Fact Sheet: CHP as a Boiler Replacement Opportunity

I. Introduction

The purpose of this paper is to present combined heat and power (CHP) as a viable boiler replacement alternative. To illustrate the potential economic, operational, and environmental benefits of replacing a boiler system with a CHP system, the paper presents a representative analysis that compares a natural gas CHP system to natural gas boilers.

With nearly one-half of the U.S. boiler population with a capacity greater than 10 MMBtu/hr at least 40 years old[1], many facilities with boilers are confronting a number of issues leading them to consider boiler replacement:

- Increased maintenance costs for units nearing the end of their useful lives.
- New regulations that may require investments in existing boilers (e.g., the Industrial/Commercial/Institutional Boiler MACT).
- Current and future corporate or institutional sustainability objectives.
- Steam demands that are increasing beyond current boiler capacity.

Facilities considering boiler replacement have a number of potential options:

- Install emissions control systems on existing boilers[2].
- Install new natural gas boilers.
- Install a natural gas combined heat and power (CHP) system.
- Cease operations[3].

Industrial/Commercial/Institutional Boiler MACT

The National Emissions Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters (commonly known as the Boiler MACT) will affect approximately 14,000 boilers located at large industrial sources of air pollutants in the United States. Finalized on March 21, 2011, and amended on December 20, 2012, the rule limits emissions of toxic air pollutants from new and existing boilers and process heaters at major source facilities. Rule requirements include emissions limits for some coal, oil, and biomass boilers (the highest emitting 12 percent) and annual tune-ups for all boilers. EPA estimates that the capital costs for compliance for coal boilers will be $2.7 billion (an average cost of $4.4 million per boiler) and $1.7 billion for oil boilers (an average cost of $1.9 million per boiler).

More information on the Boiler MACT rule can be found at:
http://www.epa.gov/ttn/atw/boiler/boilerpg.html

The Department of Energy is offering a technical support program for facilities facing MACT compliance that are interested in CHP:
http://www1.eere.energy.gov/manufacturing/distributedenergy/boilermact.html

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[1] http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/characterization_industrial_commerical_boiler_population.pdf

[2] This option also requires continued maintenance of the existing boilers. Control systems include scrubbers, precipitators, and fabric filters.

CHP, a proven technology that has been used for decades, can replace on-site boiler use and grid-supplied electricity, often referred to as separate heat and power (SHP). CHP is used in every state and in the District of Columbia at over 4,100 facilities including factories, commercial buildings, hospitals, and universities.[4] Approximately 12 percent of the total electricity generated in the United States comes from CHP.[5]

Natural gas-fired CHP can be a particularly attractive option for facilities. It can meet all of a facility's steam needs, reduce net steam costs[6], and produce an attractive return on investment while creating a number of other economic, operational, and environmental benefits:

- **Economic and operational benefits**
    - CHP designed to operate during grid outages can enable continued operations during power disruptions and avoid the costs of facility shutdowns.
    - CHP can significantly reduce operating costs, including net steam costs, by efficiently producing steam and electricity on site and reducing the amount of purchased electricity.
    - CHP can provide a hedge against rising electricity costs.
    - CHP can avoid costs associated with complying with new regulations on coal- and oil-fired boilers. These regulations may require subject facilities to install emissions control equipment. Investments in control equipment may require scarce capital and do not typically lower operating costs or provide a financial return on investment. This capital could be invested more productively in energy production infrastructure, especially highly efficient CHP, which can produce attractive rates of return while meeting regulatory requirements.

- **Environmental benefits**
    - Switching to natural gas reduces emissions of greenhouse gases and other air pollutants compared to coal or oil boilers.
    - Because CHP consumes less fuel to produce each unit of energy output, CHP further reduces emissions.

II. Comparison of Natural Gas Boilers and CHP

Table 1 presents an illustrative financial comparison of a natural gas CHP system (a combustion turbine and a heat recovery steam generator) to two natural gas boilers[7]. The CHP system and the boilers have the same steam output. The comparison is based on a CHP system sized appropriately to meet the steam needs of a small industrial or medium-sized institutional facility.

This specific comparison was selected as the focus of the paper because if a decision is being made to replace a coal-fired or other boiler system, often a natural gas boiler would be a logical option.

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[3] http://www.cibo.org/newsletters/jan2013.pdf. Certain industry groups have suggested that some facilities may make this choice.

[4] https://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf

[5] http://www.eea-inc.com/chpdata/index.html

[6] Net steam costs are defined as total CHP operating costs minus the value of the electricity generated.

[7] Two boilers are used in this analysis consistent with industry practice.

Table 1: Financial Comparison of Natural Gas Boilers and CHP			
	Natural Gas Boilers	**Natural Gas CHP**	**Impact of CHP Increase / (Decrease)**
Peak Boiler Capacity, MMBtu/hr input	120	NA	
Peak Steam Capacity, MMBtu/hr	96	96	
Average Steam Production, MMBtu/hr	76.8	76.8	
Boiler Efficiency	80%	NA	
Electric Generating Capacity, MW	NA	14	
CHP Electric Efficiency	NA	31%	
CHP Total Efficiency	NA	74%	
Steam Production, MMBtu/year	614,400	614,400	0
Steam Production, MMlbs/year	558.6	558.6	0
Power Generation, kWh/year	NA	106,400,000	106,400,000
Fuel Use, MMBtu/year	768,000	1,317,786	549,786
Annual Fuel Cost	$4,608,000	$7,906,716	$3,298,719
Annual O&M Cost	$729,600	$1,687,200	$957,600
Annual Electric Savings	0	($6,703,200)	($6,703,200)
Net Annual Operating Costs	$5,337,600	$2,890,719	($2,447,331)
Net Steam Costs, $/1000lbs	$9.56	$5.18	($4.38)
Capital Costs	$4,200,000	$21,000,000	$16,800,000
10 Year Net Cash Outlays	$65,389,602	$54,138,850	($11,250,752)
Payback – CHP vs. Gas Boilers			6.9 years
10 Year IRR - CHP vs. Gas Boilers			10%
10 Year NPV – CHP vs. Gas Boilers			$2,580,588

Source: ICF International

Notes: Based on 8,000 hours facility operation, 7 cents per kWh electricity price, and $6/MMBtu natural gas price. Natural gas boiler estimated capital cost of $35/MBtu/hour input and O&M cost of $0.95/MMBtu input were provided by Worley Parsons. CHP capital cost of $1,500/kW, turbine/generator and heat recovery steam generator O&M costs of $0.009/kWh and 31 percent electrical efficiency are taken from a California Energy Commission Report, "Combined Heat and Power: Policy Analysis and 2011 – 2030 Market Assessment", 2012. Annual CHP O&M cost includes an amount to maintain the steam system, which is approximated by the O&M cost of the boilers, which produce the same steam output. CHP availability of 95 percent and portion of electric price avoided by on-site generation of 90 percent are values based on typical CHP feasibility analyses. 10 year net cash outlays are the sum of 10 year's operating costs escalated at 3 percent annually. NPV determined using a 7% discount rate. All efficiency values and natural gas prices are expressed as higher heating values.

III. Economic and operational advantages of CHP compared to natural gas boilers

For facilities considering boiler replacement, CHP can offer several distinct economic and operational advantages:

Reduced Operating Costs. Table 1 demonstrates the lower steam and operating costs that can be achieved with CHP:

- The CHP system achieves net annual operating cost savings of more than $2.4 million.

- The value of the electricity produced by the CHP system is greater than the additional fuel and O&M costs associated with the CHP system.
- Net steam costs for the CHP system are $4.38/MMBtu less than for the gas boilers.
- The CHP system requires a capital expenditure of $16.8 million more than the gas boilers; however, this investment provides a net present value of nearly $2.6 million, an internal rate of return of 10 percent, and a payback period of less than seven years.

A Hedge against Future Electricity Prices. Since 2003, the U.S. average retail price of electricity has increased approximately 30 percent to more than 10 cents per kWh for commercial customers and more than 6.5 cents per kWh for industrial customers.[8] During the same time period, natural gas prices have declined 12 percent for commercial customers and 33 percent for industrial customers.[9] Through the highly efficient production of steam and electricity on site using natural gas as a fuel, CHP can provide a hedge against increasing electricity costs by reducing electricity purchases from the grid.

Mitigating the Impacts of Electric Supply Disruption. CHP can provide enhanced power supply reliability, mitigating or eliminating the potential costs associated with electricity supply disruption. Data from various studies estimate the costs from power-related outages to the U.S. economy to be between $104 billion and $164 billion annually.[10] CHP systems can be designed to operate independently of the grid and provide the host facility with the ability to maintain operations—partially or completely, depending on design—during grid outages.

External events, such as storms or failed substation transformers, can shut down the electric grid for extended periods of time and disrupt operations of customers. Facilities dependent on a stable electric supply may incur costs due to loss of production, compensation to customers, and equipment damage. Biotechnology research facilities risk the destruction of irreplaceable research materials when refrigeration or climate control systems fail. Medical centers and nursing homes may be unable to continue to provide essential patient care. Many CHP systems at hospitals, universities, and other facilities operated continuously during major storms like Hurricanes Katrina and Sandy as nearby buildings lost power for several days.[11]

IV. Environmental Benefits of CHP

Through the recovery and use of otherwise wasted energy and the elimination of transmission and distribution (T&D) losses[12], CHP systems require less fuel than SHP systems (i.e., grid electricity and on-site boilers) to produce the same amount of useful energy. These fuel savings result in a significant reduction in the total emissions of greenhouse gases and other air

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[8] http://www.eia.gov/electricity/data.cfm. Depending on the amount of electricity purchased, institutional customers pay commercial or industrial prices.
[9] http://www.eia.gov/totalenergy/data/annual/#naturalgas. Depending on the amount of gas purchased, institutional customers pay commercial or industrial prices.
[10] http://www.fas.org/sgp/crs/misc/R42696.pdf
[11] http://www.gulfcoastcleanenergy.org/Portals/24/Downloads_misc/CHP-Sandy-media-coverage.pdf
[12] T&D losses refer to the electricity lost by transmitting and distributing power from the point of generation to the point of consumption. Nationally, these losses average about 7 percent. Source: http://www.eia.gov/tools/faqs/faq.cfm?id=105&t=3

pollutants[13] associated with producing electricity and steam. In this context, “total emissions” include emissions from on-site equipment (i.e., CHP or gas boilers) and the emissions associated with any purchased electricity generated off site.

This reduction in total emissions lowers a facility's environmental footprint, improves organizational environmental performance, and helps meet sustainability goals. Table 2 compares the fuel consumption and CO_2 emissions of the CHP system and the combination of boilers and grid electricity presented in Table 1.

Table 2: Fuel Consumption and CO_2 Emissions

		Fuel (MMBtu/yr)	**CO_2 (tons/yr)**
Natural Gas Boilers and Grid Electricity	Boilers	770,000	45,000
	Grid Electricity	1,090,000	99,000
	Total (a)	1,860,000	144,000
Natural Gas CHP (b)		1,320,000	77,000
Change in Total Fuel Consumption and CO_2 Emissions (a – b)		**(540,000)**	**(67,000)**
Percent Change		(29%)	(47%)

The CHP and the boilers produce equal amounts of steam. Because the CHP also produces electricity, it consumes more fuel than the boilers. The increased fuel use can lead to an increase in emissions on site, including CO_2, NO_x, VOCs, PM and CO.

Replacing a boiler system with a CHP system or new natural gas boilers may require an emissions assessment and a modification to a facility’s air permit. A permit modification would need to take into account a number of different factors, including existing and planned fuel use, combustion technology and efficiency, CHP capacity, emissions controls, and facility air permitting status. Because these factors will be unique to each facility, it is beyond the scope of the paper to cover the range of permitting implications for either boiler replacement option.

V. Resources and Additional Information

The U.S. Environmental Protection Agency CHP Partnership is a voluntary program that seeks to reduce the environmental impact of power generation by promoting the use of cost-effective CHP. The Partnership works closely with energy users, the CHP industry, state and local governments, and other clean energy stakeholders to facilitate the development of new projects and to promote their environmental and economic benefits. See http://www.epa.gov/chp.

The U.S. Department of Energy’s (U.S. DOE) eight regional Clean Energy Application Centers promote and assist in transforming the market for CHP and district energy throughout the United States. See http://www1.eere.energy.gov/manufacturing/distributedenergy/ceacs.html.

[13] Pollutants emitted from fuel combustion include nitrogen oxides (NO_X) and sulfur dioxide (SO_2), which contribute to the formation of acid rain, particulate matter (PM), volatile organic compounds (VOCs) and carbon dioxide (CO_2).

The U.S. Clean Heat and Power Association (USCHPA) is a trade association that brings together diverse market interests to promote the growth of clean, efficient local energy generation in the United States. USCHPA's mission is to increase deployment of combined heat and power and waste energy recovery systems to benefit the environment and the economy. See http://www.uschpa.org.

CHP Financing

Many facilities prefer not to use limited capital resources for infrastructure like CHP and have instead used mechanisms such as leasing, third-party financing, or build/own/operate arrangements to finance their CHP systems. Additional information is available in the Procurement Guide: CHP Financing, a resource available at http://www.epa.gov/chp/documents/pguide_financing_options.pdf.

There are also a number of state and federal incentives for CHP including tax credits, grants, loans, production incentives and rebates. The EPA CHP Partnership maintains a comprehensive database of various state and federal incentives in its Database of CHP Policies and Incentives (dCHPP) available at: http://www.epa.gov/chp/policies/database.html.

Through its Clean Energy Application Centers, the DOE also offers direct project assistance in the form of site assessments and feasibility studies: http://www1.eere.energy.gov/manufacturing/distributedenergy/ceacs.html.

For more information, contact:

CHP
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