Hurricane_2006/MississippiBaptistMemorialHospital.pdf.

Figure 5: Systems Are Cost-Competitive in Industrial and Commercial Sectors



24 **Beloit Memorial Hospital** Beloit, WI

OVERVIEW: Beloit Memorial Hospital is a 340,000-square-foot facility in Beloit, Wisconsin, with approximately 190 beds. Confronted by the need to upgrade its electrical distribution system, the hospital installed a 3-MW CHP system in 2000 at a cost of $1.2 million. The CHP system provides the hospital with 1.5 MW of power, and the additional 1.5 MW is sold to the local utility, Alliant. In addition, the CHP provides heating, cooling, and hot water to the entire facility. The Fairbanks Morse engines are specially designed to provide the facility with backup emergency power in the event of grid failure; they are dual-fuel engines capable of running on diesel fuel for fast start-up, although they are normally operated on natural gas for greater overall performance. With an overall energy efficiency of nearly 70 percent, the system has annual energy savings of $223,000 and a reported payback of 5.4 years.

FINANCING AND INCENTIVES: Alliant partly financed the project with a low-interest rate.

SECTOR: Health care

OPERATION START: 2000

TECHNOLOGY: Reciprocating engine

FUEL: Natural gas, diesel

MANUFACTURER: Fairbanks Morse

CAPACITY: 3 MW

INSTALLED COST: $1.2 million

OVERALL EFFICIENCY: 69.8%

ENERGY SAVINGS: $223,000/year

REPORTED PAYBACK: 5.4 years

OTHER BENEFITS:

- Reliability (backup emergency power)
- Sale of electricity

Source: Mark Stevens, *Beloit Memorial Hospital Case Study for CHP Applications*, Midwest CHP Application Center, May 2002, available at http://www.midwestcleanenergy.org/Archive/reviewdocs/pdf_completed/2002_May_%2520Beloit_Hospital_SiteReport.pdf.

© Finley Buttes Regional Landfill

25 **Finley Buttes Regional Landfill** Boardman, OR

Black lines schematically show capture of gas from landfill (top-right), and transfer to CHP system (bottom-left, black rectangle). Cascade Specialties onion and garlic dehydration plant is adjacent.

OVERVIEW: Finley Buttes Regional Landfill receives approximately 500,000 tons of municipal solid waste every year. Currently, the waste occupies 80 acres with an average depth greater than 100 feet. The facility installed a 4.8-MW CHP system to take advantage of the abundant source of landfill gas as a fuel. The CHP system collects methane gas from more than 80 vertical and horizontal landfill gas wells to power three electrical generators, and Finley sells more than 30 million kWh to the local utility, PacifiCorp, each year. Heat from the engine's exhaust and from the water-cooling system is captured and the thermal energy is sold to Cascade Specialties, a neighboring onion and garlic dehydration plant. As a result, Cascade Specialties has reduced its natural gas consumption by 25 percent to 30 percent. Together, the landfill and the dehydration plant have reduced CO_2 emissions by more than 15,000 tons annually.

SECTOR: Landfills

OPERATION START: 2007

TECHNOLOGY: Reciprocating engine

FUEL: Landfill gas/methane

MANUFACTURER: Caterpillar

CAPACITY: 4.8 MW

INSTALLED COST: $9.7 million

OVERALL EFFICIENCY: 70% to 80%

ENERGY SAVINGS: N/A

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reduced emissions
- Revenue streams: sale of electricity and thermal energy

Source: Washington State University Extension Energy Program, *Finley Buttes Regional Landfill*, Project Profile, 2011, available at http://www.northwestcleanenergy.org/NwChpDocs/Finley%20Buttes%20 Landfill%20to%20Gas%20CHP%20system%20-%20pp011811.pdf.

26 **Naval Station Great Lakes** Great Lakes, IL

OVERVIEW: Naval Station Great Lakes (NSGL) is a 278-building military base 35 miles north of Chicago. In 2005, NSGL upgraded to a CHP system to achieve the reductions in energy consumption mandated to all federal facilities by the Energy Policy Act of 2005. The system now includes two 5.5-MW Solar Taurus 60 combustion turbines with heat recovery steam generators, and two 1.5-MW back-pressure steam turbines. The CHP system provides the base with 14 MW of electric power and more than 100,000 pounds per hour of high-pressure steam. In addition, the engines are capable of running on natural gas or No. 2 fuel oil, offering NSGL flexibility in fuel choice and the ability to operate independently of the utility. The system has resulted in significant emissions reductions from the previous boilers, which used No. 6 fuel oil.

SECTOR: Military

OPERATION START: 2005

TECHNOLOGY: Gas turbine, steam turbine

FUEL: Natural gas, No. 2 fuel oil

MANUFACTURER: Solar Turbines

CAPACITY: 14 MW

INSTALLED COST: $34.1 million

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: $3.5 million/year

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reduced emissions

Source: U.S. Department of Energy, Midwest CHP Application Center, *Naval Station Great Lakes*, Project Profile, August 2010, available at http://www.midwestcleanenergy.org/profiles/ProjectProfiles/GreatLakesNaval.pdf.

© Wikimedia

27 Cornell University Ithaca, NY

OVERVIEW: In January 2010, Cornell University began operation of two natural gas-fired combustion turbines with an electric capacity of 30 MW. The heat exhaust from the turbines is recovered and used to produce steam for heating the campus. Before 2010, the campus relied mainly on coal for steam production. The CHP installation was driven by Cornell's need for renewal and additional steaming capacity in its central steam-generating facility. It also provides the additional benefits of improved system reliability, the ability to manage costs, and reduced emissions. As a result of this project, the university has reduced its CO_2 emissions by 50,000 tons per year (20 percent), its NO_X emissions by 250 tons per year (55 percent), and its sulfer dioxide (SO_2) emissions by 800 tons per year (55 percent). This project, along with other significant efforts such as the environmentally beneficial Lake Source Cooling Project, supports the university's Climate Action Plan, which aims to reduce Cornell's net greenhouse-gas emissions to zero by the year 2050.

SECTOR: Universities, colleges

OPERATION START: 2010

TECHNOLOGY: Combustion turbine

FUEL: Natural gas

MANUFACTURER: N/A

CAPACITY: 30 MW

INSTALLED COST: $82 million

OVERALL EFFICIENCY: 78%

ENERGY SAVINGS: ~30%

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reduced emissions
- Business continuity planning
- Reliable power source

Source: Lauren Gold, "Cornell plans heating plant upgrade that will cut greenhouse gas emissions by 20 percent," Chronicle Online, January 18, 2006, available at http://www.news.cornell.edu/stories/jan06/chp.expansion.lg.html.

28 Rochester Wastewater Reclamation Plant Rochester, MN

OVERVIEW: The Rochester Wastewater Reclamation Plant treats up to 24 million gallons of wastewater per day. The plant uses two anaerobic digesters to stabilize the sludge before the bio-solids are applied on land. The original CHP system was installed in 1982. In 2002, one of the engines was replaced, followed by the second unit in 2008. The facility upgraded its existing 0.8-MW CHP system to a 2-MW system (lean-burn, turbocharged, spark-ignition GE Waukesha engines) at a cost of $4 million. The facility's digesters produce approximately 338,000 cubic feet of 62 percent methane biogas every day, enough to generate 650 kW of continuous electric power. The jacket water and exhaust heat are captured and used to keep the digesters at 98°F and to provide space heating throughout the facility. The installation has resulted in annual energy savings of more than $650,000 for the City of Rochester.

SECTOR: Wastewater treatment

OPERATION START: 1982 (upgrades in 2002 and 2008)

TECHNOLOGY: Reciprocating engine

FUEL: Biogas, natural gas

MANUFACTURER: GE

CAPACITY: 2 MW

INSTALLED COST: $4 million

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: > $650,000/year

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reduced emissions
- Reduced odors
- Emergency backup power
- $240,000 energy rebates

Source: U.S. Department of Energy, Midwest CHP Application Center, *Rochester Wastewater Reclamation Plant*, Project Profile, available at http://www.midwestcleanenergy.org/profiles/ProjectProfiles/RochesterWWT.pdf (accessed March 2013).

© Crave Brothers Farmstead Cheese

29 Crave Brothers Farmstead Cheese Waterloo, WI

OVERVIEW: In 2009, Crave Brothers Farmstead Cheese, a dairy farm and cheese factory located in Waterloo, Wisconsin, installed a 633-kW CHP system using a GE Jenbacher JMC312 engine, which operates on anaerobic digester gas from cow manure. The CHP system allowed the farm to expand capacity by mitigating problems associated with waste disposal. Previously, the manure was stored in an open lagoon that released methane into the atmosphere. By using digester gas as fuel for the CHP, it has reduced emissions equivalent to 7,125 tons of CO_2 per year. The electricity generated is sold to the Wisconsin Electric Power Company, and the recovered heat provides heating and hot water for the farm and maintains the temperature of the anaerobic digester. The CHP system provides annual energy savings of up to $300,000, resulting in a simple payback of less than five years.

SECTOR: Dairies

OPERATION START: 2009

TECHNOLOGY: Reciprocating engine

FUEL: Biogas

MANUFACTURER: GE

CAPACITY: 633 kW

INSTALLED COST: $1.2 million

OVERALL EFFICIENCY: 83%

ENERGY SAVINGS: $250,000 to $300,000/year

REPORTED PAYBACK: 4 to 5 years

OTHER BENEFITS:

- Waste reduction
- Reduced emissions

Source: U.S. Department of Energy, Midwest CHP Application Center, *Crave Brothers Farm*, Project Profile, October 2009, available at http://www.midwestcleanenergy.org/profiles/ProjectProfiles/CraveBrothers.pdf.

30 Houweling's Tomatoes Camarillo, CA

OVERVIEW: In August 2012, Houweling's Tomatoes installed two GE Jenbacher J624 two-stage turbocharged natural gas engines and a GE-designed CO_2 fertilization system, becoming the first U.S. facility to take advantage of CHP technology for greenhouse purposes. The CHP provides heat and power to the 125-acre facility in Camarillo, California, and the CO_2 present in engine exhaust is captured, purified, and piped into the greenhouse to nourish the plants. The CHP system generates 10.6 MW of thermal power and 8.7 MW of electrical power—enough to power 8,800 average-size American homes—and reduces annual CO_2 emissions by approximately 21,400 tons. In addition, by utilizing the water condensed out of the exhaust gas, the CHP system reduces the facility's daily water use by 9,500 gallons. The system can also provide power to the utility on short notice. The installation at Houweling's Tomatoes represents a step forward in California's goal to install 6,500 MW of new CHP in the state by 2020.

SECTOR: Greenhouses

OPERATION START: 2012

TECHNOLOGY: Reciprocating engine

FUEL: Natural gas

MANUFACTURER: GE

CAPACITY: 8.7 MW

INSTALLED COST: N/A

OVERALL EFFICIENCY: N/A

ENERGY SAVINGS: N/A

REPORTED PAYBACK: N/A

OTHER BENEFITS:

- Reduced emissions
- CO_2 fertilization
- Reduced water usage

Source: Western Energy Systems, *Houweling's Tomatoes*, Case Study, 2012, available at http://seekingalpha.com/news-article/3919661-ge-and-houwelings-tomatoes-unveil-the-first-greenhouse-combined-heat-and-power-project-in-the-us-with-carbon-dioxide-fertilization.

Endnotes

1 SNL Financial, *U.S. Plant Summary by Fuel Type,* 2011, assuming average size of coal plant is 600 MW based on available data, and assigning similar capacity factors for coal plants and CHP systems for illustrative simplicity, available at (www.snl.com); ICF International, "CHP Installation Database," development supported by the U.S. Department of Energy and Oak Ridge National Laboratory, available at www.eea-inc.com/chpdata/index.html (accessed March 2013).

2 U.S. Department of Energy (DOE) and U.S. Environmental Protection Agency (EPA), *Combined Heat and Power: A Clean Energy Solution*, August 2012, available at www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf.

3 U.S. EPA, Combined Heat and Power Partnership, *Efficiency Benefits*, available at www.epa.gov/chp/basic/efficiency.html (accessed March 2013).

4 Ibid; U.S. EPA, Spark Spread Estimator (Excel tool), Version 1, available at www.epa.gov/chp/documents/spark_spread_estimator.xls; Cummins Power Generation Inc., *Cogeneration—Combined Heat and Power*, available at cumminspower.com/en/solutions/cogeneration/ (accessed March 2013).

5 U.S. DOE and U.S. EPA, *Combined Heat and Power: A Clean Energy Solution*, August 2012, available at www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf.

6 U.S. DOE, "CHP: Enabling Resilient Energy Infrastructure" webinar, April 2013, available at http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_enabling_resilient_energy_infrastructure.pdf; U.S. EPA, *The Role of Distributed Generation and Combined Heat and Power (CHP) Systems in Data Centers*, 2007, available at www.epa.gov/chp/documents/datactr_whitepaper.pdf.

7 Oak Ridge National Laboratory, *Combined Heat and Power: Effective Energy Solutions for a Sustainable Future*, December 2008 (page 15), available at www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_report_12-08.pdf.

8 ICF International prepared for Oak Ridge National Laboratory, *Combined Heat and Power: Enabling Resilient Energy Infrastructure for Critical Facilities*, March 2013, available at http://www.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_critical_facilities.pdf; "How Natural Gas Kept Some Spots Bright and Warm as Sandy Blasted New York City," *New York Times*, November 2012, available at dotearth.blogs.nytimes.com/2012/11/05/how-natural-gas-kept-some-spots-bright-and-warm-as-sandy-blasted-new-york/. "How N.Y.U. Stayed (Partly) Warm and Lighted," *New York Times*, November 2012, available at green.blogs.nytimes.com/2012/11/05/how-n-y-u-stayed-partly-warm-and-lighted/.

9 U.S. EPA, Combined Heat and Power Partnership, *Catalog of CHP Technologies*, December 2008, available at www.epa.gov/chp/documents/catalog_chptech_full.pdf.

10 U.S. EPA, Combined Heat and Power Partnership, *CHP Project Development*, available at www.epa.gov/chp/project-development/index.html (accessed March 2013); "Transmission Summit: Transmission Attracting Investment and innovation," *Between the Poles*, March 29, 2011, available at geospatial.blogs.com/geospatial/2011/03/transmission-summit-transmission-attracting-investment-and-innovation.html.

11 American Council for an Energy Efficient Economy, *2012 State Energy Efficiency Scorecard*, October 2012, available at www.aceee.org/research-report/e12c; Database of State Incentives for Renewables and Efficiency (DSIRE), available at www.dsireusa.org (accessed March 2013).

12 U.S. Energy Information Administration, *Annual Energy Outlook 2012*, June 2012, available at www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf.

13 Richard Munson, "The Battle Over Centralization," *Electricity Journal*, April 2012.

14 Brakey Energy, *Skyrocketing FirstEnergy-Ohio Capacity Costs*, 2012, available at www.brakeyenergy.com/wp-content/Brakey_Energy_FirstEnergy_Capacity_White_Paper.pdf (accessed March 2013).

15 U.S. Federal Energy Regulatory Commission, Docket No. RM10-23-000, Order No. 1000, *Transmission Planning and Cost Allocation by Transmission Owning and Operating Public Utilities*, July 21, 2011, available at www.ferc.gov/whats-new/comm-meet/2011/072111/E-6.pdf.

16 U.S. Federal Energy Regulatory Commission, Docket No. RM10-17-000, Order No. 745, *Demand Response Compensation in Organized Wholesale Energy Markets*, March 15, 2011, available at www.ferc.gov/EventCalendar/Files/20110315105757-RM10-17-000.pdf.

17 U.S. EPA, Combined Heat and Power Partnership, *Environmental Benefits*, available at www.epa.gov/chp/basic/environmental.html (accessed March 2013).

18 U.S. DOE and U.S. EPA, *Combined Heat and Power: A Clean Energy Solution*, August 2012, available at www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf. U.S. EPA, CHP Emission Calculator (Excel tool), version updated August 29, 2012, available at www.epa.gov/chp/basic/calculator.html.

19 P. Baer, M.A. Brown and G. Kim, Georgia Institute of Technology School of Public Policy, "The Job Generation Impacts of Expanding Industrial Cogeneration," April 2013, Working Paper #76, available at http://www.spp.gatech.edu/aboutus/workingpapers; American Council for an Energy Efficient Economy (ACEEE), *How Does Energy Efficiency Create Jobs?*, available at aceee.org/files/pdf/fact-sheet/ee-job-creation.pdf (accessed March 2013).

20 Ibid.

21 ArcelorMittal, *ArcelorMittal Indiana Harbor (East Chicago, Ind.) Energy Recovery & Reuse—504 Boiler Project Case Study*, 2012, (document provided by company).

22 Pew Environment Group, *Combined Heat and Power: Energy Efficiency to Repower U.S. Manufacturing*, Fact Sheet, May 2011, available at www.pewenvironment.org/uploadedFiles/PEG/Publications/Fact_Sheet/CHP%20NEW%20JERSEY%20HI-RES%2012.6.11.pdf.

23 Oak Ridge National Laboratory, *Combined Heat and Power: Effective Energy Solutions for a Sustainable Future*, December 2008 (page 15), available at www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_report_12-08.pdf.

24 E-mail and telephone conversation between GE and NRDC, November 2012.

25 2G Cenergy, *German Clean Energy System Manufacturer Creates Jobs and in the USA*, PR*Urgent, March 2012, available at www.prurgent.com/2012-03-26/pressrelease232863.htm.

26 E-mail and telephone conversation between Recycled Energy Development and NRDC, January 2013.

27 U.S. DOE and U.S. EPA, *Combined Heat and Power: A Clean Energy Solution*, August 2012, available at www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf.

28 Ibid.

29 U.S. DOE, Energy Efficiency and Renewable Energy, Combined Heat and Power (CHP) Project Profiles Database, available at www1.eere.energy.gov/manufacturing/distributedenergy/chp_database/Default.aspx (accessed March 2013).

30 McKinsey & Company, *Unlocking Energy Efficiency in the U.S. Economy*, July 2009.

31 U.S. DOE and U.S. EPA, *Combined Heat and Power: A Clean Energy Solution*, August 2012, available at www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf.

32 Executive Order, "Accelerating Investment in Industrial Energy Efficiency," August 30, 2012, available at www.whitehouse.gov/the-press-office/2012/08/30/executive-order-accelerating-investment-industrial-energy-efficiency.

33 State and Local Energy Efficiency Action Network, *Guide to the Successful Implementation of State Combined Heat and Power Policies*, March 2013, prepared by B. Hedman, A. Hampson, J. Rackley, E. Wong, ICF International; L. Schwartz and D. Lamont, Regulatory Assistance Project; T. Woolf, Synapse Energy Economics; and J. Selecky, Brubaker & Associates, available at www1.eere.energy.gov/seeaction/pdfs/see_action_chp_policies_guide.pdf.

34 U.S. EPA, Combined Heat and Power Partnership, *Catalog of CHP Technologies*, December 2008, available at www.epa.gov/chp/documents/catalog_chptech_full.pdf.

35 Carbon Trust (U.K.), *Introducing Combined Heat and Power*, September 2010, available at www.carbontrust.com/media/19529/ctv044_introducing_combined_heat_and_power.pdf.

36 U.S. DOE, Midwest Clean Energy Application Center, "Combined Heat and Power 101," presentation to the Public Utility Commission of Ohio, June 2012.

37 U.S. EPA, Combined Heat and Power Partnership, *Catalog of CHP Technologies*, December 2008, available at www.epa.gov/chp/documents/catalog_chptech_full.pdf.

38 Ibid.

39 U.S. EPA, Combined Heat and Power Partnership, *Economic Benefits*, available at www.epa.gov/chp/basic/economics.html (accessed March 2013). U.S. EPA, Spark Spread Estimator (Excel tool), Version 1, available at www.epa.gov/chp/documents/spark_spread_estimator.xls; U.S. DOE, "CHP: Enabling Resilient Energy Infrastructure" webinar, April 2013, available at http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_enabling_resilient_energy_infrastructure.pdf.

40 U.S. EPA, Combined Heat and Power Partnership, *CHP Project Development Handbook*, available at www.epa.gov/chp/project-development/index.html (accessed March 2013). U.S. EPA, Spark Spread Estimator (Excel tool), Version 1, available at www.epa.gov/chp/documents/spark_spread_estimator.xls (accessed March 2013).

41 Adapted from U.S. DOE, Midwest Clean Energy Application Center, "Combined Heat and Power 101," presentation to the Public Utility Commission of Ohio, June 2012.

42 U.S. DOE and U.S. EPA, *Combined Heat and Power: A Clean Energy Solution*, August 2012, available at www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf.

THE EARTH'S BEST DEFENSE

Natural Resources Defense Council
40 West 20th Street
New York, NY 10011
212 727-2700
Fax 212 727-1773

Beijing

Chicago

Los Angeles

Montana

San Francisco

Washington

www.nrdc.org

www.nrdc.org/policy
www.facebook.com/nrdc.org
www.twitter.com/nrdc

Printed on recycled paper