



# The Confusing Allure of Combined Heat & Power

The Challenge of Reducing Energy Spend & Carbon  
Emissions through Onsite Power Generation



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## ABSTRACT

Sixty-one percent of global executives surveyed by McKinsey & Co. (in 2008) expect the issues associated with climate change to boost profits—if managed well. What these executives recognize is that new regulations, higher energy costs, and increased scrutiny by private gate-keepers (such as Wal-Mart) offer an opportunity to identify and implement more efficient practices in commercial and industrial environments. One of the most impactful solutions for the industrial sector—from the perspective of reducing energy spending and energy-related carbon emissions—is combined heat and power (“CHP”), sometimes referred to as cogeneration. However, the results of CHP deployment to date have been mixed—largely because companies do not fully appreciate the challenges of maintaining and operating a CHP system, optimizing its performance, and taking full advantage of the many benefits it offers. Despite these challenges, the slogan for CHP should perhaps be: “CHP, now more than ever”.

## INTRODUCTION

Sixty-one percent of global executives surveyed by McKinsey & Co. (in 2008) expect the issues associated with climate change to boost profits—if managed well. Eighty-two percent of those same executives expect some form of climate change regulation within five years. While new regulations typically equate to higher costs, what these executives recognize about climate change regulation is that sustainability should not constitute an additional cost but rather an opportunity to identify and implement more efficient practices in commercial and industrial environments. One of the most impactful solutions for the industrial sector—from the perspective of reducing energy spending and energy-related carbon emissions—is combined heat and power (“CHP”), sometimes referred to as cogeneration.

However, while many companies have deployed CHP systems at their plants across the country and world, the results have been mixed—in large part because companies do not fully appreciate the challenges of maintaining and operating a CHP system and optimizing the performance of the system across the lifetime of the system (and the plant it serves). Additionally, after making the sizeable investment in CHP, many companies fail to measure, track, and document the dramatic emission benefits of CHP—undercutting one of the most compelling virtues of the system.

Despite the numerous challenges, the slogan for CHP should perhaps be: “CHP, now more than ever”. As the days of cheap electricity move into the past and the scrutiny of public regulatory authorities and private gate-keepers (such as Wal-Mart) increases, the significant impact of CHP should not be overlooked. Electricity from the grid remains costly and inefficient, and companies pulling all of their electricity from the grid suffer the emission “penalty”



of inefficient electricity distribution from 1960s' era plants. CHP can catalyze sustainability efforts and improve the bottom line while permitting greater visibility and predictability in plant energy costs.

As companies assess the different paths to a sustainable future, CHP should not be overlooked. While management and operation of CHP systems remain big challenges for any company whose operational focus is not energy management, CHP is not only a “quick win” for energy cost and emission reduction but also a long-term strategy for managing upcoming regulations and hedging energy costs in a volatile environment trending toward dramatically higher electricity costs.

## THE ALLURE OF CHP TO THE INDUSTRIAL USER

CHP can be a very efficient system that produces power (electricity, mechanical power or thermal energy), then captures the waste heat created by the power generation process and reuses it to help meet any of a variety of needs the user may have in a facility. While traditional methods of producing separate heat and power have a typical combined efficiency of 45%, CHP systems can operate at up to 90% efficiency.

### **A Cost-Effective Response to Climate Change Concerns and Emissions Regulations**

Because of their greater efficiency and use of cleaner fuels, CHP plants produce fewer greenhouse gas emissions per unit of useful power than traditional power plants.

The efficiency gain of CHP is achieved through a variety of means. With CHP, the power generation source is located at the point of use, which eliminates the transportation losses for which the user of traditional electricity is liable. This benefit equates to an average 7.2% efficiency gain (6). Simple-cycle electrical efficiency approaching that of utility-size power plants (over 40%) can be achieved in CHP plants with reciprocating engines and fuel cell technology. The bulk of CHP's competitive difference, though, comes from utilizing the free waste heat created by the power generation process at the location where it is needed, thus eliminating any transportation or conversion losses for the heat. By using the waste heat with as few conversion losses as possible, additional efficiency can be achieved by CHP. A combined-cycle plant would, for example, require that the waste heat be converted to steam and then used in a steam turbine. The conversion of the waste heat to power means that combined-cycle utility plants still only achieve 60% efficiency.

Since most states' emissions regulations will likely require that clean burning natural gas be used as an alternative to coal or other similar products, CHP will produce even fewer emissions.

Dollar for dollar, CHP provides the industrial user with better results than any other strategy that might be used to respond to climate change concerns, except for energy efficiency. It even outperforms PV and other solar technologies.



### **Improved Financial Competitiveness**

The industrial energy user that installs a CHP system will experience improved financial competitiveness as a result of that system's improved efficiency. In addition, increasingly, incentives are being offered to business to invest in CHP. A federal Investment Tax Credit was provided in federal stimulus bills last fall and that benefit has, in the latest stimulus bill, been converted (as an option) to a grant for the same amount. Many states have CHP incentive programs that further enhance the returns for CHP installations, and a few are considering CHP as a viable alternative to meeting their Renewable Portfolio Standards (RPS) goals. These are only a few of the new drivers that continue to enhance the returns for the CHP user.

Taken together, the efficiency advantages provided to businesses through CHP (30-50% over the alternatives) and the additional incentives just discussed will, in most cases, enable the industrial user to make the investment necessary to derive the available financial gain from CHP plant operation.

### **Energy Reliability and Security**

CHP is a type of distributed (as opposed to central station) power generation, which means it is located at or near the point at which the power it produces is used. If it is managed well, an onsite power generation plant provides a huge increase in energy reliability to a facility. This can help the user avoid the risk of the devastating financial loss that can come when grid-supplied power is interrupted. CHP reliability, however, should not be taken for granted, and does come with its fair share of challenges. This will be elaborated upon in the following section.

### **Fuel Flexibility**

CHP plants can operate using a variety of fuels, including natural gas and renewable and locally sourced fuels such as biogas made from waste material created by the end user (which would otherwise need to be discarded). This flexibility will be an increasingly valuable asset to businesses if the availability and price of fossil fuels continue to be unpredictable, as they are expected to do.

## **OBSTACLES TO SUCCESSFUL INDUSTRIAL CHP USE**

A CHP system is a major investment for any company. If managed properly, such a system should pay for itself and reduce the company's overall operating expenses relatively quickly. Proper management of a cogeneration system, however, is not easily accomplished by a company whose primary focus is not energy management.

### **Mismatched Power Supply and Demand**

For CHP to be successful (i.e., economically beneficial to the company that invests in it), the electricity and heat produced by the CHP plant must be fully utilized at all times. Though this may sound simple, it is actually fairly difficult to achieve. One reason for this difficulty is that a facility's thermal load, in particular, is hard to measure and understand.



During the due diligence phase prior to building a CHP system, it is common to collect both electrical and thermal data. The key to success is to collect enough granular data that the anticipated electrical and thermal supply will match the electrical and thermal load at the plant.

The utility will, in most instances, be able to provide very granular, 15-minute interval electrical data to the host, which makes this analysis fairly straightforward. With 15-minute interval data, one would be able to size a base loaded CHP system without trouble, assuming the past year's load is a good proxy for the future.

Thermal data is usually available from the local gas utility; however, it is often not available at the required granularity. Gas data is usually provided as monthly totals, rather than daily or hourly amounts. This is the first challenge that needs to be overcome in the thermal due diligence period. The second challenge that faces the developer of CHP at an industrial usage site, beyond the load at the main gas meter, is the actual usable load at the plant itself. With some CHP technologies, it is more difficult than with others to determine this load. Gas turbines, that for the most part generate high-pressure steam, may be easier to integrate into a system because the steam output to the industrial user can be measured by a steam flow meter. The difficulty occurs when the industrial user does not have a steam flow meter, so that extrapolated or otherwise calculated steam profiles are used for the sizing of the plant.

Some technologies, such as reciprocating engines, generate both steam and hot water, making it even more difficult to determine a thermal load profile and, therefore, whether a reciprocating engine would be the best choice for the user. Detailed data logging is usually necessary to be able to make an appropriate determination of the hot water load at a plant. This data is not commonly available at an industrial plant, but is a key to predicting the future success of CHP.

In addition, the following are some of the other ways that power generation by a CHP plant and electricity and thermal energy use by a facility—also known as “load”—can fail to match up:

1. Current and future load are either not considered or not well understood when the prime-moving technology for the CHP plant is selected.
2. Current and future load are either not considered or not well understood when the size of the cogeneration plant is chosen
3. No arrangement is made to have trained experts evaluate performance and make adjustments to the system after startup of the CHP plant.



## 1. Prime Mover Selection.

There are a variety of prime-moving technologies that can be used in cogeneration. Common technologies include the following:

- Reciprocating Engines (lean burn and rich burn)
- Gas Turbines
- Micro Turbines
- Fuel Cells

The type of prime-moving technology that will deliver the best results in a particular CHP application depends on the facility's specific electricity and thermal energy needs. Most cogeneration systems work well when they are base loaded, which means they are designed to produce the minimum amount of electricity or heat needed by the plant at all times. Most work best when they are also designed to match the facility's demand for heat (in terms of quantity, temperature and other factors) as completely as possible.

Reciprocating Engines may be the best choice when the following circumstances are present:

- Processes are cyclical or not continuous
- Demand for power is between 0.5 and 5 MW
- Low-pressure steam or medium or low temperature hot water are needed
- There is a low heat to power demand ratio

Reciprocating engines can be spark ignition or compression ignition. Spark ignition engines are best when electrical load is less than 1 MW, while compression ignition engines are preferred when it is greater than 1 MW. Spark ignition engines do not follow non-constant load very well, especially when load drops below 50 percent, so this should be a consideration as well. This is also important to consider when exploring the use of natural gas fired reciprocating engines for reliability purposes. In such cases, it may be necessary to use a diesel fired reciprocating engine in combination with the natural gas fired engine to stabilize load swings.

Reciprocating engines can also be lean burn or rich burn, lean burn having high electrical efficiency and rich burn producing high thermal output.

Gas Turbines are often the best selection when the following conditions exist:

- Demand for power is continuous, and is over 5 MW
- There is a high demand for medium or high pressure steam or hot water
- There is demand for hot gases

Micro Turbines may be the best choice under the following circumstances:

- Electric and thermal loads are relatively coincident
- Power demand is between 30 kW and 200 kW



- There is a need for hot water
- Electric demand to thermal demand ratio is in the 0.5 to 2.5 range

Both gas turbines and micro turbines may be good choices when considering CHP for reliability enhancement reasons.

Fuel Cells are an emerging technology. Fuel cells are still being deployed at costs that make them a poor choice as a CHP alternative in many areas. A few states do have incentives that are substantial enough to make fuel cells worth considering under the right circumstances. Very high efficiencies and reliabilities are also reasons to consider fuel cells, but excessive maintenance costs at 3-, 5- and 10-year intervals drive operating costs of fuel cell plants above those of any other CHP alternative.

## **2. Size Selection.**

It is important to understand not only a facility's current load but how that load might vary in the future when determining the size of the CHP plant to be built. Building the plant either too big or too small deprives the owner of the maximum benefits CHP can offer.

In addition, most industrial energy users have energy efficiency opportunities that, if identified and acted upon, will reduce the overall load at the plant to a level that could make an initially estimated CHP size seem excessive.

For example, a dairy installed a cogeneration plant at its site. It was determined, based on a survey of the current operations, that the plant should have a capacity of 3.1 MW. It was decided that the plant should employ two 1.6 MW internal combustion reciprocating engines. After construction and startup of the CHP plant, the dairy completed an energy efficiency audit to identify energy efficiency projects and, subsequently, implemented these projects. These projects were so effective in reducing the energy demands of the dairy that it now needs only about half the power it originally needed. Consequently, most of the time, only one of the CHP's engines is in use. As a consequence, the dairy had to devise an alternative CHP deployment strategy for the second engine at the plant. Fortunately, it was able to do so.

## **3. Fine-Tuning the System.**

For a facility to maximize the benefits of its cogeneration plant, the CHP plant must be "tied in" in the correct way to the correct processes. In other words, connections between the CHP plant and the facility must be set up in such a way that the right type of energy, in the right quantity, is delivered to the right place at the right time.

Industrial plants are very dynamic. One change in production, or in one piece of equipment, can have a "ripple effect" that causes changes in electric or thermal energy needs in one or more parts of the plant. When this occurs, many cogeneration plants will continue to operate as they always have, now delivering too much or too little electricity or heat to the part of the plant that has undergone a change in needs. In this way, many CHP plants fail to live up to their potential.



Since industrial facilities are so dynamic, it is important to have a dedicated expert overseeing the cogeneration plant and its performance with respect to the facility (and its changing needs). Contractors that specialize in building and installing cogeneration plants will monitor the performance of the plant they have built and installed, but many will not look at whether or not the plant is tied in to the facility in a way that delivers maximum benefits. Facility owners will certainly want to investigate to ensure this, but may not have the time or the expertise necessary to conduct such investigations successfully, and as often as they must be done to ensure maximum benefits at all times.

## NAVIGATING A “BIG POND” AS A RELATIVELY “SMALL FISH”

Many of the challenges business owners who build, own and operate CHP plants encounter arise from their relative small size and isolation from other cogeneration plant operators. The industrial business that operates its own CHP system providing power to its plant is particularly vulnerable to the following risks:

1. Paying too high a price for the natural gas required to run the CHP plant
2. Inadequate resources to manage the CHP plant as effectively and efficiently as possible
3. Inadequate resources to measure, track, document and report emissions benefits as effectively and efficiently as possible

### **Paying Too Much for Natural Gas**

The success of CHP plants is often determined by “spark spread.” In laymen’s terms, spark spread is the difference between the cost of electricity and the cost of natural gas multiplied by the heat rate.

Natural gas is the single-biggest cost of running a CHP plant. If the owner of a plant is not able to obtain natural gas at the best possible price, that owner will pay too much for the gas, reducing the economic benefits CHP should provide.

An owner of one small plant is sometimes not able to negotiate as competitive a natural gas rate as the owner or manager of a large plant or multiple plants, simply because of the owner’s lack of bargaining power as a user of a relatively small amount of the fuel. Other times, CHP plant owners pay too much for natural gas because they are unfamiliar with the natural gas market.

### **Inadequate Management Resources**

Other barriers to profitable CHP operation by owners of single, small plants are lack of budget for the staff needed to manage the plant effectively and inability to compare operations between plants, in order to discover ways to run their plant more effectively.

Companies that own or manage more than one cogeneration plant are often able to afford one employee who splits his or her time between managing several plants. They are also able to learn lessons from one plant that they can apply at all the plants they own or manage.



Further, owners of cogeneration plants are required to report the plants' emissions to local air quality management boards. This requirement can be cumbersome for small operators, who may not have room in their budgets to dedicate staff to fulfilling it.

### **Inadequate Measurement, Tracking & Documenting Emissions Benefits**

One of the greatest virtues of CHP is the reduction in emissions of greenhouse gases such as CO<sub>2</sub> and pollutants such as NO<sub>x</sub> it offers over traditional separate electricity generation and heat production. In the United States today, the electric power sector produces the largest portion of the country's CO<sub>2</sub> emissions. A 2007 study by McKinsey & Company shows that, under proper market conditions, CHP provides CO<sub>2</sub> reductions at a negative marginal cost for the industrial sector. The study also shows that CHP is more economically advantageous than many other technologies that are considered environmentally friendly (4).

In some parts of the country, rebates and other incentives are available to companies that reduce their CO<sub>2</sub> and/or other emissions. In addition, increasingly, companies have a market advantage when they are able to claim emissions reductions. However, to take advantage of these benefits, the company that implements CHP must measure, track, document and report the reduction in their carbon and other emissions footprint. Many companies that implement CHP do not know how to do this or do not believe they have the time or the resources to do it. However, it is so beneficial that CHP owners cannot afford not to do it.

## **CONCLUSION**

CHP is a very efficient system for producing some or all of the electricity and thermal energy needed by an industrial facility. It offers considerable benefits to the industrial business owner, including the following:

- Provides a cost-effective response to climate change concerns and emissions regulations by providing needed power with greatly reduced CO<sub>2</sub> and other emissions
- Improves financial competitiveness through greater energy efficiency, which saves companies money on energy spending
- Provides increased energy reliability and security, which can save companies money and even shield businesses from the catastrophic effects of events to which business entirely supplied by the grid are vulnerable
- Offers fuel flexibility, which will be increasingly valuable to businesses if energy markets continue, as expected, to be volatile

However, obtaining the full benefits of CHP requires proper management of the cogeneration plant and its interaction with the facility it serves. One of the most important requirements is that the electricity and thermal energy produced by the CHP plant be fully utilized by the facility at all times. For this to occur, there must be understanding and consideration of both the current and future energy needs of the facility before choosing the type and size of CHP plant to build. There must also be expert attention paid to the cogeneration plant and how



well it is fulfilling the changing needs of the facility over the course of both the CHP plant's life and that of the facility. In addition, the cogeneration plant owner must be careful to avoid the obstacles that can come with being a relatively "small fish" in the "big pond" of cogeneration owners and operators.

In spite of these obstacles, the industrial business owner should not be dissuaded from exploring CHP. In today's business environment, with its volatile energy prices and increasing focus on climate change issues, it is clearly one of the most powerful solutions companies have at their disposal. With its ability to reduce energy spending, improve a company's environmental footprint, and make the business more competitive, CHP is indeed more relevant to industrial businesses than ever.

## ABOUT EPS CORP

EPS Corp is a leading energy intelligence company that develops and implements analytic, efficiency, and clean-generation solutions for Fortune 1000 companies. The company's integrated product and services suite is delivered using The EPS Way<sup>®</sup>, an innovative three-step process that maximizes energy and carbon reductions through financially compelling solutions. EPS delivers the right information – at the right time – to enable decisions that improve energy efficiency, reduce costs, and achieve sustainability goals. An Accredited Carbon Calculation Partner with the Carbon Disclosure Project, EPS was founded in 2001 and is headquartered in Costa Mesa, California. Visit [www.epsway.com](http://www.epsway.com) for more information.

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