Title: Combined Heat and Power Plants: A Balanced Alternative
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Presented at: Electric Power Conference
Date: May 6, 2008

ABSTRACT

Today's electric power industry is challenged to meet the demands of many masters: client needs, economics (lowest cost), environmental permitting and citizen focus on global warming. One option to balance these issues is the combined heat and power (CHP) plant design. CHP is more than a piece of equipment; it is a system of simultaneously producing electricity, steam and/or chilled water from a single fuel source. CHPs are much more efficient than traditional power plants in reducing the production of greenhouse gases such as carbon dioxide. CHPs, however, are not a new, experimental technology, but employ traditional technologies such as boilers, auto-extraction steam turbines, and combined cycle turbines, thus providing reliability and predictable costs.

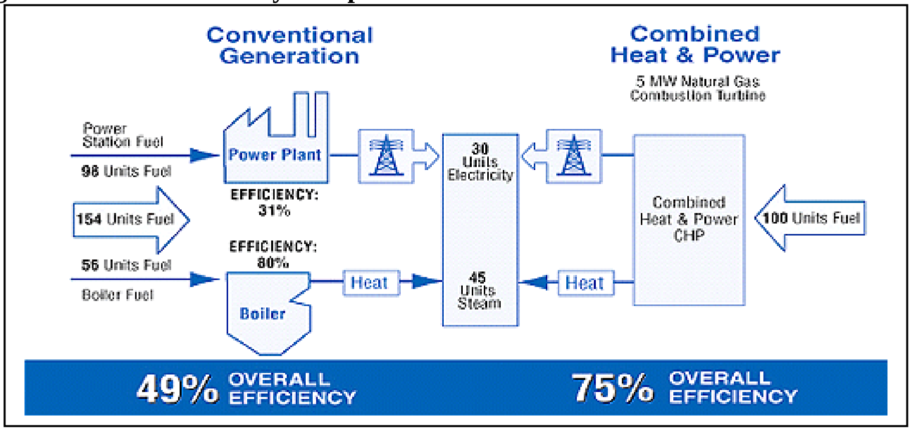
As innovative as CHPs are in addressing customer demands and environmental concerns, they are still held subject to the traditional air permitting pre-construction requirements. Several companies have balanced these issues with new CHPs. This paper will examine the CHP design, its permitting requirements, and the success of three specific projects.

THE COMBINED HEAT AND POWER DESIGN

A combined heat and power (CHP) system produces multiple products, including electricity, steam and chilled water. In contrast, a traditional power plant focuses on the production of electricity and might recover the waste energy through a heat recovery system to generate more electricity through a steam generator. Although CHP is usually a fossil fuel-based process, it can incorporate biomass or other biofuels. But regardless of the fuel source, CHP is "greener" than a traditional power plant by virtue of its higher efficiencies. CHP systems typically achieve total system efficiencies of 60 percent to 80 percent[1] for producing electricity and thermal energy compared to average fossil-fueled power plant efficiencies of 33 percent in the United States.[2] Thus more power can be generated for the same emissions in a CHP than from a traditional power plant. CHP is a proven, implemented process with more than 80,000 megawatts (MW) of CHP capacity in the United States.[3] Figure 1 shows the efficiency advantage of CHP compared with conventional central station power generation and on-site boilers.[4]

[1] http://www1.eere.energy.gov/office_eere/pdfs/biomass_fs.pdf
[2] http://www.epa.gov/combdhpp/documents/chppfactsheet.pdf
[3] http://www.epa.gov/combdhpp/documents/chppfactsheet.pdf
[4] http://www.epa.gov/chp/basic/efficiency.html

Figure 1. Overall Efficiency Comparison between CHP and Conventional Generation

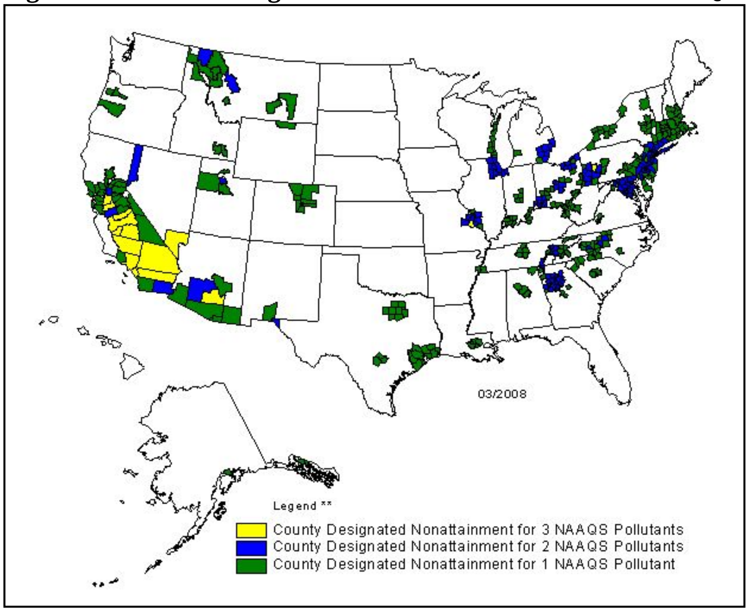


The prime mover in a CHP system is most commonly a boiler or a gas turbine burning coal, natural gas, biomass or biofuels. Mechanical energy is most often used to drive a generator to produce electricity, while thermal energy produces steam or chilled water. The steam generated from a heat recovery boiler can be used to produce additional electricity, or in educational or industrial settings, the low pressure steam can be used for process heating or to heat or cool buildings.

AIR PERMITTING REQUIREMENTS FOR CHP

Even though CHP plants are more efficient than traditional power plants, they are still subject to the same permitting requirements under the Clean Air Act. Large construction projects are subject to New Source Review (NSR). NSR is an umbrella for two programs: non-attainment NSR (NNSR) and Prevention of Significant Deterioration (PSD). Areas of the country with poor air quality (see Figure 2) are subject to the more stringent requirements of NNSR permitting. Areas of the country with sufficient existing air quality are subject to PSD permitting.

Figure 2. Counties Designated as Nonattainment for the NAAQS[5]



The determination of whether or not a project is large enough to be subject to NSR is based on three criteria (see Table 1):

- If the project will be constructed at an existing major PSD source or at a minor PSD facility (greenfield or existing minor source).
- If the type of facility is on EPA list of 28 source categories (a "listed" source).
- On the potential-to-emit of the project.

Table 1. NSR Major Source Thresholds for a Project

Facility Type	Project PSD Major Source Threshold (tpy)
PSD Minor, Listed	100 tpy of PM_{10}, CO, NO_x, SO_2, or VOC
PSD Minor, Not Listed	250 tpy of PM_{10}, CO, NO_x, SO_2, or VOC
PSD Major, Listed or Not Listed	15 tpy of PM_{10}, 100 tpy of CO, 40 NO_x, SO_2, or VOC

Of the 28 listed source categories, two are potentially applicable to CHP projects:[6]

- Fossil-fuel boilers (or combination thereof) totaling more than 250 million British thermal units per hour (MMBtu/hr) heat input.
- Fossil fuel-fired steam electric plants of more that 250 MMBtu/hr heat input.

Therefore, a boiler or other CHP component that involves steam and has a heat input greater than 250 MMBtu/hr is subject to the lower 100 tpy major source threshold. Modifications at these facilities have a lower threshold for tripping NSR requirements. A project subject to PSD or NNSR permitting will be required to have additional control devices and lower emission limits. The benefits of CHP are not recognized at the federal level when permitting new projects; however, some states have adopted specific regulations to encourage CHP projects.

Regardless of the area of the country, CO_2 is not currently regulated in the United States. The Supreme Court has ruled that EPA can regulate CO_2,[7] but to date, EPA has not. California and 17 other states tried to

[5] http://www.epa.gov/air/oaqps/greenbk/mapnpoll.html
[6] 40 CFR 52.21(b)(1)

regulate CO_2 on their own and the EPA denied their request for a waiver under the Clean Air Act, which would have allowed stricter-than-federal limits on greenhouse gas emissions from motor vehicles.[8]

REGULATORY INCENTIVES FOR CHP

Traditional air permitting limits are based on emissions per amount of fuel input (lb/MMBtu). Output-based emission limits, however, are based on emissions per useful energy output (pound per megawatt hour [lb/MWhr]). Output-based limits are becoming more common and have been included in federal regulations, such as the New Source Performance Standards for utility boilers (40 CFR Part 60, Subpart Da). They encourage technologies such as CHP by accounting for both the thermal and electrical output, reflecting the increased efficiency.

Some states have issued their own rules to reward the higher efficiencies of distributed generation facilities such as CHP. The California Air Resources Board (CARB), a branch the California Environmental Protection Agency, has implemented a certification program for distributed generation units to encourage operation of "the cleanest engines available." In recognition of their benefits, combined heat and power units that achieve minimum efficiency of 60 percent may obtain emission credits. Additionally, the legislation facilitates permitting for CHP power plants less than 50 MW by providing specific guidance to each local air district.

In Texas, electric generating units that use combined heat and power (CHP) may take credit for the heat recovered from the exhaust of the combustion unit to meet the emission standards. Credit shall be at the rate of one MWh for each 3.4 MMBtus of heat recovered.[9] The heat recovered must equal at least 20 percent of the total energy output of the CHP unit. The output-based standards that allow accounting for the efficiency of combined heat and power plants are only applicable to facilities that can qualify for a standard permit. In other words, projects which trip PSD or NNSR permitting requirements are not allowed to take the heat recovery credit.

The NO_x trading programs of Indiana, Connecticut, and Massachusetts allocate allowances specifically to highly efficient CHP facilities. Since the cost of allowances ranges from hundreds to thousands of dollars per ton, a considerable economic incentive to higher efficiencies is created.

Indiana's NO_x trading program includes a set-aside of allowance allocations for energy efficiency and renewable energy.[10] Indiana allocates 1,103 tons of NO_x allowances each year for projects that reduce the consumption of electricity, reduce the consumption of energy other than electricity, or generate electricity using renewable energy. Eligible projects can involve combined cycle systems, CHP, microturbines or fuel cells.[11]

In Connecticut, the owner or operator of a CHP system may receive a compliance credit against its actual emissions on a per pollutant basis. To be eligible for emissions credit related to thermal output, at least 20% of the fuel's total recovered energy must be thermal and at least thirteen percent (13%) must be electric, with a resulting power-to-heat ratio between 4.0 and 0.15. Additionally, the design system efficiency must be at least 55%. A CHP system that satisfies these requirements can calculate a CHP system emissions

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[7] Supreme Court Docket # 05-1120, decided April 2, 2007.
[8] EPA Press Release, December 19, 2007, "America Receives a National Solution for Vehicle Greenhouse Gas Emissions"
[9] TCEQ, Air Quality Standard Permit for Electric Generating Units, Effective Date June 1, 2001
[10] http://www.in.gov/idem/files/EE_REguide2.PDF
[11] http://epa.gov/CHP/documents/output_based_regs_fs.pdf

credit, which is subtracted from the actual emission rate of the CHP system to produce the pollutant emission rate used for determining compliance.

In Massachusetts, CHP systems that achieve an actual energy efficiency of 60% are defined as "Energy Efficiency Projects" and are eligible for allowances from the Public Benefit Set Aside. Beginning in 2003, the Department annually allocates 5% of the Massachusetts NO_x state trading program budget to a public benefit set-aside account to provide for allocation of allowances for Energy Efficiency Projects and Renewable Energy Projects.

However, regulatory incentives can only address small projects due to the all-encompassing requirements of the NSR program. When projects exceed specific size and emission thresholds, NSR regulations trump state incentives. At larger sizes, projects are hindered by the need to comply with NSR.

SPECIFIC CHP PLANT EXAMPLES

The implementation of CHP under the current regulatory framework can be explored by examining three recent CHP projects and their permits, as summarized in Table 2.

Table 2. CHP Project Examples and Permits

CHP Project	CHP Equipment	Permit Type	Control Devices and Limits
University of Chicago	Boilers	Minor permit at a PSD major facility located in a nonattainment area	Low NO_x burners, natural gas as primary fuel; actual emissions limited to less than the PSD and NSR thresholds
GRU Energy Center at Shands	Combined cycle turbines	Minor permit at a greenfield facility located in an attainment area	None, natural gas as only fuel; Facility wide NO_x emissions cap
Thermal Energy Corporation	Combined cycle turbines	Major permit at major facility located in a nonattainment area	Selective Catalytic Reduction

University of Chicago

The University of Chicago is an existing PSD major source located in a nonattainment area. In July 2006, the University applied to construct the West Campus Combined Utility Plant, consisting of five electric centrifugal chillers providing 12,500 tons of cooling capacity and two boilers providing 450,000 pounds per hour of high pressure steam primarily for comfort cooling and heating. The boilers are natural gas-fired with limited fuel oil backup and use low NO_x burners to reduce NO_x emissions.

The project was designed to limit emissions to less than the PSD major source thresholds in order to avoid PSD and NNSR. This required a limit on actual emissions of the facility as documented by fuel consumption, operating time, and a continuous NO_x emissions monitor. The boilers are subject to NO_x emission limits under New Source Performance Standards (NSPS) and to the state NO_x trading program for ozone nonattainment.

GRU Energy Center at Shands

In March 2007, Gainesville Regional Utilities (GRU) applied to construct a new CHP facility adjacent to the Shands at the University of Florida (Shands) hospital complex. The project included two Solar Mercury 50-6000R combustion turbine generators each with a fired heat recovery steam generators (HRSGs), one auxiliary steam boiler, two small cooling towers, and two emergency diesel-engine driven generators. The

CHP project provides steam and power to the Shands hospital complex, as well as power to the electrical transmission grid. The CTGs and HRSGs are fired exclusively with pipeline natural gas.[12]

The combustion turbine generators each have a nominal heat input of approximately 53 MMBtu/hour and a power generation capacity of approximately 4,600 kilowatts. Each heat recovery steam generator can produce up to 45,000 pounds per hour of steam and includes a natural gas fired duct burner with a nominal heat input of 36 MMBtu/hour. The hours of operation are not restricted; rather the facility is subject to a facility-wide emissions cap in order to keep emissions below the PSD thresholds.

The facility is subject to an output based standard of 2.3 lb/MWh of useful output, which accounts for the efficiencies of the CHP design. The gross energy output is calculated as the sum of the total electrical and mechanical energy generated by the combustion turbine, the additional electrical or mechanical energy generated by the steam turbine following the heat recovery steam generator, and 100 percent of the total useful thermal energy output that is not used to generate additional electricity or mechanical output, expressed in equivalent MW.

Thermal Energy Corp.

In September 2007, Thermal Energy Corporation (TECO) applied to construct a new CHP facility at an existing PSD major facility. Thermal Energy Corporation (TECO) provides district heating and cooling services for the Texas Medical Center (TMC), located in Houston, TX. The project consists of two combustion turbine generators with duct fired heat recovery steam generators, cooling towers, chillers, chilled water pumps, a thermal energy storage tank, and associated ancillary equipment. This planned growth will provide 80,000 tons of chilled water, 100 MW of on-site generation, and 540,000 pounds per hour of steam.

Since this project is subject to NSR, it is not able to take advantage of the output based standards available to projects subject to the standard permit. The NSR permit for this project had not been issued at the time of this paper.

SUMMARY

With a national growing concern over greenhouse gas emissions, CHP is an excellent alternative to a traditional power plant. CHP has higher overall efficiencies and produces more useful power for fewer emissions. Although some states have recognized the benefits of CHP and adopted rules to encourage CHP projects, federal regulations have yet to follow suit. Large CHP projects which are subject to NSR permitting requirements are not able to take advantage of state CHP permit benefits.

[12] Permit # 0010129-001-AC