Energy Efficiency Drives Environmental Efficiency Case Study of the Thermal Energy Corporation Energy Center at Texas Medical Center in Houston, Texas

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ABSTRACT

While the momentum continues to grow for renewable energy and sustainable solutions, it will likely be a long time before we are able to completely wean our energy plants from using fossil fuel. In the meantime, it is important to continue to find ways to use fossil fuel in a more efficient and environmentally sound way. This article will address an approach to integrating state-of-the-art technology to implement an on-site energy system that generates electric power and thermal energy at significantly higher efficiencies and produces lower emissions than our traditional central generation facilities. Another increasingly important benefit to on-site energy systems is the increased reliability and security an on-site energy plant brings to facilities, especially those that serve or have a critical mission, such as hospitals, data centers or command and control centers.

BACKGROUND

To appreciate the value of this project, it is also important to understand the current energy situation in the State of Texas. A recent analysis prepared by the American Council for an Energy Efficient Economy projected that over the next 15 years, Texas' population growth will continue at an annual rate of 1.7% through 2023, with the state's economy projected to grow at an annual rate of 3.2%. The Electric Reliability Council of Texas (ERCOT) reported that the current forecast is for peak electric energy demand to increase by 2.3% annually from 2007 through 2012. ERCOT predicted the state might be without sufficient generation for peak demands beginning in 2009 [1]. The greater Houston area faces the greatest challenges of any of the other regions in Texas because electricity consumption is projected to grow at an annual average of 2.2% over the next 15 years compared with 1.6% per year statewide.

Thermal Energy Corporation (TECO) operates the nation's largest campus chilled water district energy system, which serves the largest medical center in the world. TECO currently provides thermal energy utility services to 18 customer-owned institutions in the Texas Medical Center (TMC) in Houston, Texas (see Figure 1). TECO operates two thermal utility plants with a combined capacity of 80,000 tons of chilled water; 762,000 pounds-per-hour of steam; and a direct-buried distribution system of over 35 miles of piping serving over 15 million square feet of space, or approximately 75% of the facilities within the Texas Medical Center. Peak loads are projected to increase by 30% in the next 5 years and 100% in the next 10 to 15 years.

TECO has begun to embark on a major utilities system expansion that will significantly change its operations, add capacity, improve efficiency, reduce emissions, and strengthen its overall systems reliability and emergency operating capacity. By utilizing combined heat and

Figure 1. Texas Medical Center, Houston, Texas

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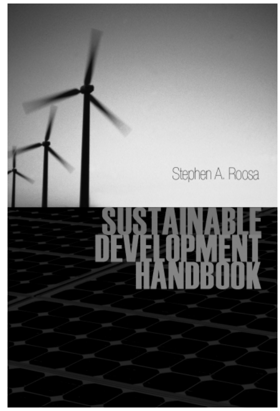

By Stephen A. Roosa, Ph.D.

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power (CHP), this expansion will allow TECO to serve the continually growing needs of its Texas Medical Center customers with significantly increased efficiency and reduced unit costs, while significantly reducing overall environmental emissions. Of equal or even greater importance, this expansion will provide significant improvements to the security and reliability of the utility infrastructure that serves one of the nation's most important medical centers. Establishment of local electric generating capacity at TECO's Energy Center will significantly increase the reliability of the entire thermal system and support the TMC during crisis situations. The importance of this necessity was recently demonstrated during Hurricanes Katrina and Rita in 2005.

The 13 county region currently has only 3 level 1 trauma centers, 2 of which are located in the TMC along with 13 renowned hospitals and 2 specialty institutions. TMC is a vital medical resource for the region and the nation in responding to man-made or natural disasters.

Early in the master plan process, TECO made the decision to make this expansion as energy efficient as possible. To accomplish this, TECO made the decision to integrate an on-site CHP plant as part of the strategy to squeeze every bit of the energy out of every Btu of fuel consumed to generate electricity and thermal energy. Very tight site and environmental permitting requirements for a generator in a non-attainment area have provided significant challenges that are being managed through an innovative approach to design and construction methodologies.

TECO PROJECT OVERVIEW

TECO's board of directors has adopted the Master Plan 2006 recommendation to use combined heat and power technology for expansion. This plan will bring different technologies to TECO and represents a significant shift in its operations. The master plan calls for phased district energy system additions to build out the Energy Center site that was recently increased in size from approximately 4-1/2 to 6-1/2 acres, see Figure 2.

With land and space in the TMC being valuable, TECO's Master Plan calls for optimum use of available space at its Energy Center site. TECO's Energy Center will ultimately increase from 56,000 tons, 720,000 pph and 14 MW on the 4-1/2-acre site to 136,000 tons, 995,000 pph and

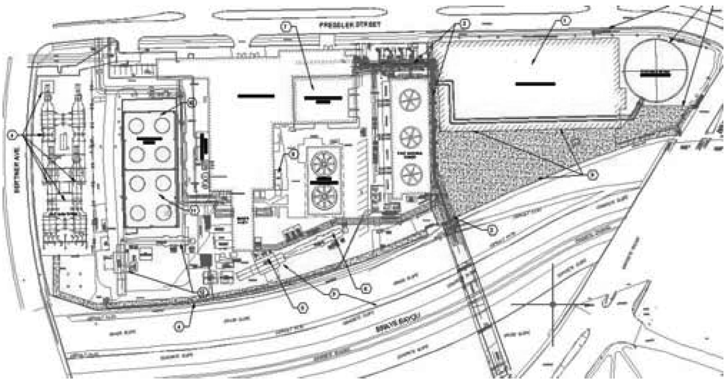

Figure 2. TECO Plant Expansion Plan View

107 MW on a 6-1/2-acre site. Concentrating thermal and electric generation at TECO's plant site allows functions more critical to the customer's core operations to be located at their facilities. It also reduces the load on the local provider's electric distribution system.

Significant program expansion features include:

- Installation of 100 MW of on-site electrical power generation utilizing combustion gas turbines with 540,000 pph of heat recovery steam generator (HRSG) units.
- Installation of a 6 MW back-pressure steam turbine generator unit.
- Installation of 152,000 ton-hrs of chilled water storage (16,000 tons).
- Installation of 80,000 tons of electric motor-driven chillers.
- Removal of one older boiler (125,000 pph total) with significantly higher air emissions rates.

ENERGY EFFICIENCY

When considering energy efficiency, we must consider more than how efficient one piece of equipment is or even how efficient an energy plant might be. Today with the ever increasing interest for expanding renewable energy options, we must not forget that fossil fuel is our most abundant natural fuel source. It makes good economic and environmental sense that when using fossil fuels to strive to be as efficient as possible with every Btu of fuel consumed.

In the United States the average efficiency for generation of electricity is approximately 35 percent. That is, for every Btu of fuel consumed, only 35 percent of the Btu of fuel is actually converted to electricity and the rest of it, or 65 percent in this example, is lost to the atmosphere as waste heat. To get the electricity generated at the central generation plant to the customer, we will lose on average another 4 to 6 percent from resistance losses that occur over transmission and distribution systems that bring the power to the actual customer's site or facility. Overall, at the customer's meter, the net result is a 29 percent primary fuel conversion to useful energy efficiency. Regardless of how energy efficient we make our buildings, we have still wasted more than 70 percent of the energy used to generate and deliver the energy before it even gets to the meter on the outside of the building.

By integrating an on-site energy system or CHP that provides electricity and useful thermal energy, such as steam and/or chilled water, one can be much more efficient when considering the conversion of primary fuel to useful energy. In this case, we use a prime mover to generate electricity on-site, then use all, or nearly all, the waste heat to produce thermal energy, such as steam for process heating and/or HVAC cooling without the need for additional fuel. It is not uncommon to achieve primary fuel to useful energy efficiencies of 70 to 80 percent. These types of efficiencies are attainable because the electricity is generated and consumed at the same location without transmission and distribution losses, and the waste heat can be used to produce useful thermal energy, in the form of steam, chilled water or even additional electricity, without the need of additional fuel. Facilities that have a base load, or 24/7, 365 days a year requirement for electricity and thermal energy typically provide the best return on investment.

Another important aspect related to economic viability of on-site generation is using a CHP prime mover with a competitive heat rate efficiency when compared to the heat rate efficiency of central generation. The Energy Information Administration reports that the National average heat rate (Btu per kilowatt) for a simple cycle gas turbine is 11,664 Btu/kW and combined cycle gas turbine is 7,502 Btu/kW [2]. Within ERCOT, the system heat rate efficiency for central generation in Texas fluctuates between a low of 8,500 Btu/kW to a high of 10,700 Btu/kW. The calculated heat rate efficiency for the TECO CHP system will range from a low of 5,000 Btu/kW at full load to a high of 8,500 Btu/kW during part load operations. This demonstrates the TECO CHP system will provide competitive heat rate efficiency when compared to ERCOT central generation.

In addition to the improved efficiency from electricity generated on-site, consideration also needs to be given to the amount of useful thermal energy that is produced from the waste heat, or exhaust, of the prime mover without any additional fuel input. This means that all of the electricity produced on-site from natural gas along with the thermal energy produced from the waste heat allows for a significant shift away from the grid, which reduces the demand off of the central generation during peak periods, relieves congestion on the grid and increases reliability and energy security to facilities served by the CHP system.

The combined efficiencies of on-site generation and using the waste heat to provide a thermally balanced plant means that these types of CHP systems use approximately 250% less energy than a traditional central utility plant (CUP) with natural-gas-packaged boilers and electric centrifugal chillers fed from the central generation and the grid.

Fuel Conversion Efficiency

	Output	*Required Input*
• Utility @ 29%	1kW = 3,413 Btu	11,769 Btu
• CHP @ 74%	1kW = 3,413 Btu	4,612 Btu

Facility Electric Load @ 31,950,038 kWh

- CUP = 3.7602×10^{11} Btu
- CHP = 1.4735×10^{11} Btu

In this example, the CUP (fed from grid and serving the same load) uses 255% more energy than on-site CHP.

ENVIRONMENTAL EFFICIENCY

CO_2 Regulation

Regardless of the area of the county, CO_2 is not currently regulated in the United States. The Supreme Court has ruled that EPA can regulate CO_2, but to date, it has not. [3] California and 17 other states tried to regulate CO_2 on their own, and the EPA denied their request for a waiver under the Clean Air Act, which would have allowed stricter-than-federal limits on greenhouse gas emissions from motor vehicles. [4] However, some form of CO_2 regulation has become inevitable, whether in the form of a carbon tax or a cap-and-trade program. Reduction of CO_2 emissions and increased efficiencies go hand-in-hand.

Regulatory Obstacles to Increasing Efficiency

Increased energy efficiency is a stated goal of most environmental conscious minds. It would make sense then to have environmental regulations written to encourage and promote efficiency.

The component of the Clean Air Act that deals with modifications to existing equipment including changes specifically designed to increase efficiency is New Source Review (NSR). NSR is an umbrella for two programs: non-attainment NSR (NNSR) and Prevention of Significant Deterioration (PSD). Areas of the country with poor air quality, such as Houston, are subject to the more stringent requirement of NNSR permitting. Areas of the country with sufficient existing air quality are subject to PSD permitting, see Figure 3.

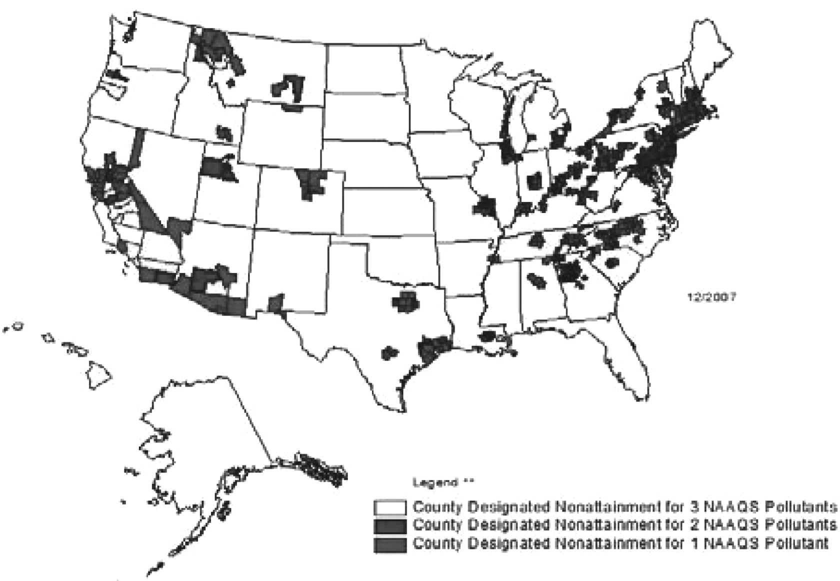

Figure 3. Counties Designated "Nonattainment" for Clean Air Act's National Ambient Air Quality Standards (NAAQS)

The first step in determining the applicability of NSR is to determine if the modification is either a physical or an operational change, excluding routine maintenance, repair, and replacement activities. The meaning of "routine," however, is critical and not defined in the NSR regulations. The second step is to determine if as a result of the modification, the emissions increase will be above the PSD significant emission rate thresholds. The determination of "increase" is based on the average annual emissions from the unit before the modification and the projected actual emissions after the modification. If the unit was not operating a full capacity in the years immediately preceding the modification, then the differential will inevitably be greater than the NSR thresholds.

Efficiency can be increased by upgrading a turbine, reconfiguring a super heater economizer section, retubing condensers, and improving air heater performance. Unfortunately, these are exactly the types of "non-routine" modifications that can trip NSR. Again, there is no regulatory definition of "routine" to guide industry.

The Supreme Court has ruled that the emissions increase is determined in terms of tons per year and not in terms of pounds per hour of emissions [5]. Therefore, there is a counterproductive incentive to maximize annual emissions before making a modification. Additionally, a decrease in the short term lb/hr emission rate could require NSR permitting if the future projected operating capacity of the unit results in a significant type increase.

Regulatory Incentives to Increasing Efficiency

Traditional air permitting limits are based on emissions per amount of fuel input. Output-based emission limits, however, are based on emissions per useful energy output. Output-based limits are becoming more common and have been included in federal regulations, such as the New Source Performance Standards for utility boilers (40 CFR Part 60, Subpart Da). They encourage technologies such as CHP by accounting for both the thermal and electrical output, reflecting the increased efficiency.

Some states have issued their own rules to reward the higher efficiencies of distributed generation facilities such as CHP. The California Air Resources Board (ARB), a branch the California Environmental Protection Agency, has implemented a certification program for distributed generation units to encourage operation of "the cleanest engines available." In recognition of their benefits, combined heat and power units that achieve minimum efficiency of 60 percent may obtain emission credits. Additionally, the legislation facilitates permitting for CHP power plants less than 50 MW by providing specific guidance to each local air district.

Texas issued standard permit regulations with output-based emission limits for small electric generators, which set specific NO_x emission limits on an output basis (lb/MWh). The thermal output of CHP units is included when calculating compliance.

The NO_x trading programs of Indiana, Connecticut, and Massachusetts allocate allowances specifically to highly efficient CHP facilities. Because the cost of allowances ranges from hundreds to thousands of dollars per ton, a considerable economic incentive to higher efficiencies is created.

However, regulatory incentives can only address small projects as a result of the all-encompassing requirements of the NSR program. When projects exceed specific size and emission thresholds, NSR regulations trump state incentives. At larger sizes, projects are hindered by the need to comply with NSR and its ingrained bias against efficiency improvements, as discussed above.

NSR regulation needs to be overhauled with common sense to encourage efficiency improvements that decrease CO_2 emissions.

CONCLUSIONS

In summary, TECO's expansion will allow for greater baseline and emergency production capacities to meet the growing need for more medical facilities in the TMC while significantly reducing overall air emissions, and increasing the overall efficiency of the conversion of fuel to useful energy.

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ABOUT THE AUTHORS

Stephen K. Swinson, P.E., is the president and chief executive officer of Thermal Energy Corporation (TECO), a nonprofit company located in the Texas Medical Center in Houston, Texas. Swinson, who has more than 20 years' experience in the district energy industry, served as IDEA chair from 1996 to 1998. In his new role, Swinson reports directly to TECO's board of directors. He will lead the company's senior management team and its plant staff of more than 80 in planning, developing and implementing policies and procedures to meet corporate objectives. They include creating future growth for TECO by expanding existing plants and/or creating a distributed network of satellite plants. TECO currently operates two plants with a combined capacity of 80,000 tons of chilled water and 660,000 lb/hr of steam. The plants supply steam and chilled water to 27 Texas Medical Center institutions in 40 buildings with approximately 14.9 million sq ft of space.

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