

New Natural Gas Technologies for Enhancing the Indoor Environment

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ABSTRACT

For decades, natural gas has been used largely as a heating fuel for commercial buildings. Today's technologies provide an opportunity for natural gas to provide far more to your commercial clients by providing an enhanced indoor environment at reduced costs and with less environmental impact than conventional electric systems.

THE ENVIRONMENT

Natural gas is the cleanest burning of the fossil fuels, and using natural gas in place of electricity benefits the environment. In large part, producing electricity requires burning coal, oil, or natural gas, yet 60-70% of the energy is wasted, either at the power plant or during electric transmission. Using natural gas directly to meet the heating, cooling and humidity requirements of commercial buildings can reduce overall fossil fuel consumption. In addition, central power plants use large quantities of water. Using natural gas can also reduce the consumption of this essential resource.

THE ELECTRIC GRID AND THE COOLING LOAD

In almost all areas of the United States, the demand for electricity peaks in summer months (NERC 2005), pushing power generating

capacity and the electric transmission system to their limits. As deregulated pricing has moved into many areas, the price of electricity becomes most volatile in the summer.

Even more troubling, there are very few incentives at present to make the transmission investments needed to handle these large peak summer electric loads. Current estimates have suggested that adequately updating the transmission system to handle the power from a new power plant can be as expensive as the power plant itself. Undertaking this investment to handle loads that occur only part of the year has not proved to be an attractive investment, as suggested in Figure 1. The net result has been deferring the needed transmission expansion and reinforcement.

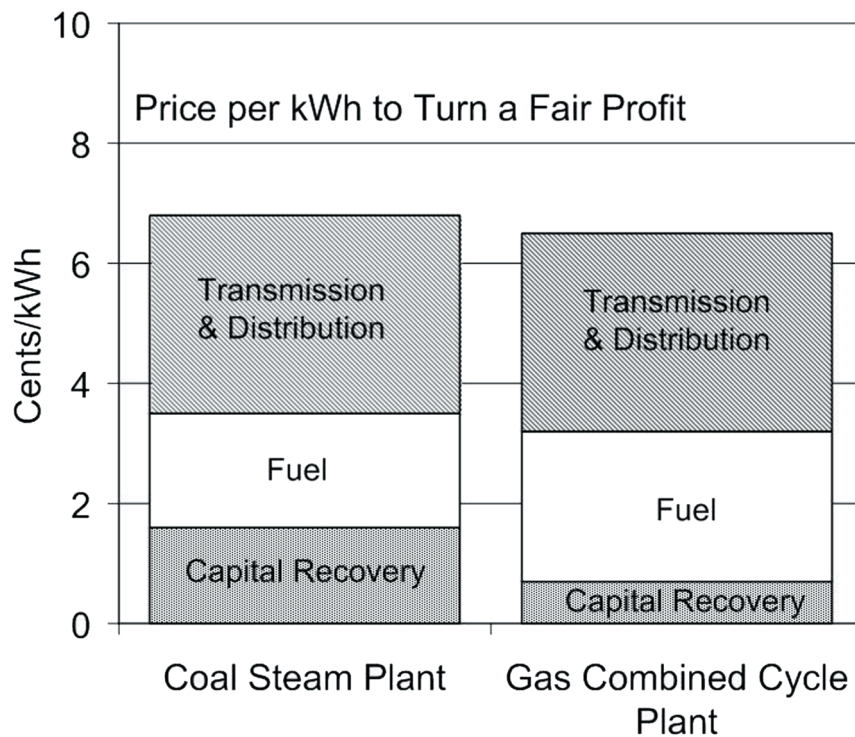


Figure 1. Estimated Total Cost of Electricity from Central Power Generation Delivered to the Customer

At present, electricity is being sold at lower prices by deferring needed transmission and distribution investment. This figure does not include the effects of recent increases in natural gas and coal costs. (Data from Casten 2001, 2002)

The east coast blackout in August 2003 has been tied to the lack of electric transmission investment. Quoting from the final report of the joint U.S./Canadian task force that studied the blackout; "Over the past decade or more, electricity demand has increased and the North American interconnections have become more densely woven and heavily loaded, over more hours of the day and year. In many geographic areas, the number of single or multiple contingencies that could create serious problems has increased. Operating the grids at higher loads means greater stress on equipment and a smaller range of options and a shorter period of time for dealing with unexpected problems." (DOE 2004) The report then tied in the needs for system expansion, improved operator training, and more capable safety controls, all of which will tend to increase the cost of electric transmission.

On the generation side, the availability of electric generating plants to service the summer electric peaks is declining (NERC 2005) as shown in Figure 2. Because the generation of electricity has been extensively deregulated, constructing new generating plants is an investment that must compete for capital with all other non-regulated industries. Since 2002, building new generating plants has not appeared to have been an attractive investment. Current fuel price uncertainties may tend to exacerbate the situation in the near future.

Conversely, in summer months, the natural gas distribution system

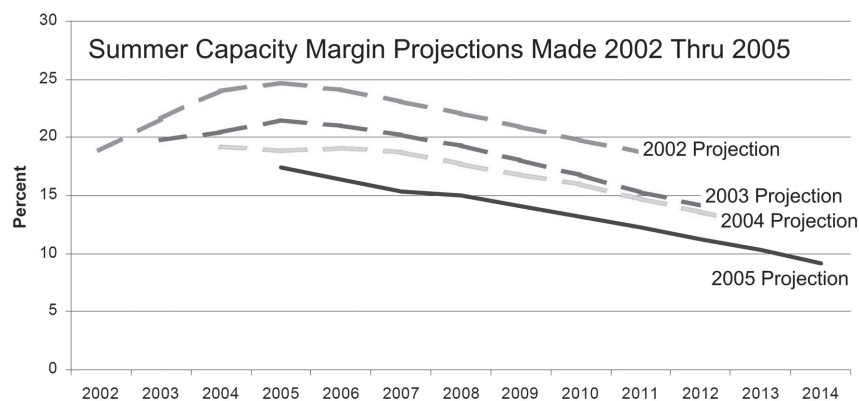


Figure 2. NERC Long-term Summer Reserve Projections from 2002 to 2005

The outlook for summer generating capacity reserves is not only declining but each year the long term projections worsen

is underutilized. As electric supply has deregulated and many areas of the country are faced with volatile open market rates for bulk electricity, using natural gas to drive central cooling equipment has become a viable and reliable option. Many commercial buildings have found that depending on natural gas chillers or a mix of natural gas and electric chillers is a good way to handle uncertainties about future summer electric prices.

GAS PRICES

As of December 2005, at the beginning of an early winter and immediately after the damaging hurricanes in the gulf, current gas prices are high by historical standards. Damage to gas production in the Gulf of Mexico is still being repaired and spot gas prices are quite volatile.

Quoting from (EIA 2005A); "The supply of natural gas has been disrupted because of hurricane damage to production platforms, sub-sea pipelines, and natural gas processing plants. We now expect shut-in Federal Gulf of Mexico natural gas production to fall to 0.66 billion cubic feet (BCF) per day (6.5 percent of pre-hurricane Gulf production) by March 2006."

Since "shut-in" production is gas production capacity that is not currently operating either because of damage at the well or in the collecting field. The steady reduction in shut-in capacity, as shown in Figure 3, means that the overall gas supply system is being repaired.

Once this period of repair is complete, there is every reason to believe that natural gas should fall to prices that are more in line with those seen in past years.

NATURAL GAS COOLING TECHNOLOGIES

When considering any new cooling system, efficiency is important. Readily available natural gas cooling equipment offers efficiency and durability.

Engine-driven Chillers

Engine-driven chillers are very similar to electric chillers. A natural gas, long life engine replaces the electric motor in a chiller, as shown in

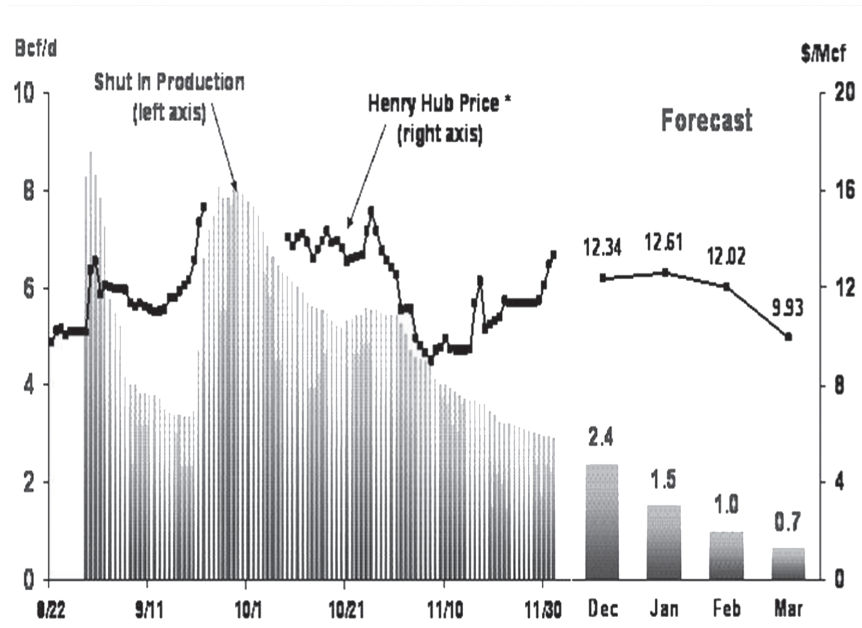


Figure 3. Shut In (Unavailable) Gas Production Capacity, Fall 2005
In Billion Cubic Feet per Day — (EIA 2005B)

Figure 4 and Figure 5. Gas-engine-driven systems offer a coefficient of performance (COP) as high as two. These systems follow the cooling load by operating at the variable speeds possible with an engine. This provides significantly enhanced efficiency at the low load conditions that dominate the cooling operating hours in most central plants. Conversely, variable speed operation is a very expensive option with electric chillers.

Electric chillers have higher efficiency, but in much of the country the price of electricity is more than 3 times higher than the price of gas, on a per unit of energy basis, making the gas chillers less expensive to operate.

Gas chillers are often mixed into central plants with electric chillers allowing the customer to choose between energy sources, depending on current market conditions. These “hybrid” cooling plants also provide customers with greater flexibility when negotiating for an electric supply contract, and allow the customer to retain chiller capacity during a power failure without having to add additional emergency generators to cover electric chiller loads.

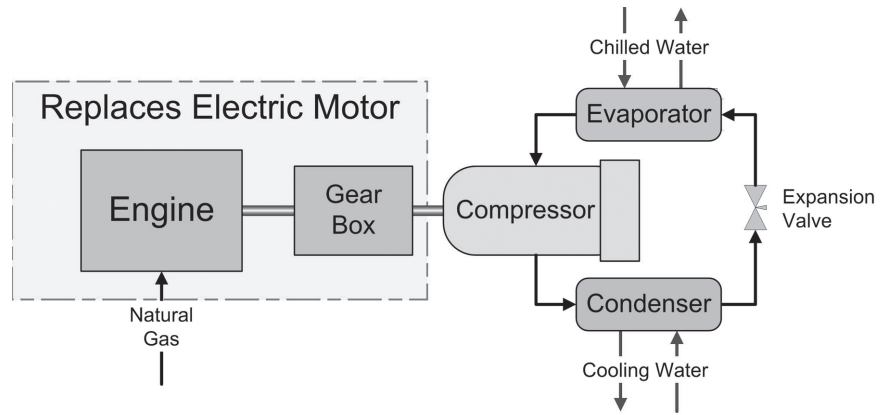


Figure 4. Basic Layout of an Engine Chiller

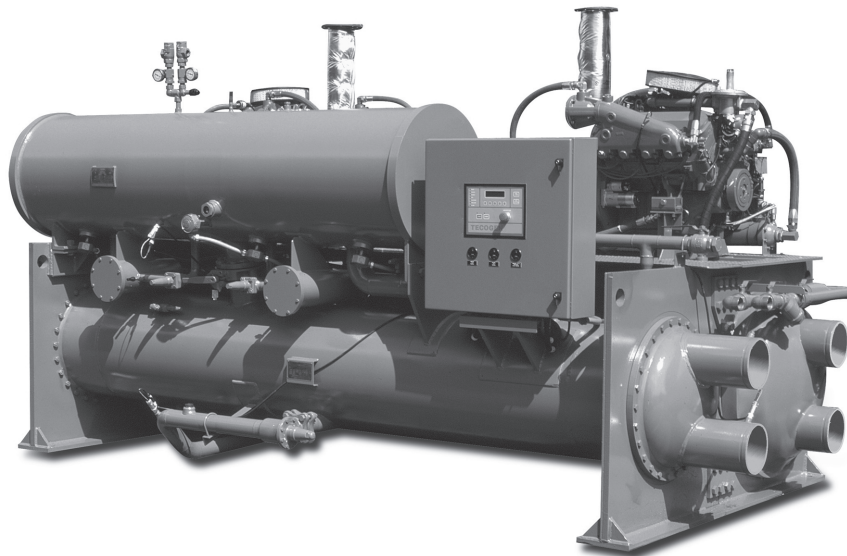


Figure 5. Packaged Engine Chiller Ready for Installation

(Photo Courtesy of Tecogen)

An exciting high efficiency option with engine-driven chillers is recovering the high-grade heat from the engine, as shown in Figure 6. For each ton of cooling delivered, as much as 2,000 to 3,000 Btu/hr of hot water is available at temperatures of up to 205°F. This hot water can be used for space heating, domestic water heating, space cooling,

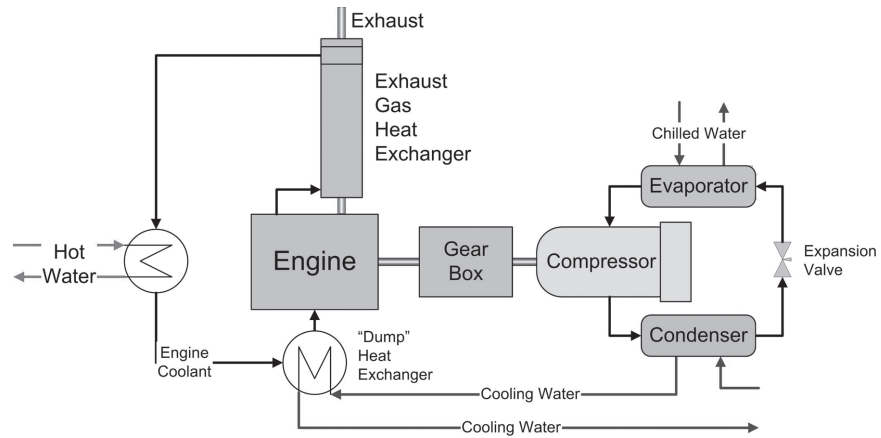


Figure 6. An Engine Chiller with Heat Recovery

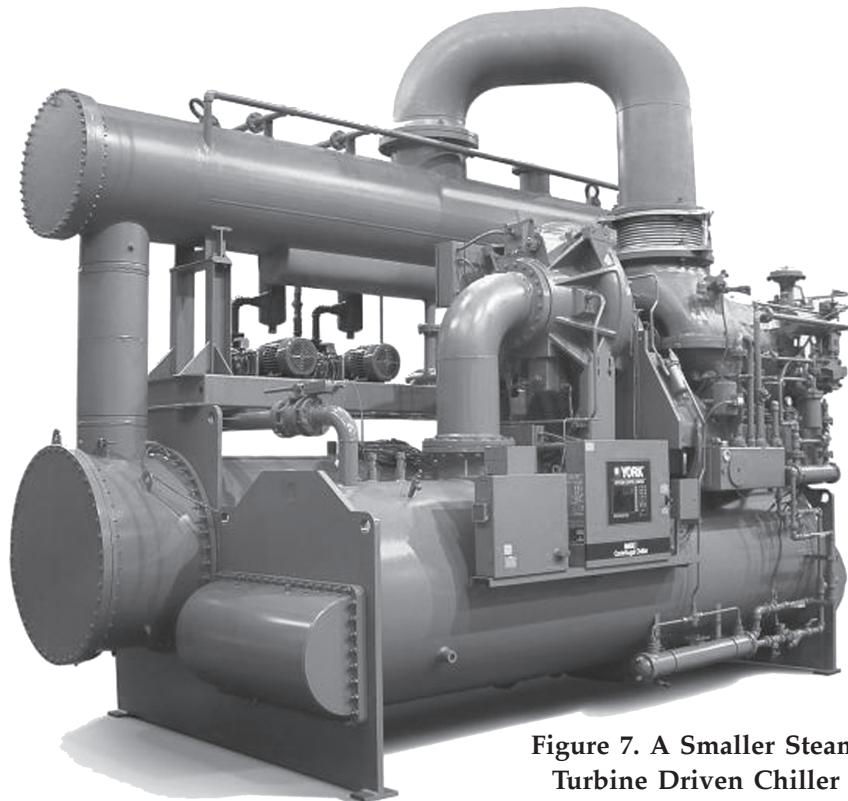


Figure 7. A Smaller Steam Turbine Driven Chiller
(Photo Courtesy of York JCI)

or pool heating. This waste heat can also be used for operating reheat or desiccant systems for humidity control.

Steam-turbine-driven Chillers

For larger commercial and industrial customers, driving conventional chillers with steam turbines rather than with electric motors can be an attractive option. Steam-turbine-driven chillers are efficient, and avoid electric demand charges.

These chillers are available to sizes as high as 5,000 tons, provide variable speed operation and can use steam from any boiler using fuels as diverse as industrial waste and coal to natural gas. Smaller steam turbine driven chillers, as shown in Figure 7, often use steam from municipal heating systems that are also lightly loaded in the summer.

Absorption Chillers

Absorption chillers, as shown in Figure 8 and 9, are another option for gas cooling. Absorption chillers are driven by heat and can be fired either directly by a gas burner or by steam or hot water from a boiler or some source of recovered heat such as a engine-driven generator or an engine chiller. Absorption chillers produce chilled water and are used in the same manner as electric chillers.

Absorption chillers are also available equipped to be directly fired by a gas burner. Direct fired absorbers are configured as chiller/heaters, producing chilled water during the cooling season and then, using the heat from the gas burner, producing hot water for heating during the heating season. This allows the chiller to replace a boiler, saving first cost and floor space. Although not as efficient as engine chillers, absorption chillers require less maintenance and have a long history in the HVAC industry. Both domestic and overseas suppliers of absorption chillers produce modern machines that have overcome issues such as crystallization and feature completely new automated controls systems.

ENHANCED COMMERCIAL HEATING

New space and water heating options are also available to increase the efficiency of already highly efficient gas heating.

These include higher efficiency condensing boilers, as shown in Figure 10, for commercial buildings with hydronic heat and higher

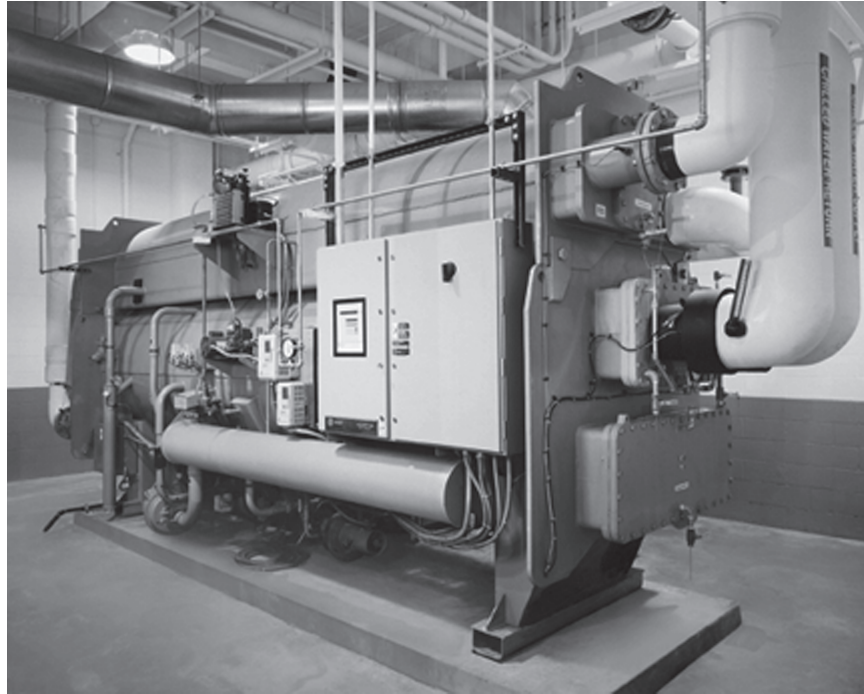


Figure 8. Absorption Chiller
(Photo Courtesy of The Trane Co.)

efficiency direct contact water heaters, as shown in Figure 11, for commercial applications with large hot water loads such as laundries and food preparation.

ENHANCED DEHUMIDIFICATION

Desiccant Dehumidification Systems

Desiccant dehumidification systems are widely used in industrial applications to provide carefully controlled dehumidification in process applications. In more recent years, these systems have been moving into dehumidifying outdoor fresh air that is being supplied to commercial buildings. By reducing the moisture content of outdoor air, indoor humidity can be kept under better control than is possible with conventional air conditioning systems alone, particularly in hu-



Figure 9. Hot-Water-Driven Absorption Chiller
(Photo Courtesy of Thermax)

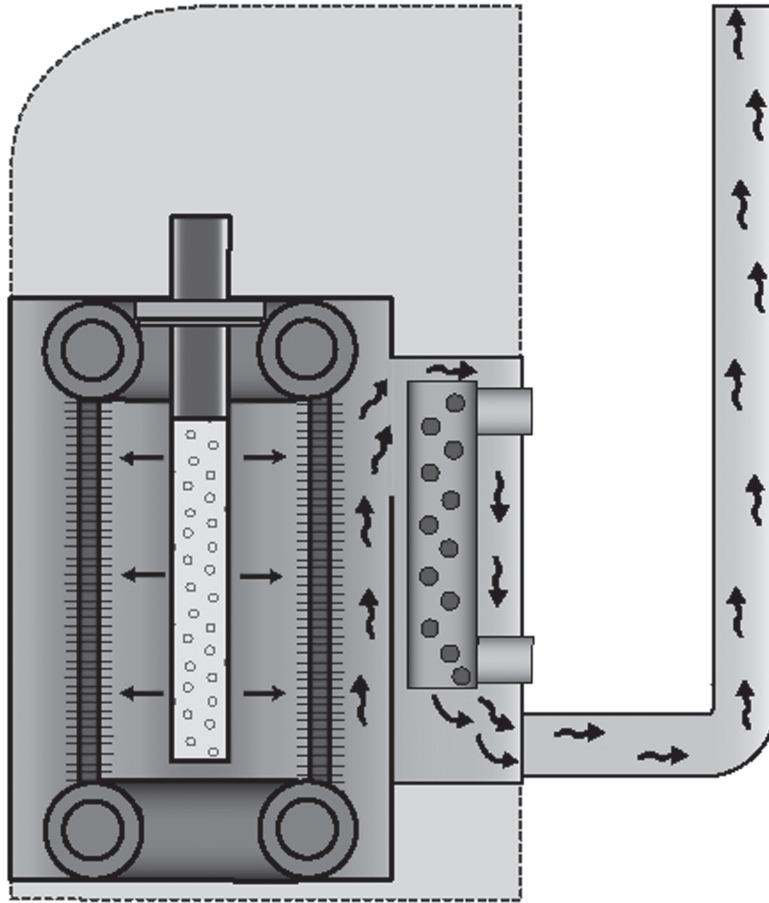


Figure 10. Condensing Boiler

The standard heat exchanger in this copper boiler is augmented by a stainless steel condensing coil (shown on the right). (Drawing Courtesy of Lochinvar)

mid climates. By reducing the humidity, cooling tonnage capacity can be reduced, providing additional first cost cooling equipment savings, reduced electric peak demand and operating costs. Better humidity control can improve indoor air quality by controlling mold and mildew in building materials.

A typical system, shown in Figure 12, consists of a wheel impregnated with a water-absorbing chemical that pulls moisture out of a passing air stream. A small section of this rotating wheel is constantly

Direct Contact Gas Fired Water Heater

1-25 MMBtu/Hr

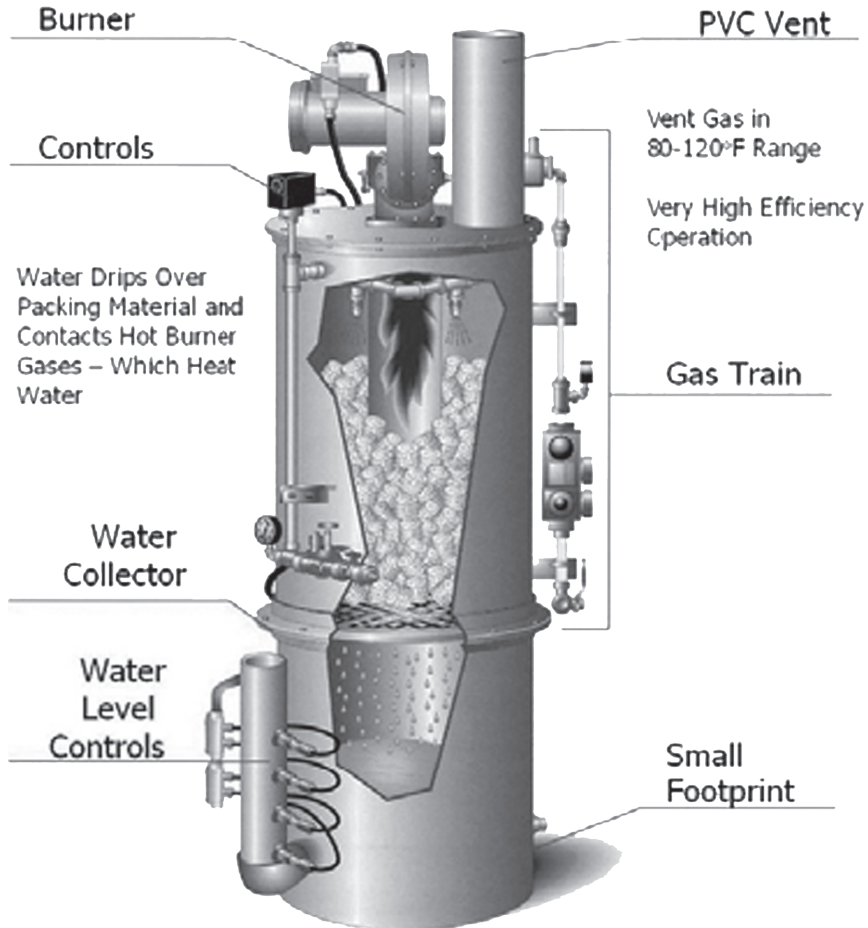


Figure 11. High Efficiency Direct Contact Water Heater

Natural gas combustion produces such clean exhaust gases that they can be put into direct contact with domestic water to produce a very highly efficient and compact high capacity water heater. (Drawing Courtesy of Armstrong)

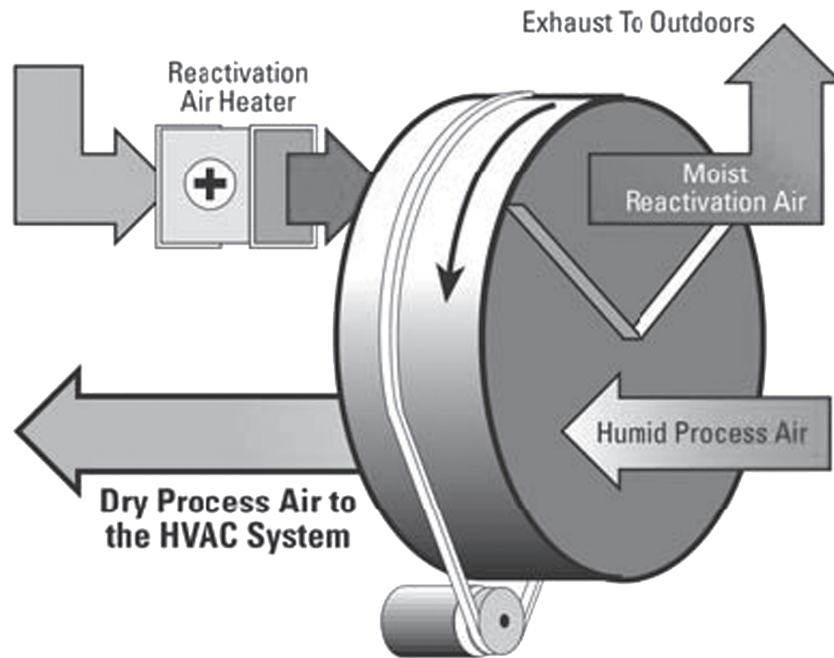


Figure 12. Desiccant Dehumidification

(Figure Courtesy of Munters)

dried (reactivated) by a hot air stream. Heat for the reactivation air can be from burning natural gas or from some waste heat source like an on-site generator or engine chiller.

Using Waste Heat for Better Humidity Control

Another approach to enhancing dehumidification is made practical by the use of engine-driven chillers. Designers have known for years that reheat systems can provide perfectly controlled dehumidification. For this reason, the system is commonly used in such critical applications as hospitals.

However, reheat systems consume a large amount of heat in the cooling season and extend chiller operating time. For these reasons, many state energy codes no longer allow this system in non-critical applications unless the heat is provided from a waste heat source. Engine chillers can work well with reheat systems, illustrated in Figure 13, because the engine produces recoverable “waste” heat throughout the cooling season.

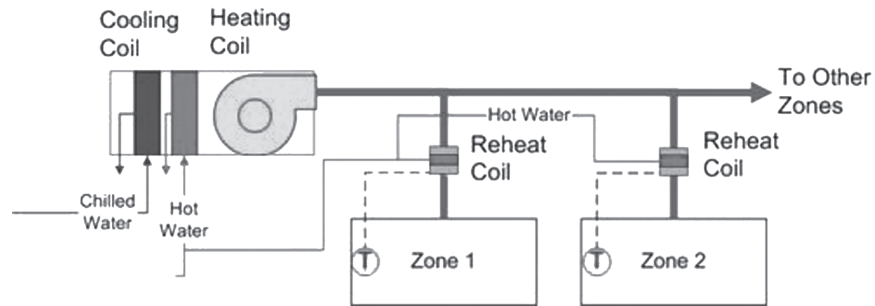


Figure 13. Reheat System Layout

Reheat systems provide enhanced dehumidification by allowing the cooling coil to overcool the air, increasing the amount of dehumidification that occurs, and then reheat this air to prevent overcooling of occupied spaces.

ENHANCED HUMIDIFICATION

In desert climates or in cold climates during the heating season, the lack of indoor air humidity can also be a major indoor air quality concern. Overly dry air can lead to health problems and spread viral infections, as well as damage furnishing. To overcome this, water vapor must be injected into the building. In some situations, using an existing steam boiler may be the most practical approach. However, most commercial buildings are no longer heated by steam. Using a small prepackaged humidifier, as shown in Figure 14, is the most practical approach. These units are a small gas-fired steam boiler that delivers humidity into one or more major air ducts somewhere in the HVAC system. Using natural gas to fire the humidifier keeps operating costs low.

DISTRIBUTED GENERATION

Distributed generation (DG) covers all types of on-site generation of electricity, as shown in Figure 15. Once largely comprised of emergency engine-driven generators, DG now is commonly used for load leveling systems, for limited electric generation during high cost periods, for continuous power and for combined heat and power systems.

Simple engine-driven distributed generation systems are often installed as engine generator outdoor packages. New smaller packages are generally run directly on the local low-pressure gas distribution system,



Figure 14. Gas-Fired Humidifier
(Photo Courtesy of Carel Co.)

avoiding the need for on-site fuel storage. Once only used for critical loads like police communication facilities, these packaged systems are now being used to backup traffic and train signals, radio and television stations, branch banks and office computers, and refrigeration equipment in food processing and food storage or medical testing facilities.

COMBINED HEAT AND POWER

Combined heat and power (CHP) systems, as illustrated in Figure 16, use an on-site electric generator to provide heat and power simultaneously and at very high efficiency. CHP can provide electric power to a commercial building, heat the building in the winter and cool the building in the summer by using the heat rejected from the generator. Additional systems are shown in Figures 17, 18, and 19.



Figure 15. Power Generation Installation

(Photo Courtesy of Tecogen)

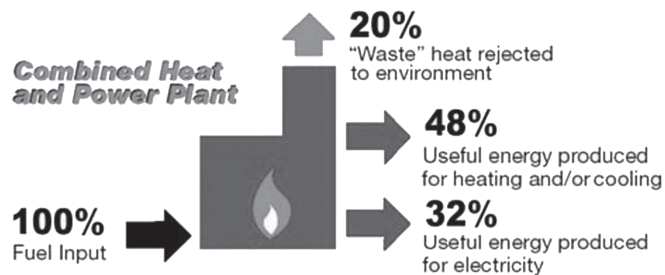


Figure 16. CHP Systems Generate Electricity and Heat at the Customers Building at Overall Efficiencies of Up to 80%. (Drawing courtesy of DOE)

Two-thirds of all the fuel used to make electricity in the U.S. is generally wasted by venting unused thermal energy (from power generation equipment) into the air or discharging into water streams. While there have been impressive energy efficiency gains in other sectors of the economy, the average efficiency of power generation within the U.S. has remained around 32-35% since 1960.

CHP systems significantly increase the total system efficiency of

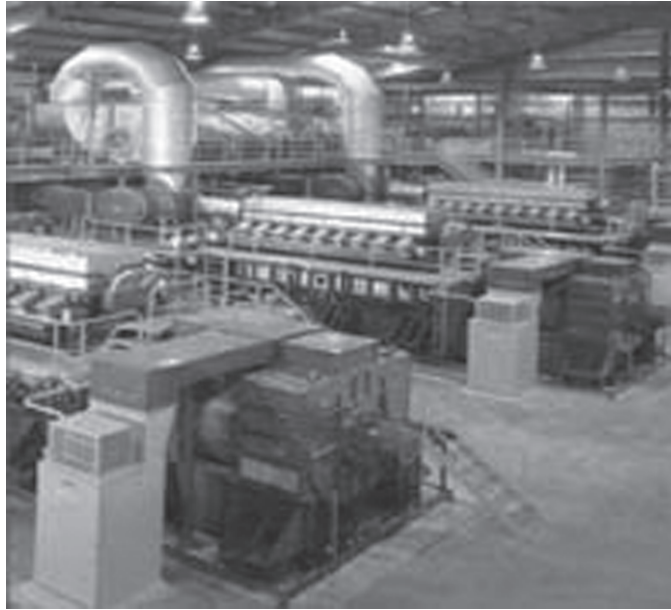


Figure 17. Example of a Large CHP Plant

Engines generate electricity and provide recoverable heat for greenhouses. (Photographs Courtesy of Wartsila Engines)

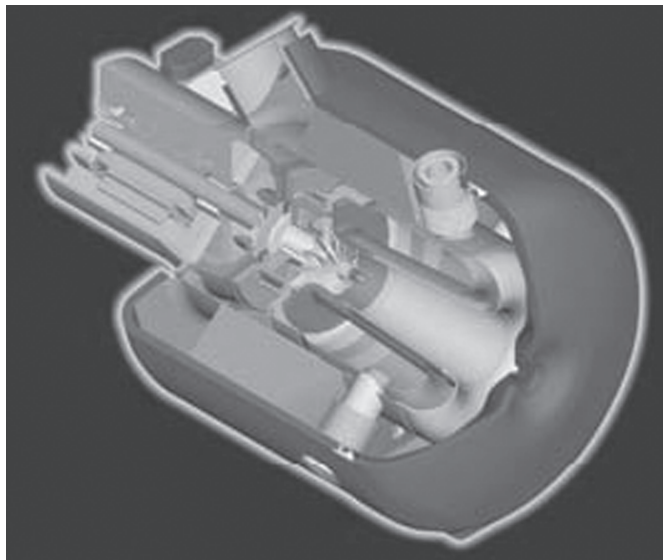


Figure 18. Microturbine Package and Cutaway of a Microturbine
Small low maintenance generator available for systems down to 30 kW. (Courtesy of Capstone Turbine)

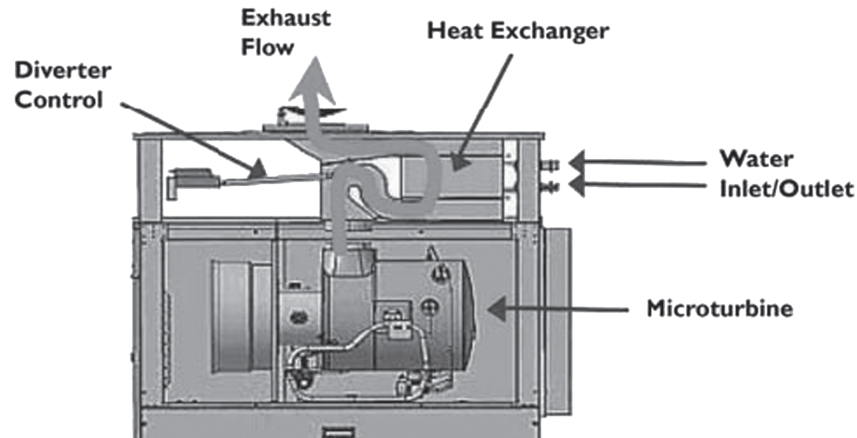


Figure 19. Microturbine Package Incorporating a Heat Recovery Heat Exchanger

Factory installation of a hot water heat recovery boiler in the microturbine package makes small CHP applications more affordable. (Courtesy of Capstone Turbine)

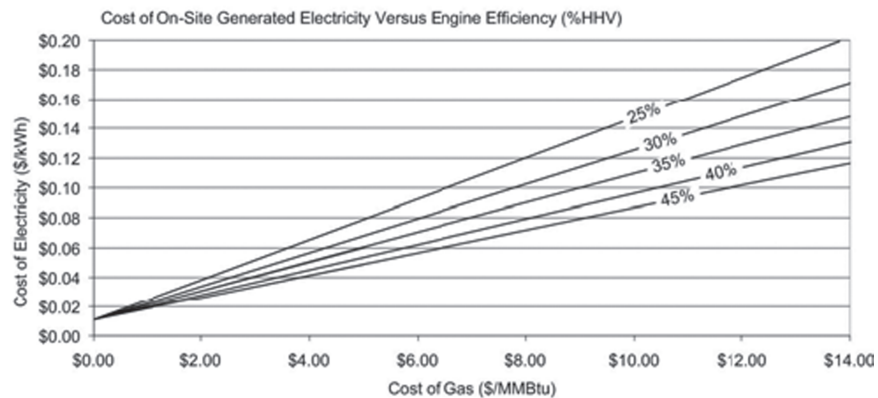


Figure 20. Cost of Generating Electricity at Differing Gas Prices with No Heat Recovery

This chart can be used to control generator operation because both gas and electric prices vary. Lines are for differing engine efficiency. A standard engine maintenance allocation is included in the cost of electricity.

energy utilization, up to 80% or more, by using the thermal energy normally rejected from power generation equipment for cooling, dehumidification, space and water heating, and industrial process heating loads.

By productively using the wasted heat from electric generation, the overall efficiency of energy delivery to the customer can significantly improve. A look at the economics of these systems is shown in Figure 20 (without heat recovery) and Figure 21 (with heat recovery). However, transporting this heat for long distances is expensive. One solution is to move the generator nearer to the customer by placing the generator "on-site."

The cost advantage of CHP is that the wasted heat is recovered for other uses instead of being rejected into the environment. If the generator is recovering heat for some heating load that would otherwise need to be heated by a gas boiler, then natural gas consumption for heating the facility will be lessened. One convenient way to view this is to subtract the fuel no longer needed by the boiler from the larger quantity of fuel used by the generator. The remainder is the amount of fuel being

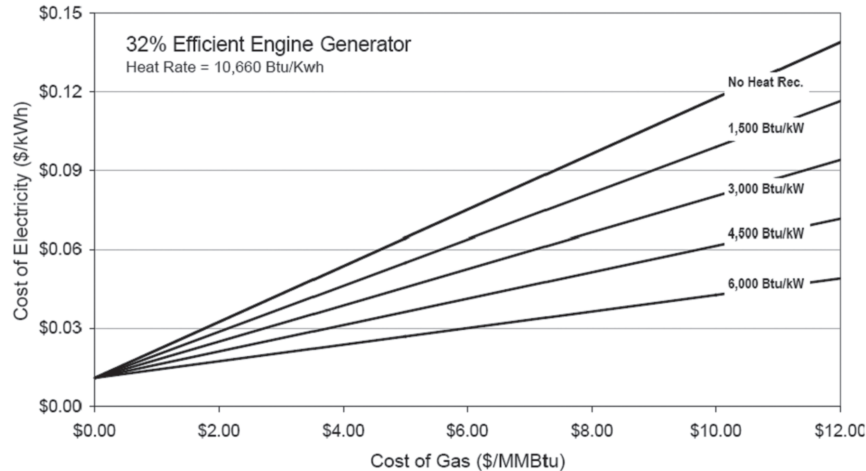


Figure 21. Net Cost of Generating Electricity at Differing Gas Prices with Heat Recovery

The net cost of electricity generated at differing gas prices after crediting for the boiler fuel gas saved by recovering heat from the generator. This graph is for a generator with a 32% electric generating efficiency (based on the higher-heating value of the fuel).

used to provide electricity. The more heat recovered productively, the less fuel used strictly for electric generation. The cost of this electric generating fuel is the “net” cost for electricity generated.

CHP AND THE COOLING LOAD

With conventional air conditioning in the summer, an on-site generator must provide even more power during a time of the year when there is little or no heating load.

For this reason, CHP operators often use absorption chillers to provide a portion of their cooling needs. Single effect absorption chillers can best utilize the low temperature heat rejected by the generator to produce cooling.

Figure 22 shows a simple, CHP/cooling system. Figure 23 shows how much cooling can be developed with the rejected heat by an engine generator. Figure 24 and Figure 25 show examples of CHP cooling systems.

In larger CHP applications, gas turbines are often used instead of engines. The hot exhaust from a gas turbine can generate steam at 125 psi or higher. For systems this large, the potential cooling output is often in excess of 1000 tons. For such applications, a steam-turbine-driven chiller is often used.

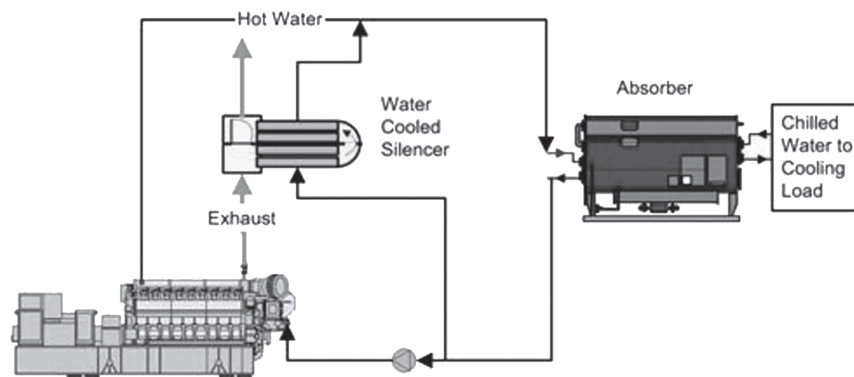


Figure 22. Engine Generator Rejecting Jacket Water and Exhaust Heat to a Single Effect Absorption Chiller

		Heat Production, Btu/kWh	Absorber COP	Cooling Available, tons/kW Gen.	Percent Cost Above Electric (At 500 tons)
Low Temp. System	Min.	3,800	Single Effect 0.7	0.22	25%
	Max.	6,000	Single Effect 0.7	0.35	
High Temp. System	Min.	1,500	Double Effect 1.2	0.15	100%
	Max.	2,000	Double Effect 1.2	0.2	

Figure 23. Matching Engines and Absorbers

Engine generators are a better match with single-effect absorption chillers. Single-effect chillers need only low temperature heat, can utilize more of the engine's heat, and produce more cooling per kW of generator capacity at a lower first cost.

CONCLUSIONS

New equipment allows today's building designers to take different approaches to providing indoor comfort in ways that minimize the effect on the environment and on energy consumption.

FOR MORE INFORMATION

www.energysolutionscenter.org
www.gasairconditioning.org
www.cleanboiler.org
www.poweronsite.org

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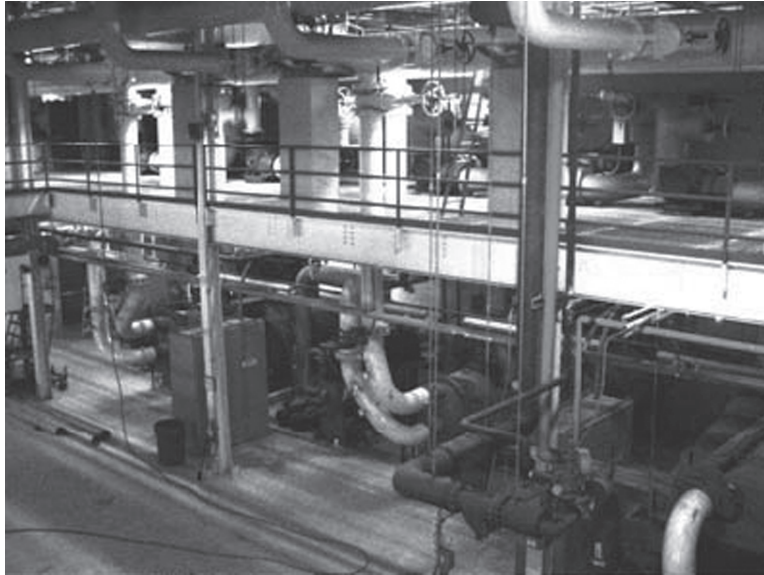


Figure 24. Mix of Absorption and Electric Chillers at a Major Chicago Hospital CHP Plant. (UIC Photo of Northwest Community Hospital)

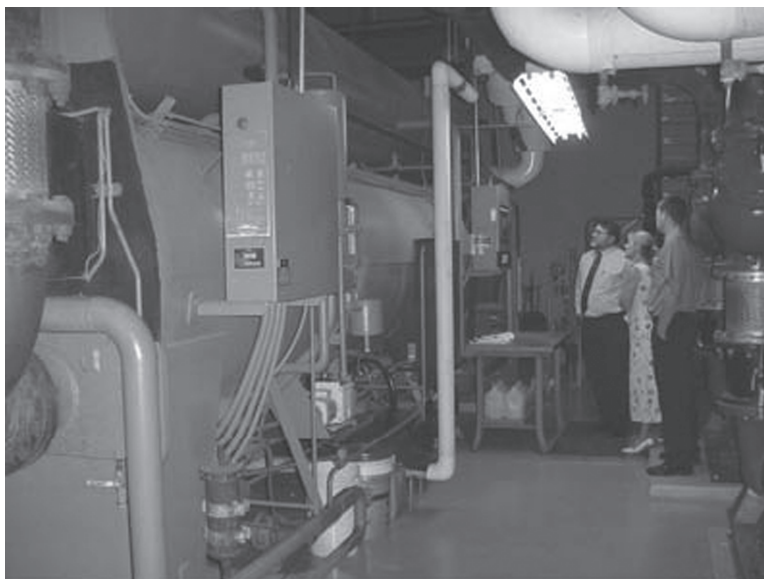


Figure 25. Single Effect Absorption Chiller Operating on CHP Heat at a Community College. (UIC Photo of Elgin Community College)

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Prior to ESC, Eric spent 13 years with Philadelphia Gas Works, most recently as part of their executive strategic planning team. He has held past positions as manager of major account sales, market manager, major accounts manager for gas cooling, and marketing engineer. He holds a B.S. in electrical engineering from Drexel and a Master of Management-Business Administration from Penn State. He is a Certified Energy Manager as well as a Certified Business Energy Professional and has served as president and board member of the Delaware Valley chapter of the Association of Energy Engineers. Mr. Burgis may be contacted at eburgis@ESCenter.org.

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