# How To Improve Reliability In Cogeneration and Steam Systems

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## ABSTRACT

Traditionally, steam and electricity have been produced separately; steam at industrial plants and electricity by utilities. Cogeneration (or combined heat and power—CHP) is the concurrent production of electrical power and thermal energy from the same heat source. Cogeneration reduces electric utility bills and environmental emissions while still providing thermal energy for industrial processes. Many different systems combining boilers and turbines are possible.

Newer technologies are making cogeneration opportunities available to smaller-sized thermal plants, and electric utility deregulation opportunities are causing many CEOs to seriously consider cogeneration in their manufacturing plants.

Whether steam is created through cogeneration or separate generation, many opportunities exist to improve productivity in the distribution system, operation, and maintenance. These opportunities are captured by taking a systems approach to steam system improvement, which can be facilitated with resources like those offered by the Department of Energy's Best Practices in collaboration with the Alliance to Save Energy and private companies.

Leading industrial companies and institutions are forever seeking new and better ways to reduce their expenses, reduce waste, meet environmental standards, and, in general, improve their bottom line. One approach to achieving all of these goals is a 100-year-old concept, cogeneration.

Many industrial and institutional plants need thermal energy, generally as steam, for manufacturing processes and heating. They also need electric power for motors, lighting, compressed air and air conditioning. Traditionally, steam is produced with industrial boilers and electricity is purchased from a local utility company. However, these needs can be met at the same time with cogeneration, using the same heat source.

Cogeneration is the concurrent production of electrical power and thermal energy from the same heat source. Large steam users commonly take advantage of cogeneration by using high pressure steam with a back pressure turbine to generate electricity, and extract lower pressure steam from the turbine exhaust for their process needs. This approach reduces electric utility bills while still providing thermal energy for industrial processes. The result is a more efficient process that uses less total heat and discharges less smoke up the stack. Newer technologies are making cogeneration opportunities available to smaller-sized thermal plants, and electric utility deregulation opportunities are causing many CEOs to seriously consider cogeneration in their manufacturing plants.

The steam generation cycle alone has a *typical* thermal efficiency of approximately 80 percent, depending on system loads, the fuel utilized, and the heat traps designed into the back-end of the boiler. Industrial boilers and utility boilers can achieve these efficiency levels while producing steam for their respective applications. Note that this efficiency level does not take into account the efficiency of the applications using the process steam or the efficiency of the steam distribution system.

The steam turbine generators used by electric utilities require moderately high steam pressures and temperatures, with levels ranging as high as 4,400 psig and 1,100°F respectively. This is expanded down to approximately 20 to 25 in Hg vacuum and 90°F to 100°F in the condenser, where the "latent heat of vaporization" is removed and discharged to the atmosphere, lakes, or rivers.

Industrial processes use lower pressure and temperature levels, from approximately 1,000 psig and 750°F, and ranging down to 150 psig and 366°F (saturation temperature). And finally, the lowest heat intensity level processes are the heating systems where pressures and temperatures of 15 psig and 250°F are frequently utilized.

## THE BEST OF BOTH WORLDS: COGENERATION

Cogeneration derives its efficiency by placing the processes in series so that the heat intensity can cascade down through the various processes from a high level to a lower level, on to a lower level, and ultimately to ambient conditions. In utility power plants, opportunities for heat recovery for process rise in the utility thermo-electric power station are at various extraction points along the steam turbine or at the condenser, where low temperature steam is condensed back to water for supply to the boiler feed pumps.

In industrial plants, opportunities for power generation fall in series with the process steam requirements. Opportunities for heat transfer fall in front of the process steam (between the combustion temperatures and the process steam temperatures.) Thus, it is much more efficient to have the boiler operate at high pressures and temperatures feeding a high pressure steam turbine, and the exhaust of the turbine serving as the supply to the low pressure industrial steam process, as shown in Figure 1-B. Also, it is more energy efficient to have the high-energy intensity combustion flow first to a gas turbine and, in turn, exhaust into the boiler, as shown in Figure 1-D, rather than to fire directly into the boiler.

Most thermo-electric steam power plants operate in the range from 30% to 40% efficiency depending on the throttle pressure and temperature, the number of reheater loops, the number of feedwater heaters utilized, and the type of heat traps utilized on the boiler. The gas turbine driven electric generator has historically operated in the high 20's to 30%, but with today's high gas temperatures and compressor outlet pressures the efficiency is ranging upwards of 35%.

The latest utility power plant designs utilizing a combined cycle (a form of cogeneration) have high heat intensity gas power turbine's exhausting into heat recovery boilers. Steam from these boilers then feed a moderate heat intensity steam turbine generator. The combined operating efficiencies are in the 55% to 58% efficiency range. There are prototype designs being tested that exceed 60%.

However, modern industrial steam-electric cogeneration systems **can boast overall thermal efficiency levels to an enviable 80-85 percent** by recapturing enough waste heat from electricity-producing gas turbines to meet a portion of the industrial process requirements.[1]

Figures 1-A through 1-G show various simple generation cycles, and popular combined cycles.

Typically, cogeneration facilities for industrial or institutional users are much smaller than conventional electric utility plants, and are often built on-site for industrial plants. Typical users are college and university campuses, hospitals, municipal heating systems, and large commercial buildings. In addition to achieving high system thermal efficiency, steam-electric cogeneration systems can, if designed properly:

- enhance the reliability of the power supply by having some generating capacity on site to support operations during stormy conditions, when distribution lines may be down,

- reduce fuel costs by 15 to 20 percent by extracting more energy released from the fuel when operating in the cogeneration format;

- reduce or eliminate power purchases;

- reduce overall emission levels since less fuel is being consumed for the amount of useful energy being extracted,

- perhaps provide additional revenue through selling excess power, or peaking power, to a district energy system or the utility electric grid at times of your own off-peak load conditions, or during strong marketing situations;

- maintain the high reliability of the single boiler process steam system by utilizing supplemental firing. A back-up forced draft (FD) fan is required when the gas turbine exhaust is not available for the combustion $O_2$ requirements.

In terms of emissions and dollar savings, the difference between cogeneration and separate steam and electricity generation can be significant. Typically, cogeneration cuts fuel costs (which can range from 30-40 percent of the selling price of power) by increasing the amount of "salable product" per unit of energy.

Table 1 demonstrates typical emission savings an area can achieve through cogeneration whether it burns coal, fuel oil, or natural gas. In this calculation, a 20 MMBtu/hr plant lowers the total emissions which accrue due to steam generation at the plant and electrical generation at the utility company.

**Table 1. Area Emission Differences Between Cogeneration and Separate Generation**

| Fuel | Pollutant Emission Reductions (lb/yr) | | | | Saved Fuel Value |
|---|---|---|---|---|---|
| | $PM_{10}$ | $SO_x$ | $NO_x$ | CO | |
| Coal | 18,300 | 49,500 | 203,000 | 3,260 | $55,000 |
| Distillate Oil | 415 | 8850 | 20,800 | 5,190 | $86,000 |
| Nat. Gas | 213 | 16.8 | 4490 | 11,800 | $85,000 |

Sources: Air Pollution Emission Factors, U.S. EPA Document AP-42 and Environmental Impacts of Steam Loss Chart, Armstrong International, 1998.

Avoided emissions may become a commodity in themselves, either directly or indirectly through payments from the utility.

Total annual emissions savings exceed 270,000 pounds for coal. 35,000 pounds for fuel oil, and 16,000 pounds for natural gas. The value of the saved fuel ranges from $55,000 using coal to $86,000 using fuel oil. These savings are derived simply through the improved efficiencies of cogeneration.

## History

Cogeneration is not a new process; it's been in use over 100 years. However, public policy toward cogeneration has been a mixed bag of incentives and barriers. The Public Utility Regulatory Policy Act

(PURPA) of 1978 renewed interest in cogeneration by addressing market barriers to "off-site" electricity production. Under PURPA, electric utility companies were required to purchase any electric power produced by cogenerators at the same rate local utilities would have paid to generate it themselves.

Starting in 1983, capacity in cogeneration grew at an average annual rate of 11 percent. This growth rate would have been greater if not for the complex environmental permitting, high "firm" power backup rates, and costly interconnection fees that PURPA did not address.

Growth in cogeneration slowed in the 1990s due to these and other PURPA complications. More recently, the 1992 Energy Policy Act (EPAct) helped cogenerators and other non-utility generation facilities break into the electricity market by requiring that utilities provide power transmission service to industrial cogenerators at a cost-based rate.

**In spite of the mixed message, cogeneration represents over half of all new power plant capacity built in North America in the last 10 years**.

This includes the combined-cycle power generating plants installed by utilities and independent power producers (IPPs), as well as cogeneration by industrial companies and institutions. As of 1994, it accounted for 6 percent of total U.S. electricity-generating capacity, and of the electricity actually generated, 9 percent came from cogeneration.

Cogeneration's future looks both bright and dark. Lower demand for electricity and increased utility resistance to industrial cogeneration are expected to diminish the prospects of seeing any new incentives for installing cogeneration.[2] However, utility deregulation and increasing concern about climate change are raising questions relative to the long-term availability and reliability of conventional power. These concerns and the availability of new low-cost generating technologies have piqued the interest of industrial and commercial customers with high thermal loads, high electricity rates, or both.

Deregulation of the electricity market could open the door for renewed growth in cogeneration, but lots of potential utility and permitting barriers still remain. Since most of the deregulation action is taking place at the state level, some time will pass before the full effect on cogeneration is felt across the nation.

The deregulation opportunity is expected to present itself in two important areas: increased competition and increased marketability of low cost cogeneration-produced electricity.

This difficulty will vary across the country as electricity rates vary. Marketability of cogenerated power will increase because cogenerators will be able to sell excess power to customers other than their local utility. That means be able to sell electricity to industrial cogenerators will be able to sell electricity to the public, to other industrials, to power brokers, and to distribution companies by wheeling it to them through the local utility's distribution system. Retail wheeling will be especially attractive in areas with very high electricity rates.

## Types of Cogeneration Systems[3]

There are three basic types of cogeneration systems, categorized by the "prime mover" of the system: engine-based, steam turbine-based, and gas turbine-based. Each is briefly characterized below.

### Engine-based System

Engine-based systems use an internal combustion engine to power a generator. Waste heat is reclaimed by sending exhaust to a steam generator, and by extracting heat from the engine and oil cooling systems. Since engine-based systems are only capable of producing low-pressure steam, they cannot be used by industries requiring pressure over 30 psig.

Of the three major types of cogeneration, engine-based systems possess the highest power-to-steam ratio.

- Power-to-steam ratio: > 1
- Size range: 10 kW-16 MW, typical size: 1 MW
- Usable fuels: Gasoline and oil

Engine-based cogeneration systems can suffer from breakdowns, thereby raising their operating and management costs, and increasing the costs of firm power back-up from local utilities. However, they have fairly low capital costs, simple operating and repair procedures, and good load-following ability. In terms of emissions, diesel engines produce substantial amounts of nitrous oxide ($NO_x$) and particulates while natural gas engines emit unburned hydrocarbons. Both types, however, emit low amounts of carbon monoxide (CO) and sulfur dioxide ($SO_2$).

## Steam Turbine-based System

The steam turbine-based system relies on a conventional boiler to generate high-pressure steam, the basic set-up is shown in Figure 1-A. However, in the cogeneration arrangement the high-pressure steam is expanded across a high-pressure turbine and the exhaust is routed to the process steam header (see Figure 1-B). The high-pressure turbine generates electricity while functioning simply as a pressure-reducing valve, providing the desired steam conditions to the process or heating system.

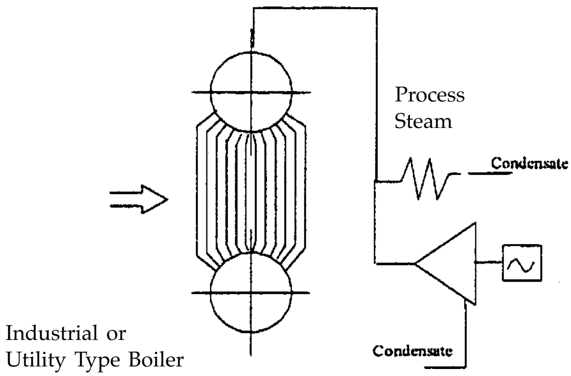


**Figure 1-A. Steam Boiler**

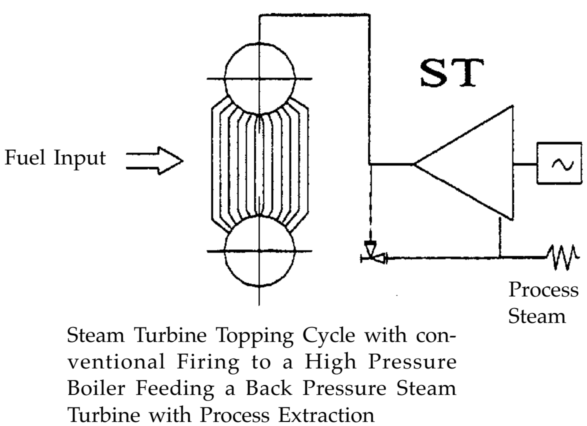


**Figure 1-B. Boiler with Backpressure Turbine**

The electrical power is generated at very high levels of thermal efficiency (95-96%), as there are no losses to the condenser. This is referred to as a **backpressure** turbine.

- Power-to-steam ratios: 0. 1-0.2
- Usable fuels: Gas, coal, oil, natural gas, biomass, wood, municipal solid waste, or industrial waste.
- Size range: 10 kW-400 MW, typical size: 10 MW

**Back-pressure steam turbine-systems** are good producers of heat, but low power producers. Therefore, they are particularly useful where large amounts of steam (a large thermal load) and moderate amounts of electricity (a low electric load) are needed. This system also allows for large electrical drive motors to be replaced with backpressure turbine drives, thereby replacing electrical consumption with steam at approximately 90% efficiency. The steam turbine drives are durable, reliable, and good load-followers. Overall emissions depends on the fuel used to fire the boiler. Coal and biomass produce $NO_x$, $SO_x$, CO, and particulates, while oil and natural gas produce $NO_x$ and CO.

## Gas Turbine-based System

Figure 1-C presents a simple cycle gas turbine system, which uses a conventional combustion turbine to generate electricity. In the cogeneration cycle, the exhaust from the gas turbine is fed to a thermal process, such as a heat recovery steam generator, to produce steam (Figure 1-D).

- Power-to-steam ratios: 0.6-1.0
- Usable fuels: natural gas and oil
- Size range: .02 MW-300 MW, typical size: 5 MW

Gas turbines efficiently produce power and heat for steam in concert and are therefore very attractive for cogeneration uses. However, they require a high-quality fuel, are poor load-followers, and their technical complexity requires specially trained staff to maintain them. In place of in-facility staff, smaller units can be offered with maintenance contracts and spare units kept available for quick changeouts.

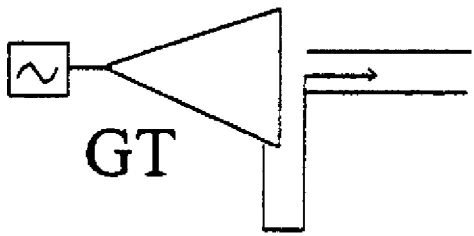


**Figure 1-C. Gas Turbine Generator**

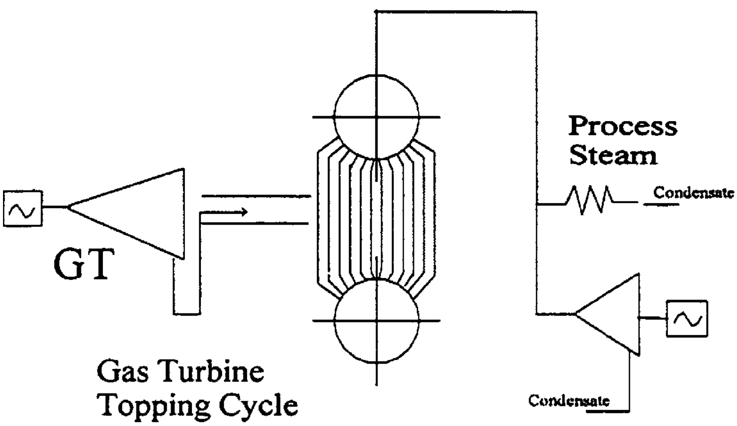


**Figure 1-D. Gas Turbine with Heat Recovery Steam Generator**

## *Balancing Electrical and Process Thermal Loads*

In many cases, the load requirements for electricity in the gas turbine topping cycle do not match the steam process load requirements as planned. The best solution for this is to size the gas turbine for the minimum consistent thermal load expected. Supplemental firing of the boiler is used to meet the peaking requirements of the process.

In this manner, the turbine generator operates at full load (its best efficiency point) nearly continuously; and the boiler can take load swings as required with supplemental firing. In reality the turbine generator (GT) could be operated like a peaking unit if so required by the electrical grid. Supplemental firing also increases the reliability of the process steam, as the burners can pick up the input requirements to the boiler if the GT shuts down.

The same can be said about the reliability of the steam turbine topping cycle, but the solution is very easy. Simply install a pressure-reducing valve in parallel with the steam turbine, and by-pass and de-superheat the steam as needed, for feed to the process, when the steam turbine is down for maintenance or if the grid load is such that the electricity isn't needed.

Various elements of these systems can be combined depending on power and steam needs. For example, a combined-cycle gas turbine system could divert all or part of the steam generated to turn a steam turbine for more electricity (shown in Figure 1-E), which can boost the power-to-steam ratio to the 1.5 range. Thus, when the process thermal load is down, the steam can be used for peaking power.

## *Popular Combined Cycles*

Currently the most popular power generation cycle utilizes the gas turbine generator. The gas turbine starts off with the highest heat intensity of any of these cycles with the gas fluid pressures and temperatures being in the range of 40 atmospheres and at 1800°F to 2300°F respectively, as it enters the turbine rotor to do work. In those systems where gas turbines are utilized, best plant efficiency is achieved when the gas turbine is sized to meet a facility's base thermal load, with additional

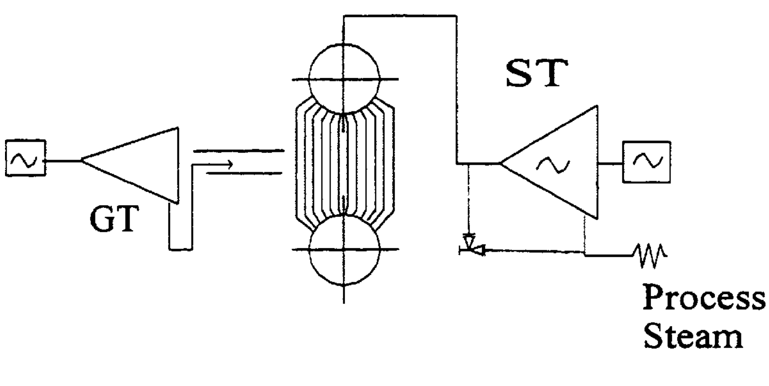


**Figure 1-E. Combined-Cycle Gas Turbine System with High Pressure Heat Recovery Boiler and Steam Turbine**

steam needs being met by a package boiler.

Alternatively, the heat recovery boiler may be provided with supplemental burners (Figure 1-F or 1-G) which does three things to reduce capital costs and improve efficiency; 1) it avoids the cost of an additional stand-by boiler, and 2) it reduces the size and cost of the gas turbine, and 3) the boiler combustion process utilizes the hot $O_2$ in the turbine exhaust gas thereby increasing the efficiency of the cogeneration cycle and further reducing pollution. Another alternative to sizing cogeneration to match a low thermal baseload in the summer time, is to install absorbers in the system, such as air conditioning, that will maintain steam usage levels when the heating load is down.

Frequently, the plant design is sized for the maximum electric load and the industrial process takes the steam it needs when it needs it. The balance of heat is dumped to waste, either lowering the cycle efficiency during low process loads, or causing power generation when grid loads are at their minimum but process steam demand is high.

There will be times when the turbine generator is down and the process must go on, and other times when electrical power demand is low or not competitive, and process thermal load must be served. Almost every cogeneration system needs an alternative source of thermal energy, either by supplemental firing with a back up FD fan, or a separate package boiler.

To obtain the best year-round cycle efficiency the plant design should be based on the thermal cycle, and electrical power production should be treated as a by-product. Gas turbine efficiency drops off quickly with load, so it should be sized to be at full load when the heat

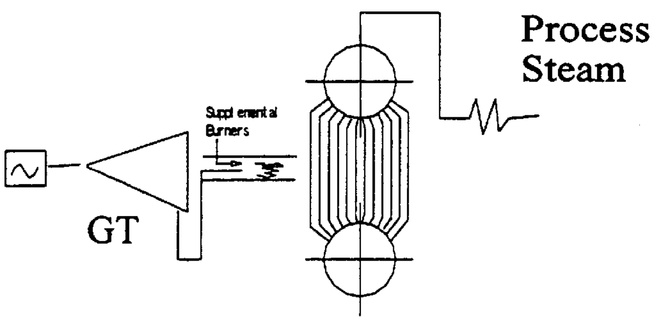


**Figure 1-F. Gas Turbine with Supplemental Firing**

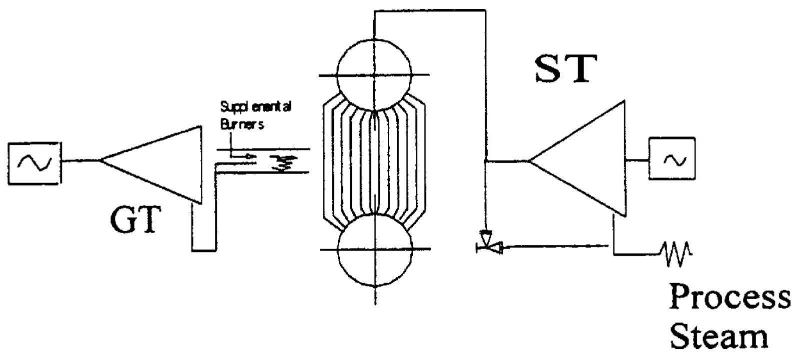


**Figure 1-G. Model Gas Turbine System**

recovery boiler is at its base load. Since the boiler operates at near 80% efficiency, supplemental firing for the peak thermal cycles does not significantly harm the overall plant efficiency. In fact, the supplemental firing enhances the efficiency by burning the $O_2$ out of the turbine exhaust gas, which in turn reduces the dry gas loss at the stack discharge.

## IS COGENERATION RIGHT FOR YOU?

Historically cogeneration was only applicable for industry and institutional users where relatively steady electrical and large steady thermal loads were present. These systems typically used the steam turbine topping cycle with the turbine exhaust supplying steam to the process header.

However, with today's technological developments in small gas turbines, along with the use of supplemental firing to support thermal peak loads swings, cogeneration is an economical and practical choice for a broad range of thermal energy users. The small gas turbines are efficient, responsive, and can be set up to be fully automated in synchronization and operation. The supplemental firing allows the operator to maintain high thermal efficiency and reliability throughout the full thermal load range of the process.

These characteristics make cogeneration attractive to small energy users as well as large process industry users. As cogeneration attracts a larger base of applications there are significant implications for improved energy efficiency and reduced environmental pollution.

**Testimonial on Combined Heat and Power**

"Trigen-Cinergy Solutions (TCS) signed a 15-year contract to install a 10.4 megawatt combined heat and power (CHP) plant and to operate the electrical and steam generation plant at Millennium Inorganic Chemicals' Hawkins Point Plant… 'This project is an important step in increasing the overall efficiency and cost effectiveness of the operation at the Hawkins Point Plant.'"

*John Davis*
*Millennium Chemical*

Source: Trigen Project News Release, Dec. 16, 1998.

**Industries that use consistent, simultaneous quantities of both electricity and steam with relatively high energy costs are the best candidates for cogeneration adoption. These often include food processing, chemical manufacturing, primary metals, commercial laundries, drywall manufacturers, and paper mills. The key to success of these systems is the ability to match the size and loads of the combined electric and steam systems.**

However, a perfect fit is not likely to happen, and the system must be properly sized and engineered to achieve maximum efficiency, reliability, and operability. Numerous combined cycles have looked quite good on paper, only to fall short of their goal because the load requirements of the two systems didn't match as planned.

## Facilities Well-Suited for Cogeneration

The facility must not currently be losing a significant portion of its generated steam and electricity through leaks and poorly designed systems. Distribution systems which lose significant amounts of steam will lead to inappropriate evaluations and an incorrect basis upon which to base the cogeneration design. The first money spent should be invested in effective operations and maintenance practices to be the most productive. **Cogeneration is not a substitute for good operations and mainte-**

**nance practices.**

Demand for both steam and electricity should be year-round and have an acceptable mix of loads over the course of a day. Energy profiles over time should be constructed to illustrate day/night and winter/summer fluctuations. A supplemental source of thermal energy is a necessity if a gas turbine topping cycle is being considered.

If the gas turbine is sized for full thermal load there most certainly will be times when there will be a mismatch in electricity demands or thermal loads, such that either heat will have to be discarded, or electrical energy demands will not be met. Since the turbine generator is the most expensive part of the cogeneration equipment, it is wise to size it small (for the consistent thermal load) and to meet higher thermal cycles with supplemental equipment.

**Support of the facility's utility company is key. The utility company can be helpful in evaluating the feasibility of cogeneration, the needs for back-up power, and the requirements for interconnection and selling excess electricity.[4]**

With utility deregulation around the corner, there are three primary strategic options posed to plant decisionmakers regarding energy production and their energy future:

## Strategy #1: Continue Current Operation

This continues the traditional operating procedure, using the thermal powerhouse and on-site utility systems, and procuring electrical resources from local utilities, or third-party brokers. Due to inadequate time or resources, no new actions are taken to improve the performance of the powerhouse or steam distribution system.

## Strategy #2: Optimize Thermal Performance

The next option assesses the plant's thermal needs and capacity and identifies cost-effective opportunities for improvement. Initially, this involves a review of operational improvements.

- SPOTLIGHT: Bethlehem Steel Corp. (BSC), the second-largest producer of steel in the United States, was looking for opportunities to improve the performance of one of their steam turbine generators at its Burns Harbor Facility in Indiana. Generator system capacity and efficiency were increased by rebuilding the turbine to incorporate the latest steam path technology, using a portion of the warm condenser cooling water exhaust stream instead of cool lake water for boiler feedwater makeup, and injecting the low-pressure steam previously used to heat the lake water into the turbine. **This project resulted in annual savings of approximately 40,000 MWh of electricity, 85,000 MMBtu of natural gas, and nearly $3.3 million, with a simple payback of just over one year.**

Ultimately, this strategy may involve the installation of a more efficient heat cycle available with today's technologies to provide thermal energy, electric power, and other services. Improvements under this strategy could include installing a cogeneration system. Excess electrical energy might be marketed to a local utility's adjacent customers, or to power brokers.

## Strategy #3: Sell Off the Powerhouse

The last option is divestiture of steam/electric energy to an energy-services provider. This farms out energy production decisions to a third-party.[5] Under this strategy, all of the plant's energy needs are provided by the third-party provider under an energy services contract which takes responsibility for the operations of the energy producing equipment on site.

In order to maximize their profits, the new owner seeks to provide those energy services in the most efficient manner possible. Ownership of energy generation equipment and the method of sharing savings will vary depending upon the contract agreements.

- SPOTLIGHT: Trigen Energy Corporation and Nations Energy Corporation of Orlando, Fla., have completed the purchase of all energy production assets from Coors Brewing Company in Golden, Colorado, and signed an agreement to sell electricity and steam to the world's largest single-site brewery. Trigen/Nations will upgrade the Coors' power plant to increase electric capacity from 40 megawatts to 77 megawatts while reducing overall coal use by 9 percent and air emissions by 10 percent.[6]

**Coors received a cash payment of $22 million and will avoid an estimated $40 million investment in facility upgrades, by buying electricity and steam from Trigen/Nations. This allows Coors to focus on production and the brewing process.**

## SYSTEMS THINKING

When considering which option to take, "systems" thinking offers the most advantageous way to operate a plant. Systems thinking involves looking at the overall plant resource and energy consumption and production to determine the areas in greatest need of optimization. In incorporating systems thinking, it is useful to borrow a tool from The Natural Step (TNS).[7] TNS has a framework based on simple thermodynamic-based principles and has developed several tools as guides to develop business toward a sustainable future. One of these tools, the Compass, entails:

1) Assessing your current inputs, outputs, and operating practices

2) Visualizing how you would like to be operating decades down the road

3) Formulating a path to get you to this desired level by changing practices, policies, and operations.

The Compass can be applied to cogeneration. Ideally, a plant should be operating as close as possible to 100 percent cost-effective efficiency—making maximum use of resources and minimizing input costs. In achieving maximum cost-effective efficiency, cogeneration can be an integral part of the process. In order to reach your goal, the current state of practices and operations must already be conducive to making the move to cogeneration.

## BESTPRACTICES

Opportunities for better system performance also exist after the generation stage. No matter which of the three primary energy production strategies you choose to produce steam and power, improving the efficiency of process operation and steam distribution are always important for best productivity. BestPractices, a new program offered by the U.S. Dept. of Energy's (DOE) Office of Industrial Technology (OIT), offers resources specifically designed to do this in collaboration with the Alliance to Save Energy.

Like cogeneration, BestPractices aid facilities in increasing reliability, productivity, cutting costs and reaping the environmental benefits of better energy management. Its goal is to increase US industrial energy efficiency by helping industry adopt a systems approach in designing, purchasing, installing, and managing boilers, distribution systems, and steam applications among other systems.

**Table 2. Steam System Efficiency Improvement Potential**

| Steam System Area | Potential % improvement | Total system improvement |
|---|---|---|
| GENERATION | | 2-5% |
| Boiler tune-ups | 1-2% | |
| Heat recovery equipment | 2-4% | |
| Emissions monitoring/controls | 1-2% | |
| DISTRIBUTION AND MAINTENANCE | | 15-20% |
| Steam traps | 3-5% | |
| Steam Leaks | 10-15% | |
| Insulation | 5-10% | |
| Water treatment | 10-12% | |
| RECOVERY | | 10-15% |
| Condensate return | 10-15% | |
| Total | | 20-30% |

The fuels generating industrial steam release approximately 140 million metric tons of carbon dioxide and other gases while producing steam.[9] These emissions represent over 30 percent of all U.S. industrial emissions of carbon dioxide and over 10 percent of total U.S. emissions.

A goal of 20 percent efficiency gains in typical steam systems means over 1.4 quadrillion Btus (1,400 trillion) of energy, as well as approximately $4.0 billion in steam generation costs, could be saved industry wide. This includes prevention of 30 million metric tons of carbon emissions and 11 thousand metric tons of nitrous oxide emissions. **Again, these savings are primarily in addition to those which wider implementation of cogeneration projects might provide.**

Because steam system losses in one area can have a significant impact in other areas (e.g. distribution leaks altering boiler and downline equipment operation), steam system efficiency potential is defined as the total of all cost-effective efficiency opportunities in steam generation, distribution, application, operation, and maintenance throughout the system. The Alliance estimates this potential to be 20 to 30 percent in a typical industrial plant.[8]

Table 2 shows the specific areas in steam generation, operation and maintenance, and distribution where efficiency gains can be made. Often the bulk of the improvement can be in the post-generation stages, i.e., system operation, maintenance and the distribution system. However, poorly maintained boilers can provide robust savings, not to mention cogeneration opportunities.

## RESOURCES AND OPPORTUNITIES

There has been little public information that describes how these various technologies work together and affect the performance and efficiency of a total steam system. For plant managers and operators, the Department of Energy's BestPractices offers assistance through a network of training workshops, educational documents, an information Clearinghouse with a hotline and technical experts **(800-862-2086, steamline@energy.wsu.edu)**, and a web site **(www.oit.doe.gov/bestpractices/steam)**.

Steam-system equipment provider companies, university energy institutes, energy service groups, and industry users form a steering committee to direct steam resource development and marketing. Other companies participate in BestPractices in many different capacities, including: co-sponsoring case studies and workshops; disseminating products and information; contributing technical data, and providing expertise in product development, marketing, or training. This active participation mutually benefits both DOE and companies by ensuring tools and resources reach plant operators and managers, while lending credibility and strength to the private company's work.

## Demonstrations

Cost-sharing up to $75,000 is available for companies willing to undergo an energy profiling of their plant and release their data to the Dept. of Energy for development of a case study. Through this cost-sharing agreement, technical assistance and the opportunity to see the benefits of new technologies is also available. The company has the final decision on case study publication.

Case studies at Bethlehem Steel, steam distribution work at a Georgia-Pacific plant, a BWX Technologies system overhaul, three system upgrades from the Chemical Manufacturers Association, and a petroleum plant controls installation illustrate savings opportunities.

## Training and Workshops

To identify curriculum requirements to comprehensively cover entire steam systems, a summit of trainers was held in December of 2000. A list of commercial training workshops for better steam system management has been compiled and is on-line at the website.

In concert with the non-profit Alliance to Save Energy, BestPractices organizes steam efficiency sessions at conferences, trade shows, and seminars to present steam management resources and experiences of partner companies.

## Materials

In addition to case studies, BestPractices materials include:

- Tip Sheets
- Databases of energy management references, software tools, industry best practices, and training
- Software for steam system scoping, insulation optimization, pump savings opportunities, and motor management
- Training courses for motors, pumps, and compressed air systems

- Council of Industrial Boiler Owners *Energy Efficiency Handbook*
- Case studies of manufacturing plants

## CONCLUSION

Each steam efficiency opportunity, by itself, may appear small compared to the potential gains with installation of a cogeneration facility. But as stated previously, cogeneration is only as good as the delivery system and operation practices surrounding the cogeneration equipment. Losses in the system will downplay the cogeneration gains. Bonuses of energy savings in steam system improvement are often inexpensive and can add up quickly compared to more significant capital and planning costs of cogeneration.

With cogeneration achieving efficiency levels over 80 percent, fuel costs and emissions are lowered and additional profits are available from the sale of excess power. Advanced design and new technology has lowered generation capacity tremendously, to the point where even small plants can feasibly install cogeneration facilities.

Cogeneration combined with the energy delivery improvements suggested here increase these benefits even more. However, before installing a cogeneration system there are several screening factors to be considered, including individual thermal profile, initial capital outlay, permitting standards, and readiness to be in the power provider business. Most important is the fact that the existing system components which will support cogeneration equipment must be running as efficiently as possible.

Cogeneration is not a substitute for efficient operations and maintenance. Steam system upgrades help industry prepare for cogeneration down the road. In addition, the same wealth of benefits accrues for improved environmental and economic performance.

**While cogeneration's future in the face of imminent deregulation remains hazy, it will continue to be a "power"ful generation option.**

## References

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5. "Determining the Future of Industrial Energy Needs in a Deregulated Utility Marketplace," conference report by Stratton Schaeffer, Council of Industrial Boiler Owners Conference on Deregulation, July 17-18, 1997, Baltimore, MD.
6. "Trigen/Nations Finalizes Contract With Coors," September 15, 1995 Trigen news release, White Plains, NY.
7. TNS is a movement that began in Sweden. It is dedicated to helping understand our social and environmental problems and moving beyond them by redesigning our interactions with our surroundings as businesses, communities, and individuals.
8. Calculated using industrial experience of the Council of Industrial Boiler Owners, steam trap manufacturers, controls manufacturers, and university research.
9. U.S. Dept. of Energy, Energy Information Administration, 1993. *Emissions of Greenhouse Gases in the United States 1985-1990*. Table B-3). Subtracted 1991 $CO_2$ total for electricity from $CO_2$ total for all of industry and multiplied by steam energy ratio to arrive at steam $CO_2$ emissions of 196 million metric tons in 1995.

## ABOUT THE AUTHORS

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covering conventional and specialty fuels, and the HRSG types.

Of particular interest now is the re-powering of the "Package" boiler, in that nearly all of the 20,000 or so units that fall within this category were designed with a "cold windbox." Without an air heater, these units are readily adaptable to the Combustion Turbine Topping Cycle. Utilizing the abundance of oxygen in the turbine exhaust as hot combustion air for supplemental firing to the boiler, the electrical and thermal loads can be managed separately. In combination with the existing FD fan, the host site has an opportunity for an upwards leap in energy efficiency and flexibility without losing the high reliability associated with a separately fired boiler.

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