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Success in a package

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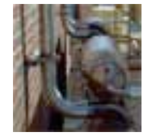

a winning formula for modern CHP

A CHP investment does not come cheap. And with the sheer number of options and regulations out there, making an educated investment decision is not easy either. But, as William Cristofaro points out, the secret of modern CHP is to combine the right factory 'package' with proper site design, modularity and automated control and monitoring.

On-site power plants using cogeneration have been a small part of the energy landscape for some time; however, a variety of driving factors promises to accelerate development of small-scale cogeneration. A formula for successful CHP plants is now emerging that takes advantage of the positive technical, regulatory and market factors, while working around or addressing barriers to CHP.

This article focuses on CHP plants in the 100–5000 kW range. These are usually plants built on the customer's site for the primary purpose of providing electric power, heat and cooling directly to the customer. Such systems may also sell some power back to the utility grid, and heat and cooling to a nearby facility. These CHP plants are often natural gas-fired prime movers or fuel cells. Current technology typically includes:

- sizes from 100 kW to 2000 kW, while higher sizes are available
- natural gas engines n gas expansion microturbines (75–250 kW)
- larger gas expansion turbines (1500 kW and up)
- fuel cells (5–200 kW) n induction or synchronous plants
- steam turbines (added to existing steam sources).

A successful CHP plant is really the proper integration of many central plant components

It is crucial to realize that a successful CHP plant is really the proper integration of many central plant components to deliver electric power, heat and cooling to the customer economically. CHP plants are seldom economical and are of limited benefit unless these components are integrated properly.

Figure 1 illustrates the fundamental arrangement common in successful CHP plants.

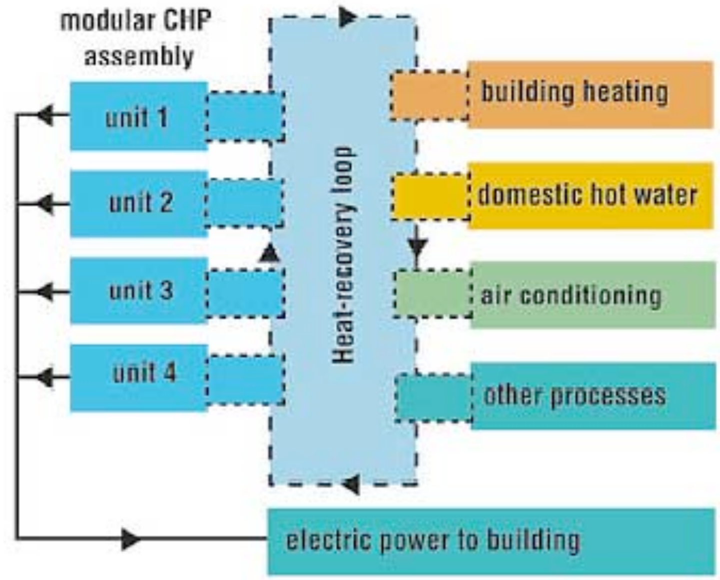

Figure 1. Typical CHP plant layout. Modular units provide greater reliability and better load-following capability. Air conditioning, via absorbers and making use of the waste heat from the cogen units, uses ozone-free refrigerant (distilled water)

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CUSTOMER DRIVING FACTORS

Customers consider various issues to be of primary importance regarding CHP plants: energy cost savings, return on investment (economical construction), reliable operation, protection from volatile fuel pricing, low emissions, standby power and infrastructure upgrades.

Benefits to the customer include:

- return on investment
- reduction in operation and product cost
- green, alternative energy
- credits available for the Leadership in Energy and Environmental Design (LEED) Green Building Rating System, a US-wide standard for developing high-efficiency, sustainable buildings
- various economic incentives available
- production of electric power, heating and air conditioning from one plant
- may help fund other necessary infrastructure improvements
- automated, clean, quiet and easy to operate.

BARRIERS AND RESTRAINING FACTORS

Despite many advances in CHP plants and technology, the industry faces several restraining factors. These are often overcome by knowledge of the regulatory environment, skilled technical design, careful project execution, and plain old persistent determination. However, the restraints slow down the process, kill some projects and may wear out the less hardy. The major restraining factors are summarized as follows:

Exhaust heat-recovery exchangers and catalytic converters, mounted on the roof of a prefabricated enclosure of a packaged 380 kW modular system at 4C Foods in Brooklyn, New York. A standard container can be trucked across the US without special permits. Sound is attenuated to less than 45 dB at 6 feet (1.8 m)

- *Awareness* – few people know of CHP. For those of us immersed in the business, this may be a bit of a shock. But go ahead and quiz a few business owners you know, and you'll likely be surprised at some of the answers. Public education and awareness is a big factor.
- *Education* – once customers have an interest, they would usually demand some greater knowledge of the whole process. Black boxes for $20 sell at the candy store, but black boxes of power and heat for $1,000,000 don't necessarily.
- *Regulation* – standby tariffs, interconnection standards and utility processes are all parts of the CHP plant process. Progress in these areas has been made in some states such as New York and California. However, the rules, tariffs and regulations within a single state (such as New York) can vary between utilities. Some states have already quietly approved very poor standby tariffs, losing the game for CHP providers before the first pitch. Hard work in this area is needed and will be continuous.
- *Proper guidance* – with the complexity of the issues regarding CHP, in many cases there is a lack of talent to properly identify and lay out the site-specific solution. Opportunity for a good CHP plant can often be misdiagnosed or missed by the untrained. Conversely, only certain sites lend themselves to good CHP economics.
- *Financial ability* – this seems to have become less of an issue recently due to the low cost of and investment interest in alternative energy. However, most plants will require a financing package to be put in place either by the owner or a third-party developer.
- *Market uncertainty* – the volatile cost of fuels, particularly natural gas, can cause owners to procrastinate in moving ahead with CHP. However, with good heat recovery, natural gas prices actually have very little effect on overall project economics. This is because the heat recovered may offset other uses of natural gas for on-site heating. In addition, a 10% increase in saved electric cost may cancel out a 30% increase in fuel cost with a CHP plant.

THE EARLY DAYS AND PITFALLS OF CHP PLANTS

Despite all the excitement and promise of CHP, on-site power in past years has sometimes moved erratically, with obstacles along the way. Improper technical design, high construction cost, operational problems, regulatory confusion, and firms going bankrupt have all taken their toll, leaving a bad impression with some unfortunate owners. However, some plants operating today came online over 15 years ago, and many others have been operating for years and, most importantly, delivering what was promised. What can be learned from those plants that failed, and those that have been and are successful? Upon examination, a winning formula emerges.

A WINNING FORMULA

A large absorption chiller using cogen waste heat provides 250 tonnes of cooling

Several ingredients can be combined to provide a blend of technology, wisdom, common sense, and market and regulatory knowledge. The following are important for an economically and technically successful CHP plant:

- proper analysis, engineering and sizing
- client and customer education and planning, and vice versa – viewing the application from the customer's perspective n modular cogen plant – that is, multiple cogen units
- prepackaged unit and system components (an example of packaged cogen units is C-Tainer type systems)
- robust design, high-quality mechanical and electrical equipment
- automated full digital control (not just for the cogen units, but for the entire plant, including pumps and heat exchangers)
- proper utility interconnection and standard hardware (custom

to a large high school

programming)maximize value by integrating related infrastructure improvements where applicable (for example, upgrading an old electric service panel)
- proper full maintenance and warranty contracts. These provide an escrow or a fund for scheduled overhauls and replacement of the engine or prime mover; analogous to an extended service plan on a vehicle
- proper commissioning and follow-up.

Some plants operating today came on line over 15 years ago and many others have been operating for years

The first step is the most important one. That is especially true when embarking on a CHP project. There is potential for great savings. But how large should the plant be? How much will it cost to build, and how much can be saved? To what loads should it be connected both electrically and from a heat-recovery standpoint? How will it really work with the rest of the facility? We have found that an engineering feasibility study answers these questions and sets a good foundation for the project to proceed. Now the owner can make an informed decision.


Modular CHP plant at a large high school in New York State. This 1320 kW plant consists of four 330 kW packaged cogen units. Each unit has its own pump, heat exchanger assembly and microprocessor controller. The modular arrangement provides great reliability for this off-grid plant

Prepackaging of both the individual cogen units and overall cogen plant prepackaging is beneficial from both an equipment quality and construction cost standpoint. At 4C Foods in Brooklyn, New York, a 380 kW cogen subsystem – complete with three cogen units, three-way catalytic converters, sound enclosure, utility parallel interconnect controls, system computer control, excess heat radiator (used sparingly), heat-recovery hot water pumps and other devices – was pre-built and housed in a standard 9.0-foot (2.7-metre) wide C-Tainer transportation unit. This allowed fabrication off-site in a controlled environment and at less cost.

Adding absorption chillers to a CHP plant provides many advantages. These advantages include lower electric demand cost, ozone-free refrigeration, quieter operation and energy savings.

A fully automated system is also a major factor for success. The computer control system continually operates the cogen units and the entire plant. Just as important, the system displays information about the plant to the owner or operator in an immediate and fully comprehensible way.

A good digital system takes all the mystery and frustration out of the process and replaces it with confidence and understanding. Colour graphics on a PC display what the plant is doing and provides trends of power and thermal performance. The operator can interrogate the plant and make subtle changes to improve efficiency with a click of the mouse.

THE FUTURE OF CHP

Cogeneration and CHP plants are expected to evolve both at the cogen unit level and on the system level. At the cogen unit level, the following advances and enhancements are expected:

- *More factory-built cogen units*. Presently only certain manufacturers build specifically designed units at the factory; these units come complete with heat exchangers, computer controllers and packaged exchangers. Many units (built in a similar process) are actually primary power units that are shop-modified near the point of installation. More standard factory fabrication will lead to greater economies and reliability.
- *Enhanced fuel efficiency and emission controls*. More can be expected in relation to control of fuel systems and catalytic converter packages. Enhancement of lean-burn fuel controls can also be expected.
- *Greater advances in unit microprocessor control*. Already quite advanced on some models, controllers for on-board cogen units are expected to become more robust and capable of more function and protective features.
- *Quieter operation*. Noise reduction is already a strong trend in nearly all equipment sectors. Cogen units will need to keep pace with expectations of quieter, more user-friendly packages.
- *More compact packaging and with more integral components* such as pumps, exchangers, and utility

interconnect relays. Some units already have this.

A good digital system takes all the mystery and frustration out of the process

At the systems level, more exciting advances are already underway. When we talk about the systems level, we are addressing the CHP plant in its entirety, which includes the cogen units, heat recovery systems, and the building and electric utility interface. This is a concept of the CHP plant operating as one intelligent central plant, which responds to site needs and market conditions for maximum economy and performance. It includes various functions:

- Automated control (already integrated in the design of some plants) that allows the CHP plant to make intelligent decisions about, for example, when to sell power back to the grid based on the market cost of power sale, fuel cost and on-site heat-recovery efficiency.
- In a similar mode, distributed CHP plants may be grouped into a network of plants that, from a point of central operation, supply excess power to the grid in time of grid peak demand. (The CHP plant owners can be paid a premium for this.)
- Improved reporting methods. Better data reduction and summary programs that will take advantage of all the recorded data about plant operation, and condense it into a summary readable by the layman.
- More advanced use of waste heat, particularly for absorption cooling of more varied sizes and applications.
- Web-based access to allow both more convenient access and monitoring and for education and public awareness.

GLOBAL POWER – THE NEED AND THE OPPORTUNITY

While it is clear that CHP can provide many benefits in developed nations in need of more efficient and clean power, the opportunity in developing nations is huge, challenging and intriguing. In his energy policy book From Edison to Enron, Richard Munson reports that nearly two thirds of rural residents in Africa, Asia and Latin America lack access to power, affecting over 2 billion people (see Perspective article in *COSPP* Jan–Feb 2006). More to the point, the cost, logistics and potential environmental impact of electrifying developing nations is staggering: at $10 trillion and more.

A prepackaged cogeneration plant at Greater Rochester Airport, New York State. This enclosure is home to a 750 kW natural gasfired Waukesha synchronous generator with full engine and exhaust heat recovery. These units normally run parallel with the utility, but kept the airport fully functional during the great blackout of 2003. Waste heat is used for both building heating and driving a 300-tonne hot water absorption chiller

Many are wondering whether part of the power solution – at least for developing nations – is to move directly to distributed cogeneration plants, largely skipping the distribution wires, the grid system and all its trappings. (Renewable energy would also play a role where feasible.) Such distributed generation could take on various forms and structures based on the specific needs, abilities and resources of the developing country.

The application of CHP in this manner could be very precise and targeted, and, above all, economical and scalable. One could embark on electrification and make great progress without the tremendous start-up cost of large grid systems, power plants and the associated power struggles and politics.

Some developing countries have established pilot programmes to flush out the restraining factors and resources needed for successful implementation. Whatever these factors may be, distributed power invokes much less risk, and allows for rapid changes at prototype sites at lower cost than for large grid type systems.

The formula for success has emerged in the US and Europe. Now it is a matter of transporting that formula and success abroad.

GAINING FURTHER GROUND

A few years ago there may have been greater uncertainty about CHP in the

US and the global marketplace. Today, however, many industry analysts are seeing some strong trends in the direction of CHP. The energy-intensive and environmentally sensitive states of both New York and California have recognized the benefits of clean, efficient CHP plants and on-site power. In effect, clean, efficient CHP plants and renewable energy have a very similar effect on the electric and natural gas grid: they both decrease electricity and fuel use. In doing so, CHP plants also reduce overall emissions. With electric power demands steadily increasing and with continued concerns over greater energy efficiency, government support will help clear regulatory barriers.

A CHP plant recycles the waste heat from two 150 kW generators to provide hot water for a linen supply company in Brooklyn, New York

Technical advances continue to make distributed power more economical, practical and user-friendly. The explosive growth that some had predicted for CHP may have been due to unrestrained exuberance, but steady growth, with an increase of market share, seems likely. And once a plant is built and it works well, people tend to stick with it – for a long time.

The winning technical formula has emerged: properly sized systems, modularity, prepackaging, full automation, clean and quiet, and an interface carefully customized to the owner's particular facility and application. CHP is also being combined with renewable energy, thereby taking advantage of the on-site CHP infrastructure to lower the incremental cost of adding renewable technology.

Once a plant is built and works well, people tend to stick with it – for a long time

Further ground can be gained by continuing to hammer away at the various barriers of education, regulation and onerous utility tariffs. Progress has been made, but more work remains to be done.

As Winston Churchill once said, 'If mankind wishes to enjoy a prolonged and indefinite period of material prosperity, they have only got to behave in a peaceful and helpful way with one another, and science will do for them all that they desire and more than they can dream.' CHP is one such scientific advance. Just apply the winning formula.

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