Power Generation

IMPROVING ENERGY EFFICIENCY WITH CHP: HOW TO EVALUATE POTENTIAL COST SAVINGS

Combined heat and power modules based on natural gas-fueled reciprocating engines promise increased energy efficiency for a wide array of applications.

Combined heat and power (CHP), also known as cogeneration, involves the simultaneous production of heat and electric power from the same source of fuel — usually natural gas. The principle has been put to use for more than 130 years as a way to conserve resources, increase efficiency and save money. While the prime mover used in the production of CHP can be a boiler and a steam turbine or a combustion turbine burning oil or natural gas, lately there has been significant development of compact, cost-effective and efficient natural gas-fueled reciprocating engine-generators that produce both heat and electric power at more than 90 percent efficiency.

Historically, CHP was reserved for very large installations; for example, a coal-fired power plant where the waste heat was used to warm acres of greenhouses or provide heat for large apartment complexes. Today, significantly smaller facilities such as hospitals, hotels, commercial buildings or factories can reap the benefits from CHP — as long there is a simultaneous need for electric power and heating (or cooling) for most of the year. A number of manufacturers provide various CHP options today. For example, MTU offers CHP modules from 120 kW to 2,150 kW electrical, and from 730,000 Btu/Hr to 7,790,000 Btu/Hr thermal (units can be paralleled in order to meet higher heat and power demands). In addition to reducing energy costs, CHP's doubling of overall energy efficiency cuts a facility's carbon dioxide emissions in half and conserves energy

Energy Efficiency Comparison

resources. These outcomes, of course, contribute to sustainability and may help earn points for facilities seeking LEED (Leadership in Energy and Environmental Design) certification.

This paper will explore the rationale for and viability of using a natural gas reciprocating engine-driven CHP module for producing on-site electricity and heating/cooling for today's commercial and industrial facilities.

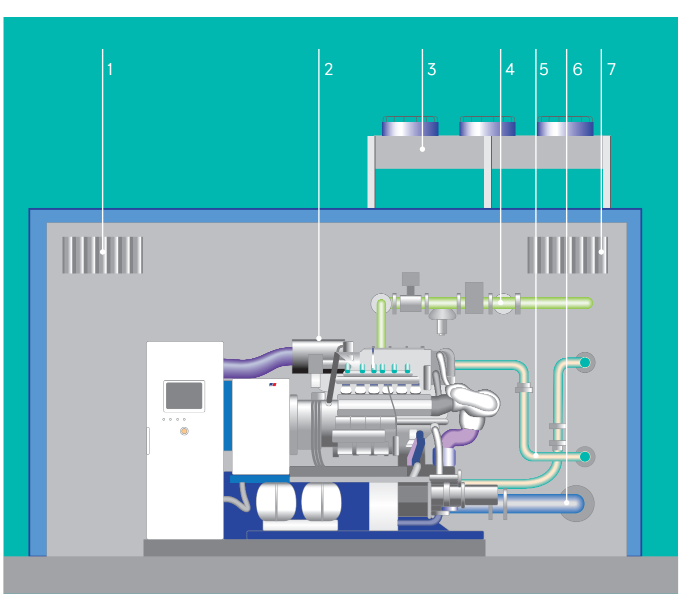
How CHP works

In a conventional facility, all electrical power is supplied by a local utility. If heat is needed, the facility would have a gas-fired boiler to supply hot water for space heating or process heat. Additionally, the facility would have separate water heaters running on natural gas or electricity for domestic hot water. In contrast, a facility with a properly sized CHP module running on natural gas would supply most of the electrical and heating loads, cutting energy usage — and expenditures — nearly in half.

A typical CHP module consists of a natural gas-fueled reciprocating engine, a generator/alternator, and a full heat recovery system integrated into the base frame of the module. Using a 12-cylinder 23-liter natural gas engine, for example, the engine-generator combination would produce 358 kW of electrical energy, and 1,791,000 BTU/Hr of thermal energy in the form of 194 degrees Fahrenheit hot water. The heat is recovered from a low-temperature coolant circuit and a high-temperature exhaust circuit. The low temperature coolant circuit recovers about 807,000 BTU/Hr from the engine jacket water, intercooler and lubricating oil. The high-temperature circuit recovers heat from the engine exhaust, which has a higher specific heat content. Up to 914,000 Btu/Hr can be recovered from 1,000-degree Fahrenheit exhaust gases. All told, this example CHP unit would produce 1,791,000 Btu/Hr of heat and 358 kW of electricity at an overall energy efficiency of 90 percent.

The electricity would be used to supply some or most of a facility's power needs, and the heat output could be used for space heating, heating domestic hot water or heating water for industrial processes. The heat output from the CHP unit can also be used for air conditioning by employing an absorption chiller. For example, a large hospital could use the CHP unit to provide much of its electricity and use the heat output for space heating/cooling and making hot water for laundry and domestic use. A large hotel may have similar needs in addition to heating a swimming pool.

Buying electricity from the local utility is convenient, but it is far from an efficient use of energy. Up to 70 percent of the energy used to generate and transport the electricity to the end user is lost as waste heat or through electrical losses from transmission lines and transformers. This also means that far more coal, oil, natural gas and



1 Generator air supply
2 Combustion air supply
3 Dump cooler
4 Fuel line
5 Heating connection to building
6 Generator exhaust
7 Exhaust air

nuclear fuel are used to generate electricity in central power stations than with an equivalent amount of natural gas running an onsite generating facility that recovers and uses the waste heat. And, although utility companies make every effort to maximize power generation and transmission efficiency, the laws of physics have proven to be an inflexible barrier to further improvements.

Generating hot water and/or steam onsite in a conventional boiler may typically be in the range of 75-80 percent efficient. But if one considers the purchase of both the fuel to run the boiler and the electricity to run the facility, the overall energy efficiency of the facility is in the neighborhood of 50 percent at best. The advantage offered by a CHP module is based on its ability to get both electric energy and heat energy from the same fuel, thereby nearly doubling overall efficiency.

Essential factors

To assess the economic viability of cogeneration for a specific facility, it is necessary to first analyze two basic factors: 1) the simultaneous need for heat and power; and 2) the local costs for utility power and natural gas.

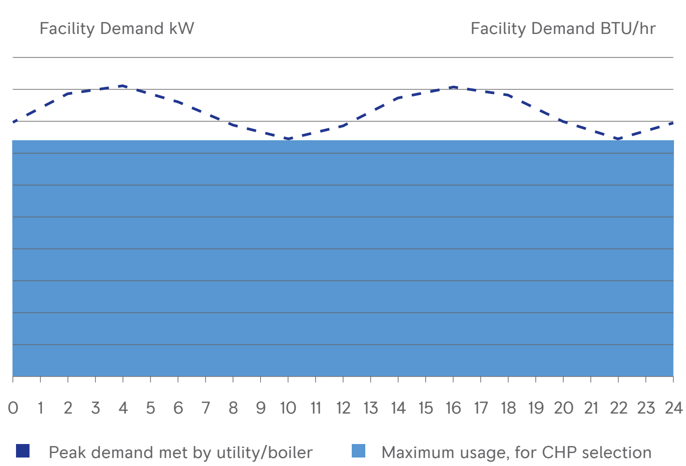
1. Heat and power needs

In order for CHP to make economic sense, a facility must have a simultaneous need for electricity and thermal energy (for heating and/or cooling) on a nearly year-round basis. The more hours per year that there is a demand for both forms of energy, the quicker the payback on the CHP system will be. In certain geographical locations, the thermal energy need will include a winter space-heating load balanced by a summer space-cooling load (met through the use of an absorption chiller).

To quantify the facility's heat and power requirements, start with the peak kW demand and total kWh usage on an annual basis. However, an annual load curve showing month-to-month demand shifts and minimum loads will be important when it comes to sizing the CHP unit.

Similarly, determine the peak Btu/Hr demand of the heating load and annual consumption, again including minimums. The final aspects of heat and power requirements are details regarding the needed hot water and steam temperatures and volume demands.

CHP plant sizing for demand



2. Local costs

Whether a CHP module will result in significant savings over time is a function of the local cost of electricity and natural gas. Start by calculating total electric costs from the local utility that include demand charges (kW) and energy charges (kWh). Also, determine if the utility will buy back excess electricity, and at what rate. While power buy-back rates are notoriously low in the United States, such power sales back to the utility (when available) can help boost system payback.

The price of natural gas and the price of electricity will determine what is known as the spark spread; that is, the amount of gross margin realized by purchasing a unit of natural gas in order to produce a unit of electricity. The higher the price of local electricity and the lower the price of natural gas, the larger the spark spread—and the greater the potential economic benefit from cogeneration.

Sizing the CHP module for maximum usage

It's important to size the CHP module appropriately for the application in order to maximize its final economic performance. In general, the CHP module should be sized to operate at full capacity for as many hours as possible on an annual basis. This means that if the facility has an electrical load curve that varies from one season to the next, the CHP module should be sized to accommodate the period of minimum kW demand, rather than the annual peak demand. This means the facility will require an electrical connection to the local utility in order to meet the annual peak kW demand and to supply power during times when the CHP module is offline for oil changes and other normal maintenance.

Similarly, the heat output of the CHP module should be sized to meet the lowest heat Btu/Hr heat demand on an annual basis so that it can run as many hours as possible at full capacity. This means that the conventional on-site boiler will also have to be operated at times to meet peak heat demand or to supply heat/cooling when the CHP module is offline for maintenance.

If the CHP module is sized too large for either the electrical load or the heating/cooling load, there will be a loss of efficiency during those times when either load drops below the capacity of the CHP module. If an excess of electricity generated, the facility owner may or may not be able to sell it back to the utility at a high enough rate to justify the fuel costs. Likewise, excess heat would need to be rejected in a remote radiator or allowed to exit the exhaust, also decreasing efficiency.

Calculating payback

Once armed with usage and cost information, the facility owner can take advantage of computerized payback calculators offered by CHP module manufacturers. These tools combine facility-specific data with CHP module recommendations to calculate the time period required for the facility to earn back its system investment in operating cost savings.

For many facilities, the payback associated with a CHP system occurs quickly. Here is a specific example, optimized so that the CHP module supplies most of the electrical demand and most of the heating/cooling demand of the facility.

The COSTS AND SAVINGS table lists the cost of the CHP module and average annual operating costs including fuel and maintenance. It also lists annual savings in gas and electricity by avoiding purchasing electricity from the utility and burning gas in a boiler, showing an annual positive cash flow that averages more than $190,000.

The PROJECT FINANCIAL OVERVIEW shows the cumulative cash flow that could be expected and indicates a break-even point early in year three. Thereafter, savings continue to accumulate. After 10 years, the total accumulated savings are in excess of $1.9 million.

Price of electricity and gas, annual operating hours and existing boiler efficiency

Price of electricity	0.10 $/kWh
Price of natural gas	$6.00/mmBtu
Annual CHP operational hours	8000
Existing boiler efficiency	80%

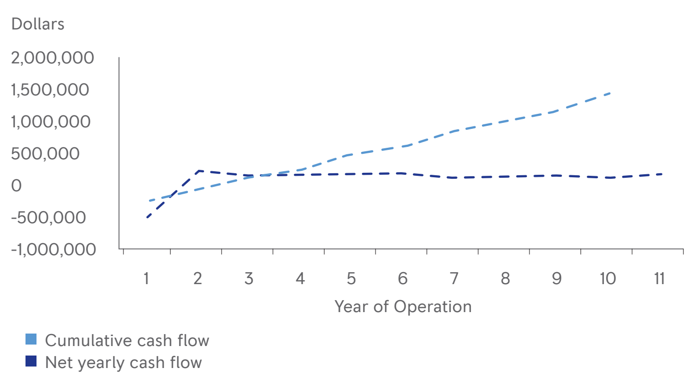
Electrical and thermal output of the CHP module, electrical and thermal demand of the facility

Electrical output of the CHP module	358 kW
Thermal output of the CHP module	1,771,000 Btu/hr
Electrical load of the facility	358 kW
Thermal load of the facility	1,771,000 Btu/hr

Costs and savings

Total installed cost of CHP module	$450,000
Annual fuel cost	$183,640
Annual maintenance	$45,941
Annual savings in electricity costs	$277,808
Annual savings in gas costs	$116,351
Annual positive cash flow	$190,965

Project financial overview



Suitable applications

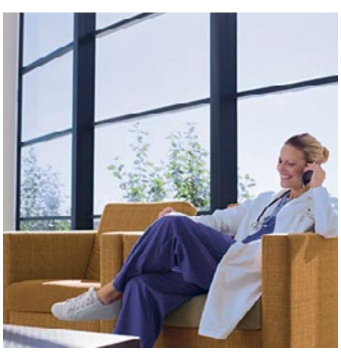
Facility types in which CHP systems are likely to be viable in terms of both need and economics include the following:

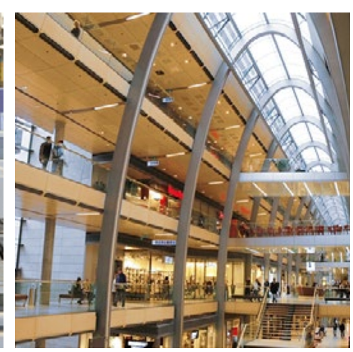
- **Hospitals**
  Large hospitals and medical centers need electricity and hot water for laundry, domestic hot water and space heating/cooling.
- **Corporate campuses**
  A large corporate headquarters could use a CHP module to produce electricity and heat for space heating/cooling.
- **University campuses**
  With many of these facilities already set up for district heating and cooling, a CHP module is a natural fit for this application.
- **Wastewater treatment plant**
  A CHP module can be used to produce the electricity needed to operate pumps and blowers, while the waste heat from the engine can be used to warm effluent tanks to speed up bacterial digestion or to dry sludge for disposal.
- **Industrial facilities**
  Facilities with simultaneous needs for power and heat/cooling include manufacturing, food processing and canning/bottling plants, ethanol plants, and pulp & paper plants.
- **Commercial facilities**
  Large resorts, hotel complexes, sports clubs, health clubs, shopping malls and greenhouses can all benefit from CHP modules.

Conclusion

Combined heat and power systems are not new, but recent reciprocating-engine CHP modules have made it possible for many more facility types to reap the economic and environmental benefits of the technology. Today's range of CHP modules can increase a facility's energy efficiency, reduce environmental impact and contribute to corporate sustainability efforts.

Determining whether CHP will be a cost-effective source of power and heating/cooling for a specific facility requires careful data gathering and computer-based analysis. CHP module manufacturers can be very helpful in this process, using sophisticated tools to calculate the payback period for various system approaches. For many facilities, this analysis will reveal whether there is sufficient payback potential—not to mention environmental rationale—to justify installing a CHP system.



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