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A TEXAS-SIZED DISTRICT ENERGY SYSTEM:

THE ENERGY BEHIND WHAT'S NEXT AT THE TEXAS MEDICAL CENTER

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Courtesy TECO. Photo Paul Howell.

August in Houston can be hot, and in 2010, it was the hottest on record. On Aug. 23, demand on the Texas electrical grid hit an all-time high of nearly 66,000 MW. But at the 201-acre main campus of the Texas Medical Center, the leaders of Thermal Energy Corp. (TECO) weren't sweating over how soaring electricity prices or the threat of blackouts might affect their district energy system, which serves 75 percent of campus building space. Even as the temperature outside soared, TECO didn't need to pull a single watt of electricity from the grid.

Instead, the not-for-profit corporation relied on its newly commissioned, 48 MW combined heat and power system to generate the power needed to supply chilled water and steam to The University of Texas MD Anderson Cancer Center, Texas Children's Hospital and 16 other institutions at the Texas Medical Center. TECO not only reduced the load on the state's electric grid that day, it demonstrated one of the major reasons why it added on-site electricity generation to its Central Plant in the first place: to ensure that the world's largest medical center's thermal energy needs could be met, no matter what.

Houston-based Jackson & Ryan Architects incorporated architectural features into TECO's Master Plan Implementation Project that reflect the surrounding Texas Medical Center.

The CHP system is a major part of TECO's $377 million district energy system expansion, Master Plan Implementation Project – Phase One, which also included adding 32,000 tons of new chiller capacity, an 8.8 million-gal stratified thermal energy storage (TES) tank, distribution piping and an expanded operations facility featuring a state-of-the-art control room. The project was completed in May 2011, transforming TECO's energy center into a model for energy efficiency, operating flexibility, environmental sensitivity and system reliability – and the largest district cooling system in the U.S.

Developing a Master Plan for Growth

In 2006, the institutions at the Texas Medical Center were projecting major growth, and TECO could foresee a related increase in demand for chilled water for air conditioning and dehumidification and steam for air conditioning, space heating, sterilization, kitchen and laundry processes, and domestic hot water use. TECO responded by working with Jacobs/Carter Burgess to complete a master plan to keep pace with that growth. The plan provided solutions to expand the system, improve efficiency, reduce emissions and strengthen TECO's overall system reliability and emergency operating capacity, especially during natural disasters and other crises. Burns & McDonnell validated TECO's master plan, developed an implementation plan and later provided engineering, procurement and construction services for the project. The firm recommended a phased approach to the project to closely match campus growth projections.

One of the company's most significant design challenges was the site's space constraints. Land on the Texas Medical Center campus is a precious commodity, and while TECO would eventually need to double its capacity, it did not have the luxury of doubling the size of its 4.5-acre Central Plant site where the new equipment was to be located.

Master Plan Implementation Project – Phase One

In January 2008, Burns & McDonnell started the first of what are expected to be multiple phases of construction (which will be determined as the Texas Medical Center develops its plans for building out the campus). In preparation for construction, upgrades were made to TECO's 138-kV substation. This was followed by completion of the TES tank and Operations Support Facility in October 2009, the CHP system in August 2010, the distribution system expansion in September 2010 and the new East Chiller Building in May 2011.

TES Tank

TECO chose to install the 8.8 million-gal TES tank as a cost-effective way to increase peak chilled-water capacity. TES allows chilled water to be produced and stored when it is the most cost-effective (generally at night) and then used when chilled-water production rates are highest. TES also helps reduce peaks on the grid during the hottest times of the day. In addition, TES enhances reliability, since it can be brought into service quickly and uses approximately 10 percent of the equivalent emergency power it would take to operate a chiller.

Chilled water leaves the tank at 42 degrees F and enters the distribution system through a 60-inch pipe. After it has been used in the buildings for cooling, the water travels back through the distribution system, returning to the tank at approximately 58 F. At night, electric centrifugal chillers cool the returned water back to 42 F for the next day's use.

For these reasons, the new TES tank was one of the first projects TECO completed. To facilitate cost-effective use of the available land, the tank was designed at 150-ft high, which makes it the tallest TES tank in the world.

Courtesy Burns & McDonnell.

Inside TECO's Operations Support Facility, the state-of-the-art control room allows the district energy plant operator to better manage the integrated utility systems serving the world's largest medical center.

Operations Support Facility

TECO's growth resulted in a need to provide environmentally controlled space to warehouse sensitive parts and materials, space for training operators and maintenance personnel, and secure areas for plant operations. To address these needs, TECO added 29,000 sq ft of new building space to its existing Operations Support Facility. The addition includes a new state-of-the-art control room that features 24 flat-screen monitors where staff can track system performance and site security and oversee daily operations. The space is hardened to ensure structural and operational integrity are maintained during severe weather conditions.

CHP System

Wanting to generate thermal energy as efficiently as possible, TECO added CHP to help squeeze maximum energy from every British thermal unit of fuel consumed. The technology has provided the additional benefit of improved reliability and significantly reduces emissions to the environment.

In a traditional central power delivery system, only about one-third of every Btu of fuel consumed is converted into electrical energy; the remaining two-thirds go up a stack and are wasted. TECO's 48 MW CHP plant, by comparison, operates at approximately 80 percent efficiency – more than 50 percent improvement over a central utility plant fed from the grid – and with a combined heat rate between 5,500 and 6,700 Btu/kWh.

TECO uses the electricity generated within its own Central Plant. The high efficiency is possible because the plant also recovers the waste heat from electricity generation and uses it to make steam and chilled water. TECO's CHP system consists of a GE LM-6000 combustion turbine and a heat recovery steam generator. It is designed to produce 125,000 lb/hr of steam – the minimum steam load for the summer months. During winter, using the natural gas-fired duct burners more than doubles

Due to campus growth, Burns & McDonnell built a permanent bridge over Brays Bayou to extend utilities to institutions that are expanding on Texas Medical Center's mid and south campuses.

Courtesy Thermal Energy Corp. Photo Paul Howell.


Courtesy GE Power & Water. Photo Woodallen Photography.

The heat recovery steam generator is a key component of TECO's on-site CHP system, which recovers waste heat via conductive heat transfer to produce steam.

the steam output to as much as 330,000 lb/hr of steam, increasing overall CHP efficiency by as much as 15 percent. The CHP system also uses chilled-water supply or return water for combustion turbine inlet cooling to maximize power production during the hot, humid Houston summers.

Because of these projected energy efficiencies, TECO received a $10 million federal grant – one of only nine American Recovery and Reinvestment Act grants from the U.S. Department of Energy for CHP and district energy technology.

Distribution System Expansion

TECO has historically served only the Texas Medical Center's main campus. (The Texas Medical Center's primary site in Houston consists of three contiguous campuses – main, mid and south.) More than 7.5 trench miles of piping supply district energy to 44 buildings. With the expansion, TECO built an additional chilled-water loop to serve new load on the west side of the main campus. It also constructed a new bridge to carry 60-inch piping over Brays Bayou, linking the main campus to the mid and south campuses, where the majority of future growth is projected to occur.

East Chiller Plant

Dedicated May 17, 2011, TECO's new East Chiller Building was constructed to house 10 8,000-ton chillers. (See "Industry News" for details about the dedication ceremony.) As part of Phase One, the first four 8,000-ton chillers and their associated equipment were installed to add 32,000 tons of chilled-water generating capacity. These four chillers and the new TES tank bring TECO's total cooling capacity to 120,000 tons, making it the largest district cooling system in the U.S.

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At full buildout, the East Chiller Building will house six additional 8,000-ton chillers totaling 48,000 tons, bringing TECO's total cooling capacity to 168,000 tons – enough to cool two Texas Medical Centers at today's size or more than 42,000 average-sized households.

Timing Is Everything

When construction on the $377 million expansion kicked off, the world was in a far different economic place than it was when construction ended over three years later. In 2007, the economy was at its peak and inflation was on the rise, raising two major concerns for the project team. First, would they be able to find the skilled labor necessary to meet their high quality standards? Second, would labor scarcity drive up construction costs?

Both questions were answered in dramatic fashion months later when the stock market crashed, and almost overnight the prices of everything from raw materials to labor dropped significantly. TECO had worked with Burns & McDonnell to establish a guaranteed maximum price on the project. Using an open contracting approach, more than 85 percent of the project was competitively bid. As a result, TECO realized more than $30 million in equipment and subcontractor savings compared to original construction cost estimates.

As the economy slowed, however, so did growth at the medical center. As a result, TECO completed the first phase of implementation with more capacity than current Texas Medical Center campus load projections require. But it also built that capacity at a substantially lower cost than if the project had been postponed.

Mission Accomplished

While first-phase projects have been operational only for a few months, early assessments indicate the new facilities are operating according to plan and are achieving the objectives outlined in TECO's master plan:

1. **Improving efficiencies.** The two-for-one payback on each Btu of fuel input is primarily responsible for the 80 percent energy efficiency CHP delivers. However, it is not the only source of energy efficiency at TECO's energy center. The chilled-water storage made possible by TECO's new TES tank improves plant operating efficiency by giving TECO the flexibility to chill water when electricity rates are lowest. TECO can also start and stop its gas turbine as needed as the cost of natural gas and electricity change. TECO's phased expansion is also contributing to long-term savings. The new East Chiller Building, for example, uses a plug-and-play design that makes it relatively simple to add individual new chillers as demand increases. Similarly, TECO elected to plan for two smaller CHP plants – one now and one in the future, rather than a single large plant – which also contributes to operational flexibility.
2. **Reducing the electric distribution system load.** The power generated by the CHP plant doesn't power institutions at the Texas Medical Center; it is used solely within TECO's plant to power equipment and provide steam and chilled water to medical center customers. TECO's customers use electricity from the grid and operate their own independent emergency generators. Since they have no on-site chillers, their need for emergency generator capacity is cut in half.
3. **Lowering environmental emissions.** Because CHP improved overall system efficiency, TECO anticipates cutting carbon dioxide emissions by more than 302,000 tons in the system's first year of operation – equivalent to taking 52,000 cars off the road or planting 72,000 acres of new trees. The CHP plant will also reduce carbon emissions by 83,000 metric tons a year compared to TECO's previous operations. The TES tank further lowers TECO's carbon footprint by using the power from the CHP system to run the electrical centrifugal chillers to charge the tank and by using power from the grid during the off-peak periods.
4. **Saving money**. In its 2010 fiscal year, TECO reduced customer rates by 2 percent; in 2011, it dropped them an additional 1.4 percent. These rate declines are due largely to efficiencies gained through these and other projects. The master plan implementation is projected to save TECO and its customers more than $200 million over the next 15 years.

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5. **Improving system security and reliability.** With critical patient care at stake and more than $1 billion in medical research performed on campus annually, TECO's service reliability must be second to none. Even when disaster strikes – as it did when Hurricanes Katrina and Rita hit in 2005 and Hurricane Ike made its presence felt in 2008 – failure is not an option. TECO's added capacity and ability to generate its own power, coupled with its detailed emergency preparedness plans, further improve the company's reliability.

TECO's Central Plant site was under construction from 2008 until early May 2011. Nine months of construction remained when this aerial image with the Texas Medical Center campus in the background was captured. The expanded district energy facility's design allows TECO's capacity to reach 100 MW of on-site power generation, 168,000 tons of chilled water, 152,000 ton-hr of chilled-water storage and 940,000 lb/hr of steam.

Still to Come

With the first phase of its master plan implementation complete, TECO is preparing to take a fresh look at the big picture. In the coming months, the project team will re-evaluate the plan in light of the medical center's latest growth projections and begin planning TECO's next steps.

Likely on the agenda will be issues such as electricity generation. The day could come, for example, when TECO could provide emergency power to some or all of its customers. TECO also has the opportunity to export more of the power it generates to the grid, something it is already doing when market conditions and other variables warrant.

For the moment, TECO and its partners are taking time to consider the enormity of what they've accomplished and the excellent working relationships they've developed in the process. Given the project's size and scope, the current economy, the tight construction site and the need to keep existing operations going throughout construction, the TECO Master Plan Implementation Project is a prime example of what happens when things go right during project planning, design and construction. It is also proof that district energy systems aren't just bigger in Texas. They can also be better.

Scott Clark, PE, leads the Burns & McDonnell OnSite Energy & Power Group. In his 24 years of experience, Clark has planned and designed energy projects for higher education, health care and aviation clients. A Certified Energy Manager, he is a current board member of IDEA and received the 2007 Energy Manager of the Year Award from the Association of Energy Engineers – Region IV. He holds a bachelor of science degree in mechanical engineering from Texas Tech University and has completed coursework toward a master of business administration degree at Texas Christian University. He may be reached at spclark@burnsmcd.com.

Ed Mardiat, principal and CHP development director in the Burns & McDonnell OnSite Energy & Power Group, has 37 years of design, project management, marketing and project development experience. He worked with the U.S. Department of Energy to coordinate installation of the first packaged CHP demonstration project, owned and operated by Austin Energy. He served on the Design-Build Institute of America (DBIA) board, as vice president of the Mid-America DBIA and as director-at-large for the U.S. Clean Heat and Power Association. Mardiat is a member of the U.S. Environmental Protection Agency CHP Partnership and IDEA. His email address is emardiat@burnsmcd.com.

Stephen K. Swinson, PE, is chief executive officer and president of Thermal Energy Corp. in Houston. Swinson has 28 years of experience in the district energy industry, including positions at Trigen Energy Corp. and Auburn University. He chaired IDEA's board of directors from 1996 to 1998 and is now a board member. A licensed professional engineer, Swinson is a graduate of Auburn University with a bachelor of science degree in mechanical engineering. He also has a master of business administration degree from Northwestern University's Kellogg Graduate School of Management. He can be contacted at sswinson@teco.tmc.edu.

About the Texas Medical Center

Founded in 1945, the Texas Medical Center is the world's largest medical center. Recognized by *U.S. News & World Report*'s Annual Survey of America's Best Hospitals in all 19 categories of adult care and all 10 pediatric care specialties, its member institutions are known throughout the world for high-quality medical care and excellence in teaching and research. Here are some vital statistics for the year 2010:

Number of member institutions	49 including: • 21 academic institutions • 14 hospitals • 3 medical schools • 6 nursing schools
Size	162 buildings with space devoted to patient care, research and education space – equivalent to the 12th-largest business district in the U.S.
Patient beds	6,800
Physicians, scientists and researchers with advanced life sciences degrees	20,000
Employees	93,500
Annual patient visits	6 million, including 18,000 from international patients
Babies delivered	28,000
Students	71,500

Source: Texas Medical Center.

System Snapshot: Thermal Energy Corp., Houston, Texas

TECO is a not-for-profit corporation created to provide reliable thermal services to institutions in Houston's Texas Medical Center. Governed by a board composed of nine of the medical center's institutions served, TECO today operates two plants – the Central Plant and a satellite, the South Main Plant – that supply chilled-water and steam service to 18 institutions representing more than 75 percent of building space on the main campus.

	Chilled-Water System	Steam/CHP System
Startup Year	1969	Steam system, 1969; CHP, 2010
Number of Customers	18 medical institutions	18 medical institutions
Number of Buildings Served	44	36
Total Space Served	18.9 million sq ft	14.9 million sq ft
Total Capacity (at Central and South Main plants)	120,000 tons including 8.8 million-gal thermal energy storage tank (with ability to expand to 168,000 tons)	816,000 lb/hr steam (with heat recovery steam generator and duct firing); 48 MW electricity
Number of Boilers/Chillers	27 chillers total: 14 at Central Plant, 13 at South Main Plant	8 boilers total: 6 at Central Plant, 2 at South Main Plant
Annual Energy Sales	267,750,000 ton-hr	1,006,797 Mlb
Fuel Types	Electricity and natural gas	Natural gas and diesel
Distribution Network Length	7.5 miles	7.5 miles
Piping Diameter Range	6 to 60 inches	2 to 16 inches
System Pressure	65 psi	250 psi
System Temperatures	40 F supply/53 F return	450 F supply/150 F return
System Water Volume	12.4 million gal (including TES)	NA

Source: Thermal Energy Corp.