Using CHP Systems In Commercial Buildings

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This is the twenty-ninth article inspired by a DOE report covering energy-saving HVAC technologies.

Most commercial buildings obtain electric power from the grid, space heating from a furnace or boiler, and hot water from a gas-fired or electric-resistance water heater. A commercial building combined heat and power (CHP) system is a different paradigm to meet these needs. CHP produces electric power on-site and harnesses "waste" thermal energy produced in the power-generation process to satisfy space and water heating loads.

CHP systems also can meet space cooling loads, i.e., by using waste heat to drive absorption chillers and/or regenerate (dry out) the desiccant in desiccant dehumidification systems. In practice, not all the heat liberated in the power-generation process can be recovered and used. Unused thermal energy includes heat a) radiated to the ambient air, b) lost from the exhaust-gas stream, c) at a temperature too low to satisfy thermal loads, or d) that exceeds thermal loads at that point in time.

CHP systems generally consist of a prime mover, power generation/power conditioning system, heat recovery device, utility interface and controls. In addition, systems may include absorption cooling equipment, desiccant dehumidification equipment and thermal or electrical energy storage. The prime mover converts fuel to mechanical energy or directly to electrical energy and produces thermal energy that the heat recovery device uses to meet thermal loads.

Potential prime movers for commercial building CHP include internal-combustion (IC) engines, microturbines, fuel cells, Stirling engines, and organic or steam Rankine cycles. These differ in development status, cost, efficiency, emissions, fuel options, life, noise/vibration, and service requirements.[1,6]

While relatively common in industrial applications, CHP has achieved limited penetration of the U.S. commercial building market to date. For example, a recent evaluation of CHP capacity in supermarkets, hospitals and nursing homes, hotels/motels, restaurants, and big box retail stores found 318 installations with a total of about 500 MW of electric generation capacity.[2]

Health-care installations dominate the commercial-building CHP installed base, i.e., they represent two-thirds of the installations and more than 90% of the capacity, with seven larger installations accounting for more than half of the total capacity. Most existing systems are smaller (less than 500 kW, with a median size of 150 kW) and found in coastal regions having high electricity rates, such as California and Northeast states.[2]

As in the industrial sector (where processes that require sustained levels of both electricity and heat are common), CHP tends to be most attractive in commercial building applications having thermal loads that are relatively high and continuous. This explains the concentration of existing commercial-building CHP in hospitals, which have regular and sizeable water heating loads.

Energy-Saving Potential

CHP has the potential to achieve primary energy savings in two ways. If the CHP system generates electricity at an efficiency higher than the grid (≈35% lower heating value [LHV] on average, taking into account transmission and distribution [T&D] losses[3]), it can reduce energy consumption based on electric output alone. If a CHP system has an electric generation efficiency similar to or less than the electric grid, energy savings depend on the extent to which waste heat can supplant space heating, space cooling, and/or water heating loads.

The bulk of commercial building floorspace, such as office buildings and retail stores, have modest space heating and water heating loads.[1,6] Thus, absorption chiller cooling and desiccant dehumidification can increase the attractiveness of CHP because they increase year-round waste heat use while also reducing peak electric demand.[1,6]

However, high electric generation efficiency is far more important in achieving energy savings compared to high use of waste heat. This is because the building's existing sources for heating and cooling are relatively efficient. For example, a typical non-condensing boiler or furnace has an efficiency of more than 80% higher heating value (HHV), which translates to more than 90% LHV. Existing vapor-cycle cooling equipment efficiencies are even higher, even after accounting for losses in the generation, transmission, and distribution of grid electricity. This fact is sometimes overlooked, e.g., some CHP promoters report "total efficiency" of CHP systems based on a first-law definition that simply sums electric and thermal outputs. Meaningful efficiency definitions, however, account for the relative values of the electric and thermal outputs.

An accurate assessment of the energy-savings potential of CHP requires careful accounting of the operational strategy and the coincidence between electric and thermal loads. One study evaluated the performance of cooling, heating, and power for three types of commercial buildings in five different locations using simulations based on hourly building loads, local utility rates, and an economics-based operational strategy, i.e., the CHP system only operated when it reduced operating costs.[1,6]

The results confirmed that primary energy savings are sensitive to generation efficiency. For example, CHP used with a large office building in New York City powered by a 26%-efficient [LHV] microturbine reduced building primary energy consumption by about 4%, while a 42%-efficient [LHV] advanced IC engine achieved about a 30% reduction.[1,6] In this application (which lacked thermal storage), the building could only use between 30% and 40% of the waste heat, due to unrecoverable losses and noncoincidence of thermal and electric loads. Extrapolating the 30% savings nationally, CHP could reduce the 17 quads of energy consumed by U.S. commercial buildings[3] by approximately 5 quads.

Market Factors

The economics of CHP greatly depend upon the local utility rates, particularly demand charges (dollars per kilowatt) and natural-gas prices, as well as CHP system capital costs. The aforementioned simulation of CHP energy savings also projected the economics of CHP systems, assuming that prime-mover technologies meet their R&D performance goals and CHP systems achieve mature production volumes. The study found that advanced-IC-engine CHP (generation efficiency ≈ 42% [LHV]) would have a simple payback period (SPP) of between one and three years for large office buildings located in Los Angeles or New York City, but the SPP would exceed 15 years in Miami and Phoenix. In contrast, the SPP for a standard or advanced microturbine (generation efficiency ≈ 26% or 31% [LHV], respectively) increased to between two and five years.[1,6]

Clearly, high electric generation efficiency is key to good economics as well as energy savings—the greater heat production of less-efficient generation technologies cannot compensate for their reduced electric output.

In addition to reducing energy costs, CHP can provide emergency power capability, improve power quality, and reduce the burden on utility T&D systems during periods of peak demand.

At present, efficiency, capital costs, maintenance costs, and reliability/availability pose significant barriers to cost-effective CHP. At present, no prime movers are commercially available in large volumes except IC engines. To significantly reduce energy costs, the CHP system should have an electric generation efficiency similar to or greater than that of the grid. This suggests that some fuel-cell technologies (such as phosphoric acid and solid oxide), and advanced IC engine technologies, may hold significant promise for CHP applications.

In addition, CHP faces several non-economic barriers to greater use in commercial buildings. Often, utility policies and regulations pose significant barriers to CHP. These include standby charges (i.e., to "reserve" capacity for occasions when the CHP does not operate) and grid interconnection requirements. Furthermore, the planning, siting, and zoning requirements for implementing on-site power generation vary significantly from one jurisdiction to another.[4]

Figuring out the appropriate process for a potential project takes time, as does acquiring the necessary permits, and can deter consideration of CHP.[4] New emissions requirements (especially in California and other non-attainment areas) also may impede the use of IC-engine- and microturbine-based CHP. Cleaner fuel cell-based CHP, however, should face fewer emissions-related barriers.

CHP is a new paradigm for commercial building applications. Many building owners and design professionals are reluctant to consider what they see as an unknown and risky technology. Despite the recent launch of a CHP system that integrates a microturbine with an absorption chiller and cooling tower,[5] a general lack of off-the-shelf, integrated systems exist. Consequently, each application requires custom selection and sizing of key system components, as well as integration and field installation. This complicates and increases the cost of CHP implementation. Lastly, although there is an extensive existing support infrastructure for IC engines, such an infrastructure for microturbines or fuel cells does not yet exist, most notably for servicing.[4]

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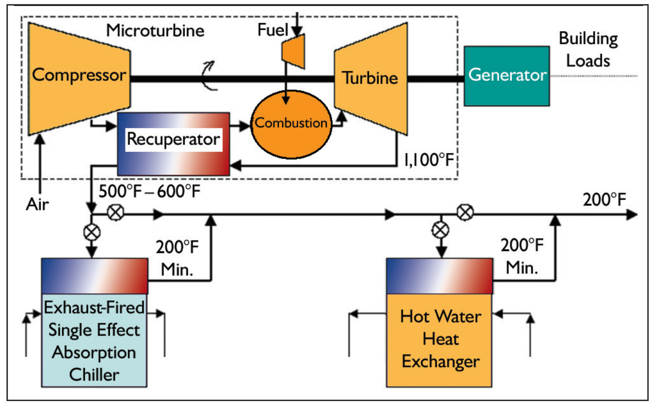

Figure 1:** **A microturbine-based CHP system with single-effect absorption chiller cooling.[1,6]