DISTRIBUTED GENERATION/ COMBINED HEAT AND POWER

A Special Supplement to *Energy Matters*

Magnesium Producer Relies on Distributed Generation with Combined Heat and Power

By Roger Swenson, E-Quant Consulting, Salt Lake City, UT, and Dr. R. Neelameggham, Magcorp, Salt Lake City, UT

More than 20 years ago, Magnesium Corporation of America (Magcorp) put in place a combined heat and power (CHP) system to help minimize energy costs. Today, the system still operates effectively, and Magcorp has integrated the system into its magnesium production process. By using a substantial portion of the total energy available from the input energy in the process, the CHP system helps the company save energy and money.

Magcorp, located on the shores of the Great Salt Lake 65 miles west of Salt Lake City, Utah, is the only large magnesium production facility remaining in the United States. It is the third largest producer of magnesium in the world. At full production, the facility exceeds 80 million pounds of magnesium per year. The Great Salt Lake provides the mineral source for the magnesium that is produced. The lake has a 0.4% concentration of magnesium—which is three to four times the concentration of the world's oceans.

To produce the magnesium, Magcorp pumps brine from the lake into shallow, manmade evaporation ponds that stretch over 120,000 acres of desert. Solar energy evaporates the pond water and concentrates the brine to more that 20 times its original level. Next, the concentrated brine is purified and directed to preheaters and into high-volume spray dryers. The spray dryers flash dry the solution into magnesium chloride powder, which is transferred to melt cells for melting and purification. Purified molten magnesium is then transferred to electrolytic cells, where direct current electricity separates the magnesium chloride into molten magnesium metal and chlorine gas. Finally, the molten metal is collected and taken to the cast house, where it is cast into ingots for shipment.

The process is very energy intensive. In fact, energy can account for 40% of production costs. Because of these energy requirements, Magcorp continues to seek ways to improve the production process to remain competitive and reduce chlorine emissions. For example, new electrolytic cell technologies have been deployed that will reduce electric energy consumption by 30%. Additionally, the initial plant configuration included a CHP system that provides substantial energy savings to the operation.

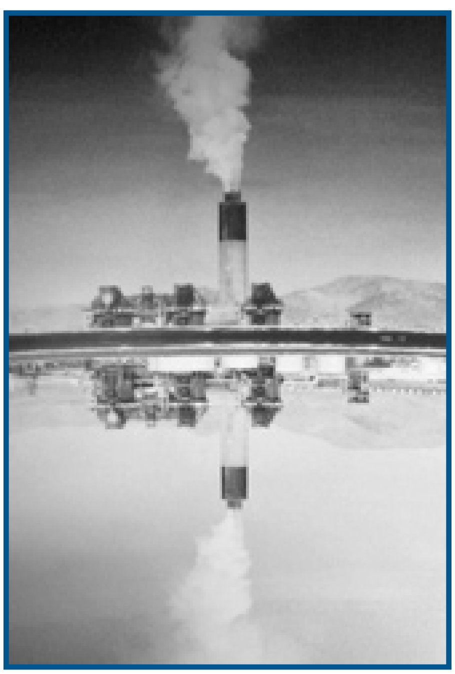

Photo courtesy of Magcorp

Magcorp pumps brine from Utah's Great Salt Lake to produce magnesium.

Photo courtesy of Magcorp

A CHP system improves Magcorp's process for producing magnesium.

The CHP System in Operation

Magcorp's CHP system generates power with three 12.4-megawatt (MW) natural gas-fired turbines. The exhaust gas from the turbine system is split between a waste heat boiler, which produces steam, and a spray drying system. Most of the exhaust gas is directed to the spray drying system; in turn, the exhaust moves to the brine preheater. The exhaust gas from the brine preheater vents through a scrubber to the atmosphere at 170°F. The equivalent energy remaining in the exhaust stream from the waste heat boiler and the brine preheater is only 13.5% of the initial input energy. Figure 1 (on page 2) shows the process.

Energy and Cost Savings

The energy savings Magcorp realizes from the CHP system make it a worthwhile investment. Table 1 (on page 2) shows the CHP system energy use and savings compared to a nonintegrated system. The CHP system requires purchased energy input of

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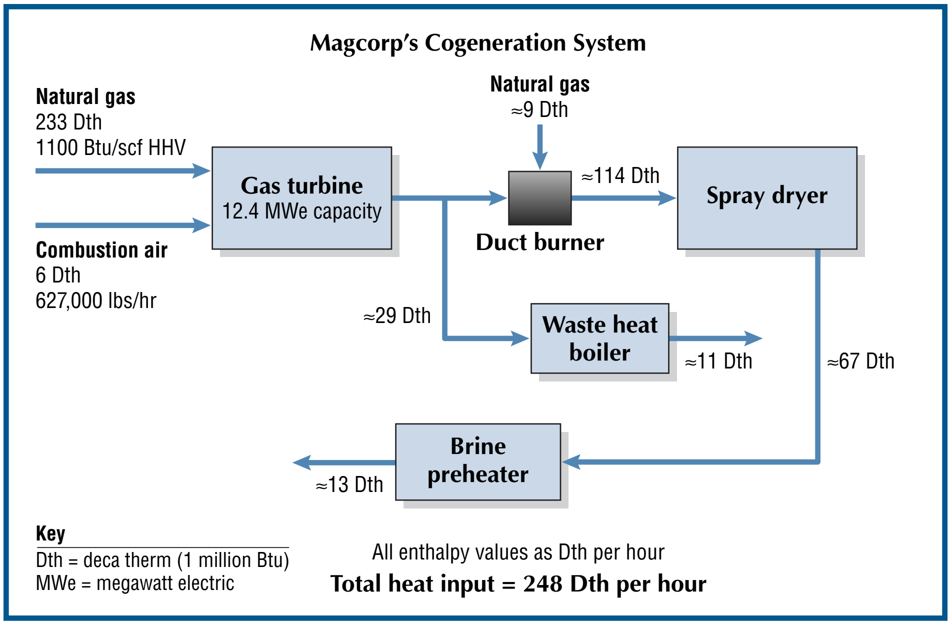

Figure 1. Magcorp's CHP system begins with three 12.4-MW gas turbines that produce enough exhaust gas to fuel a waste heat boiler, a spray dryer, and eventually, a brine preheater.

Magcorp

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natural gas to run the turbine system and a duct burner to boost the turbine exhaust to the temperature required for spray drying. In contrast, the non-CHP system would require the purchase of an equivalent amount of power produced by the CHP system, plus extra power to run a fan that pressurizes the spray drying system. In addition, a nonintegrated system would require natural gas for the spray drying system and a boiler to produce an amount of steam comparable to what the waste heat boiler generates.

Besides energy savings, Magcorp realizes substantial cost savings by using CHP. However, the economic benefits of the CHP system depend on the value of the electricity produced, the cost of natural gas, and the value of the thermal energy used by the system. Table 2 reveals the projected annual savings created by the CHP system under various power and natural gas pricing scenarios.

New and Improved CHP System

Table 2 also shows the potential savings if the system were upgraded—an option Magcorp has considered. Although still operating effectively, the existing system uses turbine technologies that are more than 20 years old. Newer turbine technologies have been developed that produce more electricity with a given amount of natural gas. So Magcorp has investigated replacing its turbine system with one of the newer, more efficient turbines in the current CHP configuration. The upgraded system would create additional savings because of the increased production of the high-value electric output. Based on an estimated $500 per kilowatt (kW), the upgraded system could have a payback of 3 years or less.

Magcorp's example demonstrates that the economic returns from a CHP system are attractive under conditions of high load factor and full thermal utilization. Lower load factor or unmatched thermal/electric utilization systems require conditions, such as higher power values and low natural gas costs to achieve desired returns on investment. Reduced need for transmission system upgrades, reduced real system losses, backup generation, and system voltage support may provide additional value if utilities pass along savings that result from a site's installation of distributed generation systems.

Careful analysis of costs and energy use assures Magcorp that the CHP system provides value to its operation; other sites can do the same to determine if CHP has potential for their operations. ●

For more information on CHP or the Magcorp process, contact Roger Swenson at roger.swenson@prodigy.net or Dr. R. Neelameggham at rneelameggham@magnesiumcorp.com.

*Magcorp recently took part in the Utah Industry Showcase in partnership with OIT and the State of Utah. The company featured its CHP installation, along with a new, efficient electrolysis system. Read more about Magcorp's involvement in the Showcase on page 1 of the Fall 2001 issue. You can also learn more about the electrolysis system upgrade by viewing the case study on Energy Matters Extra at **www.oit.doe.gov/bestpractices/energymatters/emextra**.*

Table 1. Magcorp's CHP Energy Use and Savings Compared to a Nonintegrated System

	Combined Heat & Power		Nonintegrated System	
	Dth	MWh	Dth	MWh
Turbine generator	466.00		0	
Electric purchase		0		26.80
Spray dryer	17.34		228.00	
Boiler (80% eff)			71.50	
Brine preheat			0	
Total per hour	483.34		299.50	26.80
Total per year*	4,234,058		2,623,620	234,768

*Assuming 2 units (12.4 MW each) required at 100% load factor

Table 2. Magcorp's Potential Annual Savings from CHP under Various Power and Gas Pricing Scenarios

	$3/Dth Gas, $.04/kWh	$4/Dth Gas, $.06/kWh	$5/Dth Gas, $.08/kWh
Existing system	$4,089,869	$ 7,174,790	$10,259,712
Proposed new system	$6,381,362	$10,724,763	$15,068,163

Distributed Generation: A New View on Energy Sources

Warren Gretz, NREL/PIX 00072

Distributed generation systems, such as biomass generators, can be grid connected or operate independently of the grid.

Though central power systems remain critical to the nation's energy supply, their flexibility to adjust to changing energy needs can be limited. In light of current higher energy costs and regional outages, some industries may want to consider alternatives. Distributed generation (DG), or distributed power, is modular electric generation or storage located near the point of use. Distributed systems include biomass-based generators, combustion turbines, concentrating solar power and photovoltaic systems, fuel cells, wind turbines, microturbines, engines/generator sets, and storage and control technologies. Distributed resources can either be grid connected or operate independently of the grid. Those systems that are linked to the grid are typically connected to it on site. In contrast to large, central-station power plants, distributed power systems typically range from less than a kilowatt to tens of megawatts in size.

Benefits of Distributed Generation

Because central power is composed of large, capital-intensive plants and a transmission and distribution grid to distribute electricity, significant investments of time and money are required to increase capacity. DG, on the other hand, complements central power by:

Capstone Turbine Corporation/PIX 08130

Micro turbines, one example of distributed generation, can be powered by natural gas or biofuels.

- Providing a relatively low capital cost response to incremental increases in power demand
- Avoiding transmission and distribution capacity upgrades by locating power where it is most needed
- Providing the flexibility to put surplus power back into the grid at user sites.

Applications for Industry

There are many useful industrial applications for DG. For example:

Standby Generation. Standby generators provide power during system outages until service can be restored. Large manufacturing facilities that depend on sensitive electronic controls may require reliable power in order to avoid high outage costs. Distributed resources can be used to provide on-site standby power for customers that require uninterrupted electric service 24 hours a day, 7 days a week. Industrial customers that maintain distributed power systems for back-up power may also be able to lower the cost of their power purchases by participating in peak load reduction programs offered by utilities.

Peak Shaving. Power costs vary hourly depending upon system demand and the availability of generation assets. Larger customers often pay time-of-use (TOU) rates that convert these cost variations into daily and seasonal rate categories—such as on-peak, off-peak, mid-peak, and shoulder rates. TOU customers and those competitively acquiring power could select distributed generation during high-cost peak periods, and reduce their overall cost of power. The electric supplier in turn may be able to reduce the amount of high-cost power purchased during system peaks.

Remote or Stand-Alone Generation. In isolated or remote applications, obtaining stand-alone DG may be more economic than integrating with the power grid. For instance, some combined heat and power (CHP) system owners might separate from the grid if they are unable to negotiate economic back-up power from their retail electric supplier.

Combined Heat and Power (Cogeneration). In the process of converting fuel into electricity, a large amount of heat is created (on average two-thirds of energy content of the fuel). Industrial plants can use this heat if a power generation system is located on-site or near the facility. By using CHP, plant operators can increase efficiency, lower greenhouse gas emissions, and lower power costs. CHP is best suited for mid- to high-thermal use customers, such as process industries. (For example, see the article about Magcorp on page 1.)

Barriers

There are some barriers that hinder implementation of distributed power technologies. Based on recommendations from industry and other stakeholders, DOE's Distributed Power Program is addressing a number of these barriers, including:

- Interconnection with the grid
- Utility pricing practices and tariff structures
- Siting, permitting, and environmental regulation
- Current business models and practices.

With time, these challenges can be overcome and DG applications can be a valuable tool in industry's quest to increase energy efficiency, reduce operating costs, and improve environmental performance.

For more information on DG, see the Distributed Energy Resources Web site at **www.eren.doe.gov/der**. See also DOE's Fossil Energy Distributed Power Systems Web site at **www.fe.doe.gov/coal_power/distributed_power.html**. ●

Opportunities for Combined Heat and Power

By Rod Hite P.E., Senior Consultant Energy Nexus Group, Carlsbad, CA

This article summarizes the author's paper on combined heat and power, which will be presented at the World Energy Engineering Congress in October 2001

Combined heat and power (CHP), or cogeneration, came into use at the beginning of the 20th century, and power was often generated on site at large industrial facilities, such as paper mills. With the expansion of the electric grid and inexpensive raw energy, its use declined. A major expansion of the technology occurred in the 1980s as a result of the Public Utilities Regulatory Policy Act of 1978, but interest in CHP declined near the end of the 1980s because of lack of support by utilities and economic barriers. However, today's high energy prices and constrained generating capacity have led to a renewed interest in the technology. In California, for example, where power shortages and high electric rates prevail, the economics for CHP have never been more robust. Simple paybacks for industrial process and building applications can be as little as 2 or 3 years.

CHP has applications in many of the most energy-intensive industries. The presence of a large and consistent steam load, around-the-clock operation, and fairly stable electric consumption all indicate the possibility of a rewarding project. In addition to pulp and paper mills, oil refineries, food processing plants, chemical plants, and textile mills are reaping the benefits of CHP. While the power dilemma in California provides immediacy and forces industries there to focus on power alternatives such as CHP, industries throughout the country can also take advantage of the economic and energy benefits CHP might offer.

Understanding CHP Technology

To understand its potential, industrial plants must get a feel for CHP technology. So how does CHP work and what are the technology options?

CHP is the sequential use of one fuel source to produce power and thermal energy. The energy cascade it provides helps plants avoid losses that occur when power is traditionally generated at a central station power plant and thermal energy is provided on site with a boiler. CHP can be used either in a topping cycle or a bottoming cycle, although topping cycles are the most common.

The figure below illustrates the concept. In the traditional case, steam is raised with a boiler on site and power is purchased from the local utility. The boiler requires 59 units of energy input to raise 50 units of useful steam. The utility requires 121 units of energy to generate 35 units of useful electrical energy[1]. Much of the energy loss is unavoidable because of the 2nd Law of Thermodynamics. On the other hand, CHP uses energy, which would ordinarily be 2nd law losses, for another useful purpose. In this example, CHP losses can be held to only 15 units of energy.

Prime Movers

Reciprocating engines and combustion and micro turbines are the prime movers that provide shaft power to generators. Fuel cells could one day become significant, but the technology is not yet fully developed.

Reciprocating Engines. Most CHP facilities have reciprocating engines, using natural gas as the fuel. Heat from a reciprocating engine can be either in the form of hot water or low-pressure steam (15 pounds per square inch gauge [psig] or less). The phase change from liquid to steam can either take place within the engine or in a drum separate from the engine. The hot water or steam can be used for process needs, building heat, to heat potable hot water, or to generate chilled water in an absorption chiller. Reciprocating engines are typically more efficient than combustion turbines in smaller applications less than 3 MW. Industrial uses of reciprocating engines include metal plating and food processing.

Combustion Turbines. Combustion turbines can provide higher quality heat than reciprocating engines with available steam pressures exceeding 650 psig. The steam produced can be used for process needs, building heating or in double-effect[2] absorption chillers to produce chilled water. As a class, at least in the smaller size ranges, their heat rates are higher than for reciprocating engines. Some manufacturers are developing combustion turbines with recuperation and efficiencies that approach 40%.

Micro Turbines. A micro turbine is a small combustion turbine (not larger than 100 kW). Turbine speeds exceed 50,000 revolutions per minute (rpm) and sometimes exceed 100,000 rpm. This keeps their size small. However, because they are intrinsically inefficient, micro turbines are equipped with recuperators.

In CHP analyses, the micro turbine performs like the reciprocating engine, but with a slightly higher heat rate. Micro turbines have fewer parts, which, in theory, should make them cheaper to build and maintain. However, manufacturers are anxious to recover micro turbine development costs so purchase costs remain stubbornly high. Maintenance cost will eventually decrease as manufacturers understand what those costs will be.

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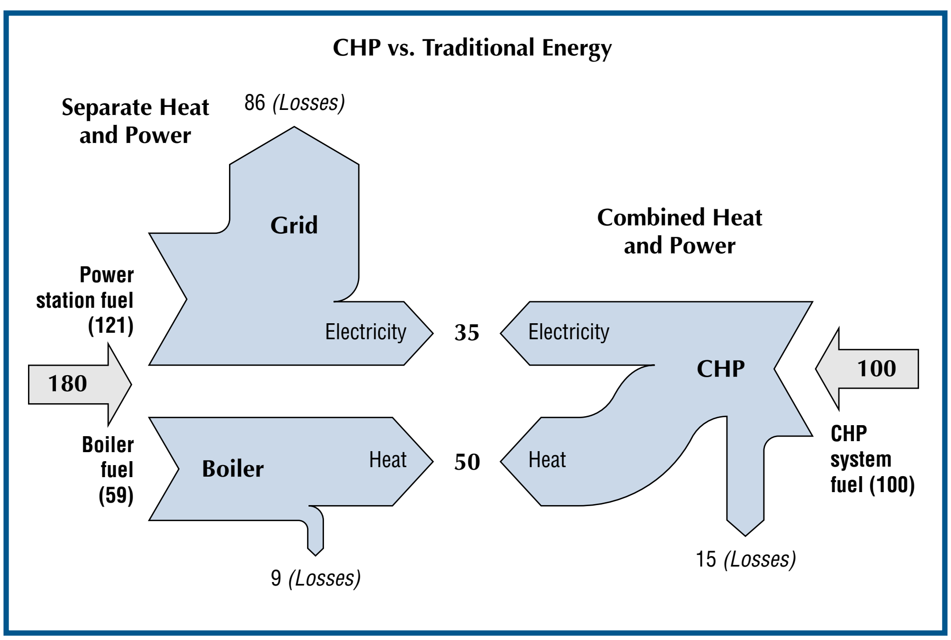

U.S. CHPA—Source: Kaarsberg 1998

CHP losses compared to traditional energy losses.

Distributed Generation Challenges: Air Quality, Siting, Permitting

By Shirley F. Rivera, Principal, Resource Catalysts, San Diego, CA

The following is condensed from the author's paper, which appeared in the Association for Energy Engineer's Strategic Planning for Energy and the Environment, *Winter 2000-2001 issue. It appears here with the publisher's permission.*

Several environmental, engineering, and social issues affect successful siting of distributed generation (DG). Addressing issues prior to equipment operations can include obtaining siting, construction, and operating approvals from multiple regulatory and governmental agencies, and possibly undergoing public review and scrutiny. The level of agency involvement typically depends on the extent of a source's environmental impact. Specific siting issues can arise that may result in project start-up delays, costly permitting, and project cancellation.

Siting Issues

With the ongoing electric utility restructuring, DG is being positioned in the marketplace as an option for the traditional central power plant energy suppliers, as well as a source of reliable and cost-effective energy supply. Since January 1998, there have been numerous regulatory initiatives and the emergence of several organizations focused on the market placement of DG.

The issue of air quality impacts is particularly critical within the context of fossil fuel-fired technologies, as well as those DG technologies that may directly replace or displace fossil fuel-fired technologies. Air quality requirements and procedures vary from state to state. Because permit requirements are dependent on emissions impacts, the type of DG technology and application will determine the complexity of permitting and regulatory scrutiny.

Project Planning

The issues affecting DG siting and permitting include environmental, energy, and social issues. *Environmental issues* include regulated media, plan or permit approvals, and compliance mandates; *energy issues* include engineering considerations; *social issues* include community concerns and economic considerations.

Projects become complex because approvals must be obtained by various local agencies, and because of the need to work with the local distribution company to ensure proper and safe interconnection. Additionally, nearby residents and other businesses may be involved in public review and comment of a DG installation.

Prepare, Execute, Communicate

Because requirements vary from agency to agency, understanding what requirements must be met involves planning to reduce the potential for project delays. To minimize the uncertainty associated with DG source installation approvals, a three-part approach is to prepare, execute, and communicate.

Prepare: Understand the Issues, Agencies, and Regulations. Prior to formally proposing a DG installation to local agencies, identify potential siting and environmental issues, direct (and oversight) approval agencies, and the applicable regulatory requirements. At this stage, potential environmental impacts/consequences should also be identified in case they must be mitigated or controlled.

One of the most overlooked factors in project preparation is consideration of the affected local community and their acceptance or rejection of a DG installation. Preparation of the rollout of a DG project should involve identifying community members who might be affected.

Execute: Scope, Compile Information, and Do Your Homework. As part of the project execution, scope out the issues and barriers and develop contingencies. This involves a more thorough evaluation of the information gathered in the preparation stage. Given the multiagency involvement, different approval criteria, and review time frames, the appropriate information for approval processes, forms, fees, and necessary equipment/operations should be identified and completed. One approach is to work closely with the approval agency prior to submitting any application.

Finally, given that many agencies' actions are through public entities, take advantage of lessons learned by other DG project efforts. At a minimum, agencies' records can be petitioned for review and copy. The first-hand experience of others may provide insight to the siting hurdles that were overcome.

Communicate: Identify the Target Audience, Speak a Common Language, and Compromise. Throughout project planning and execution, understand the target audience. Although it is not necessary to undertake an extensive public affairs effort for certain types of DG installations, it is necessary to understand what information should be readily available to properly characterize and present a project.

Too often the characterization of a project is in technical terms, which may confuse rather than properly inform agencies and the public. Preparing information that speaks to the affected parties can greatly minimize confusion, resulting in a more streamlined review and understanding of project benefits.

As part of project impacts communication, negotiation strategies should be developed to address potential regulatory (and public acceptance) barriers.

Air Quality Permitting and Regulatory Issues

There are several considerations with respect to air quality regulatory compliance issues.

- **Exemption/permit thresholds—whether a DG source triggers permit requirements.** Permit exemption levels may exist for relatively small, low-emitting operations. For example, gas turbines less than 0.3 MW are exempt from permitting in several California air districts. In other areas of the nation, sources with emissions of less than 5 tons per year may be exempt.
- **Regional air quality—whether the site is in an attainment or nonattainment area.** Sites in nonattainment areas (e.g., areas where a pollutant concentration exceeds an ambient air quality standard) have more rigorous permitting requirements.
- **Facility/site characteristics—whether the site is an existing or new facility that is considered a minor or major source.** The addition of a source to an existing major source (e.g., "major" as defined by an air agency is based on a site's total tons of emissions per year) can result in more rigorous permitting requirements.

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Report Assesses On-Site Power Potential for Industry

The potential for on-site power generation in the nine most energy-intensive U.S. industries, OIT's Industries of the Future (IOF), is the subject of a recent report prepared for OIT. On-site generation can reduce energy costs, help a facility comply with environmental regulations, and ensure a reliable power supply. Electric market restructuring and its effect on pricing and reliability are creating strong interest in this subject.

The report covers existing and potential on-site generation; combined heat and power (CHP) and its potential, its economics, and its environmental benefits; barriers to on-site generation; and policy and technology recommendations.

Here are a few highlights from the report.

- Existing on-site generation capacity in the industrial sector (not including emergency generation) is more than 45,000 MW, the vast majority of which is in CHP plants.
- The remaining potential for on-site generation in the industrial sector is estimated at 140,000 MW. The IOFs represent 79% of this potential.
- The remaining CHP potential is estimated at 88,000 MW, with 69% of that in the IOF realm.
- If the full potential for CHP were realized, it would result in a 70 million metric ton reduction in carbon equivalent emissions—equivalent to approximately 285 million tons of carbon dioxide.

To learn more, see the full report, which can be ordered from the Energy Nexus Group. Please contact Kathy Gallagher at kgallagher@energynexusgroup.com, or by phone at 760-710-1671. ●

Distributed Generation Challenges
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- **Project/equipment composition—whether there is one unit or multiple units at a site.** Cumulative emissions impact of multiple units may need to be considered in the permit evaluation versus the impact of each individual DG unit.
- **Emissions impact—whether criteria and air toxic pollutants have an impact on nearby communities.** Air quality modeling or the evaluation of public health impacts may be required, particularly for diesel fuel-fired operations.

Conclusion

DG sources can be sited, installed, and operated. By proper planning, evaluation of economic impacts and facility operations, and compliance with the local agency requirements, approvals can be obtained. Consideration must be given to the numerous siting issues and the roles of multiple regulatory and governmental agencies and the public when planning any DG project installation.

To view the full text of this excerpt, please log on to Energy Matters Extra ***www.oit.doe.gov/bestpractices/energymatters/emextra.***

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Opportunities for CHP
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Fuel Cells. Although they offer excellent potential for efficiency and emission reductions, fuel cells face many technological hurdles. Mass producing small reformers needed to create pure hydrogen to fuel proton exchange membranes (PEM) has been a challenge for the industry. Meanwhile, solid oxide fuel cells do not require fuel conditioning, but the fuel cells are difficult to manufacture. The good news is that they are very efficient (around 50%) and are being tested with micro turbines to develop a high-efficiency hybrid cycle (65% to 75%). For the near term, there is some good news emerging from the effort to develop molten carbonate fuel cells. Developing the technology, though, is still very challenging.

The Case for CHP

Although capital-intensive, CHP can be an effective way to manage energy. The following example gives estimates of costs and potential savings that an industrial plant could realize by installing a 4,900-kW combustion turbine to produce steam. Such a CHP plant might be found in a paper mill. The value of the power generated is in the savings obtained when the power is not purchased from the electric utility. The value of the steam is in the boiler fuel not purchased from the local gas utility. The primary operating cost is the turbine fuel. The power avoided is worth approximately 10.8 cents per kilowatt-hour (kWh) and the customer's net cost of generation (considering the savings from CHP) is around 4.7 cents per kWh.

Estimated Costs and Savings for CHP Installation

Combustion turbine capacity	4,900 kW
Annual value of power generated[3] (less standby charges)	$4,635,000
Annual value of steam raised	$1,544,000
Annual fuel cost	($3,324,000)
Annual maintenance cost	($258,000)
Energy cost savings	$2,597,000
Estimated first cost	$5,700,000
Simple payback	2.2 Years

CHP is serious energy management. Proven technology exists today that can reward the investor with returns not found elsewhere in the plant. Technology is evolving that promises even better efficiencies and more cost-effective CHP for smaller applications. Additionally, application of CHP could help industrial plants achieve societal goals for improved environmental performance. However, like other capital-intensive energy management, CHP requires regulatory stability to attract investment and mitigate barriers.

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[1] An adjustment is also made for the line loss that occurs when getting power from the utility's generating station to the customer's site.

[2] The two types of absorption machines are single-effect and double-effect. Single-effect uses twice the heat to produce the same amount of chilling as the double-effect. However, the single-effect machine can use low-quality heat, but the double-effect machine requires high-pressure steam (>100 psig). Double-effect absorbers cannot be used with reciprocating engines.

[3] Analysis is based on Southern California Edison's TOU-8 (Secondary) electric tariff.