Cogeneration Revisited

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Favorable markets and advancing technologies mean new opportunities for a tried-and-true route to clean, reliable, cost-effective heat and power.

Cogeneration (also called combined heat and power) is an effective approach to saving energy in facilities. For years, however, its progress has been stalled by perceptions that the economic payback is too slow. Today, the picture is changing. More competitive utility markets, more flexible financing plans, efficient generating technologies with lower first costs, and favorable government policies make cogeneration an energy option worth revisiting. Taken together, these four factors improve the outlook for developing cogeneration projects that meet organizations' financial criteria. An experienced energy service company can quickly and reliably analyze a proposed project and, if financially feasible, devise a workable plan for installation, operation and service.

It's Not Your Father's Cogeneration

Cogeneration is a proven, cost-effective energy-saving technology. It delivers heat and power from a single source, captures up to 80 percent of the energy from fuel, cuts utility costs, and reduces air pollution. And, it does all that with simple, reliable devices: engines, turbines, generators, boilers.

So, why aren't there more cogeneration systems in our nation's office buildings, factories, hospitals and college campuses? It's mainly because cogeneration (also called combined heat and power or CHP) has acquired a reputation as a niche technology.

Conventional wisdom says cogeneration works where electric power is expensive and natural gas is cheap. It works in European countries where tax incentives subsidize installation costs. Otherwise, convention says, the payback is too slow and the return on investment is too small.

In the past few years, however, things have changed. Evolving power markets, advancing technology, and new financing options all bode well for cogeneration. The time is right for a wide range of energy users to revisit the concept as a viable strategy for producing reliable, low-cost heat and power.

A More Friendly Landscape

Cogeneration has waited its turn through a long period of reliable utility power and stable, government-regulated natural gas and electricity prices. Most existing systems are large-scale. Economic performance has depended on an adequate steam load and a sufficient spread between gas and electricity rates.

Today, the fundamentals are far different. Gas is now a deregulated commodity, its price often open to negotiation among suppliers. Electricity is being deregulated. As utilities prepare for competitive markets, power price structures are shifting, and there are more opportunities for self-generators to sell power to the utility grid at market rates.

In many areas, utility power is less reliable than before. Growth in generating capacity has lagged behind growth in demand. Where supplies are stretched thin and customers face the prospect of seasonal shortages, self-generated power looks more attractive.

And, technology is improving. Engines and turbines deliver greater efficiency at lower installed cost. Heat-activated cooling devices add a new dimension in efficiency. Fuel cells and microturbines are on the horizon, promising cleaner, more efficient power even in small-scale applications.

Rising fuel and electricity prices are adding renewed urgency to all kinds of energy efficiency projects. Meanwhile, interest rates approaching the lowest levels in recent decades make project financing highly attractive. These changes can help make cogeneration an economically sound venture, whether by itself or as part of a comprehensive energy strategy. Opportunities abound in a wide range of facilities in the government, industrial, commercial and institutional sectors.

A Concept Whose Time Has Come

Cogeneration is an inherently clean and efficient way to produce energy. Large-scale electric power generation is about 30 to 35 percent efficient – the remaining energy is simply lost as heat. Cogeneration puts most of that heat to use: Eighty percent total thermal efficiency is readily achievable.

More energy from the same fuel means lower pollutant emissions. For example, when compared to coal-based power plants, cogeneration using natural gas with reciprocating engines reduces fuel burned by about 35 percent and cuts emissions of the greenhouse gas carbon dioxide by about half. Sulfur dioxide is nearly eliminated, and nitrogen oxide decreases markedly. In addition, by producing power on the customer's site, cogeneration reduces line losses in transmission and distribution thus reducing the need for new high-voltage power lines.

All these benefits make cogeneration attractive to policymakers. In 1995, according to the U.S. Combined Heat and Power Association (USCHPA), cogeneration provided about 44 gigawatts of the nation's generating capacity, about 6 percent of the total. In Europe, favorable government policies have sharply increased that contribution. Finland, Denmark and the Netherlands, for example, receive about 30 percent of their power from cogeneration systems.[1]

Policies in the United States are starting to shift. The Bush Administration's National Energy Policy proposes to support cogeneration through tax incentives and streamlined environmental permitting.[2] In 1998, the U.S. Department of Energy (DOE) issued the CHP Challenge, calling on industry and government to work together to double the nation's cogeneration to about 100 gigawatts by 2010.

The USCHPA accepted the challenge. Working with the DOE and the U.S. Environmental Protection Agency, the association produced a *National CHP Roadmap.*[3] It outlines an ambitious plan for 46 gigawatts of new cogeneration capacity by 2010, resulting in:

- 13 trillion Btu per year in reduced energy consumption.
- $5 billion in energy cost savings.
- Emissions reductions of 0.4 tons per year in nitrogen oxides, 0.9 million tons per year in sulfur dioxide and 35 million metric tons in carbon.

The *Roadmap* advocates advancing cogeneration by raising awareness, developing markets and technologies, and eliminating regulatory and institutional barriers. The latter includes simplifying interconnect requirements for cogenerators operating in parallel with utilities and making it easier for projects to secure air-quality permits.

Changing Markets, Changing Motivations

The time has passed when cogeneration must be justified solely on direct energy-cost savings and financial yardsticks like simple payback. Changes in utility markets create entirely new reasons to consider the concept.

Reregulation is fundamentally changing the way electricity is marketed and sold. Slowly, yet steadily, electric power markets are moving toward competition. In the process, sudden price swings and reliability concerns have become a part of daily life for customers. Power shortages, rolling blackouts and rising prices in California are the clearest signals of change in the making.

Today, most customers pay fixed, government-regulated on-peak and off-peak rates. In competitive markets, customers will have many more price and service options. Those willing to pay a premium for stable rates may choose long-term, fixed-price contracts. Others may opt for time-of-use prices that change hourly or even more often during the day to reflect the true cost of producing power. Still others may buy power continuously on public exchanges at prevailing market prices.

The point is that each customer will be able to choose a plan that balances price with reliability. And, in that environment, cogeneration can be a key component of an energy strategy. Where electricity prices are high relative to fuel prices, the concept will succeed on its traditional merits. In addition:

- Where power supplies are short and interruptions likely, an onsite cogeneration system provides reliability. It can protect critical processes from downtime thus preventing huge costs from lost production and customer service interruptions.
- Where utility policies permit, a cogeneration system owner may be able to sell power at a substantial profit during times of high market prices.
- Where utilities have high on-peak energy prices and demand charges, peak shaving with a cogeneration system may be economically feasible.

In addition, evolving power markets enhance opportunities for trigeneration, also called building cooling, heat and power (BCHP). This technology marries a power generator (usually natural gas-fired) with a heat recovery system and a thermally activated cooling device such as an absorption chiller or desiccant dehumidifier. Now, steam output from a power generator can help carry a building's cooling load as well as process and space heating loads. During the summer, that cooling capacity provides flexibility to avoid high on-peak electric demand and energy charges. Energy cost savings can be substantial. Like cogeneration, trigeneration has federal government support. The DOE's *BCHP Technology Roadmap* envisions trigeneration as "the preferred method of energy utilization in buildings" by 2020.[4]

Also working in favor of cogeneration and trigeneration are ever-tighter environmental regulations on large coal-based power plants. The rising cost of removing air pollutants like nitrogen oxides, sulfur dioxide and mercury will inevitably increase the cost of utility power, making cogeneration more competitive.

The Better the Financing, the Better the Project

Financing, not technical merits, often determine whether cogenerations succeeds or fails. Traditionally, an energy-saving project must meet the customer's specific hurdle rate, expressed as a simple payback period, return on investment or internal rate of return. The economics work best where a cogeneration system replaces existing boilers at the end of their useful life. Even where that is not true, cogeneration can benefit from innovative financing plans that minimize risk, reduce capital outlays and improve cash flow.

Cogeneration lends itself well to performance contracting, an arrangement that makes energy-efficiency projects essentially risk-free. Known in the government sector as Energy Saving Performance Contracts (ESPCs), these programs guarantee the customer a specific amount of savings over the project term. If the savings exceed the guarantee, the customer pockets the excess. If the savings fall short, the customer receives a check for the difference from an energy service company.

In a typical performance contract, an energy service company works with the customer to identify savings opportunities and develop a project plan. The service company then helps arrange third-party financing, completes the work, and in many cases, operates and maintains the facility for the length of the contract. The customer pays nothing up front. Often, annual energy savings exceed the annual financing payments, creating immediate positive cash flow.

Performance contracting provides flexibility to help justify a cogeneration system that by itself cannot meet a customer's hurdle rate. The addition of fast payback projects like lighting upgrades and high-efficiency motors will often create a total project with an adequate return.

In the federal government sector, new rules make performance contracts even more attractive by lengthening the term of financing. Under Super ESPCs, administered by the DOE's Federal Energy Management Program, contracts can be financed for as long as 25 years to cover the full life cycle of facility improvements. The program was created to help agencies meet the 1992 Energy Policy Act and an executive order requiring federal buildings to reduce energy consumption by 30 percent between 1985 and 2005.[5]

The program divides the nation into six regions, each with a short list of approved energy service providers. A federal agency in a region may choose any of those companies to complete an ESPC without issuing a request for proposal (RFP).

The National Animal Disease Center in Ames, Iowa, used a Super ESPC to undertake a comprehensive energy-saving program that included cogeneration.[6] The cogeneration system draws heat from a 1.2 MW natural gas-fired combustion turbine to operate incinerators and sterilizers and provide space heating in winter. The 17-year contract saves or avoids $550,000 per year in energy costs while reducing air emissions and improving indoor air quality and employee comfort.

Better Technology Lowers the Bar

Cogeneration is no longer just for large facilities with vast capital budgets. Evolving technology is steadily improving economics and bringing the concept within reach of smaller heat and power users.

Helping drive that trend are spark-ignited, engine-driven systems identified by the DOE as the fastest growing cogeneration power source for smaller installations. Usually designed as packages, these systems are simple to install, compact enough to fit in existing boiler rooms, and easy to connect to existing heat distribution systems. A one-megawatt, natural gas-fired engine-generator package can be ordered, delivered and operational within six months. Packaged systems are highly reliable, especially when connected with the utility grid for backup. Today, 94 percent to 96 percent reliability is typical.[7]

The federal government, engine manufacturers and research institutions are working together to develop even better gas-engine technologies to help customers quickly site environmentally friendly, highly efficient generating systems that cost less to install and operate. Central to this effort is the DOE's Advanced Reciprocating Engine Systems (ARES) program. Under ARES, manufacturers and supplier teams will research advanced materials, unique fuel handling and processing systems, and advanced ignition and combustion systems.[8] Objectives include:

- **Installed cost per kW: $400 to $450** (30 percent improvement over current gas engines)
- **Maximum thermal efficiency:** 50 percent (35 percent improvement)
- **Thermal efficiency with cogeneration:** 80 percent or higher
- **Maintenance costs:** $0.01 per kilowatt-hour (30 percent improvement)
- **Nitrogen oxides (NO_X) emissions:** 0.1 grams per brake horsepower-hour (95 percent improvement)

Turbine technology is also moving forward across a wide spectrum of sizes. Large-scale advanced gas turbine-generator packages are being optimized to produce highly reliable, low-cost power with electrical efficiencies approaching 40 percent. The units are designed for fast installation, easy maintenance and service, and very low emissions to simplify permitting.

On the smaller end are back-pressure turbines, which generate electricity by extracting energy from expanding steam. Back-pressure turbines are gaining favor in installations that produce high-pressure steam, but also must expand some of that steam to serve lower-pressure loads. The devices, typically in capacities of 25 kW and up, are becoming more viable as manufacturers drive down production costs. At present, the replacement of a back-pressure steam valve with a back-pressure turbine can produce payback in three to four years.

On the trigeneration front, chiller manufacturers are developing heat-activated products well suited for cogeneration systems. Single-effect, double-effect and triple-effect absorption chillers, for example, operate efficiently with heat sources like jacket water or low-temperature exhaust produced by an engine- or turbine-driven generator. In larger sizes, simple single-effects units cost only slightly more than electric chillers.[9]

Looking ahead – no one is sure precisely how far – microturbines and fuel cells may enter the picture for small-scale cogeneration. Microturbines are the much smaller cousins of the large turbines that power industrial plants and provide peak-time power for electric utilities. They are typically sized from 25 to 300 kW with efficiencies from 25 to 30 percent (much higher with heat recovery), high reliability, operating life up to 50,000 hours and very low emissions.[10] Many experts regard microturbines as the power source of the future. However, durability and reliability are still unproven and they are not yet cost-competitive with other technologies such as natural gas-fired engines.

Fuel cells are probably farther from commercial feasibility than are microturbines, but they promise to deliver clean power at efficiencies up to 54 percent, which is better than today's turbines and reciprocating engines.[11] With heat recovery, as in cogeneration, efficiency can reach 70 to 90 percent. Fuel cells operate by converting a fuel (usually methanol or natural gas) to hydrogen, which then undergoes chemical reactions that produce only water and heat.

Deregulated power markets make fuel cells more attractive because they offer users self-reliance and protection from supply-and-demand price volatility. Safe, quiet operation makes them ideal for siting outside small factories or office buildings. Fuel cells also promise a clean sine wave – power free of voltage sags, surges and noise. This makes them attractive for telecommunications, data processing and industrial processes that use variable-speed drives and voltage-sensitive microprocessor controls.

Advancements will continue in all these technologies. Each improvement that lowers cost, simplifies maintenance or increases efficiency helps broaden possibilities for cost-effective cogeneration systems.

Taking a Closer Look

Today's changing markets, advancing technology and receptive government policies make cogeneration an energy option well worth considering.

Exploring a site's cogeneration potential is relatively simple. The DOE recommends starting with a facility walk through to assess site conditions.[12] If the outlook is positive, the next step is a more detailed feasibility analysis that closely considers factors like fuel and electricity prices, operation and maintenance costs, utility interconnect standards, environmental permitting requirements, insurance and financing.

Today's power monitoring technologies can help customers evaluate cogeneration with considerable accuracy. Electronic metering and submetering systems can deliver energy information in fine detail – by building, by floor, by department, by process or by device in intervals down to 15 minutes or smaller. Meanwhile, building automation systems and sophisticated software simplify the tedious job of analyzing energy data.

A well configured monitoring and metering system accurately spells out how much energy an enterprise uses, in what areas, at what times of day and at what prices. It analyzes data on building occupancy schedules and weather conditions. And, it presents the information in graphic displays that are easy to understand and manipulate.

Special software can take all that data and run projected utility bills against any set of usage and price assumptions. In minutes, it can accurately project return on investment from a cogeneration system or even compare outcomes under two or more suppliers' energy pricing plans. Calculations can be as simple as editing numbers in a spreadsheet or erasing and redrawing a line on a computerized load-profile graph.

A qualified energy service company can analyze a project and, if it proves feasible, design and install the system. After installation, the owner can delegate day-to-day operations and focus on the core business. Support packages can range from planned maintenance agreements to complete, turnkey service contracts.

Customers considering cogeneration are best served by choosing an energy service company with the broadest experience in energy projects. Such a company can reliably evaluate a system's technical and economic feasibility – and do so in the context of the overall enterprise energy strategy. The result is a system that meets the customer's business objectives while producing many years of reliable, low-cost heat and power.

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