Lessons Learned from World's Largest Fuel Cell Installation: Connecticut Juvenile Training School

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ABSTRACT

This article addresses the practical application of emerging distributed technology (fuel cells) in a real-life project under way in Connecticut. Select Energy Services, Inc. (SESI), formerly HEC Inc., has installed and is operating the world's largest commercial fuel cell installation. This 1.2-megawatt energy plant provides electricity, heating, and cooling for the state-of-the-art Connecticut Juvenile Training School (CJTS). The discussion chronicles the creative engineering and business solutions that overcame the obstacles faced by Connecticut State agencies in constructing this project, and how state government and private industry collaborated on this technically complex project.

Since going fully on line in November 2001, the plant has operated continuously for 12 months, logging 9,000 hours of uninterrupted production of power, heat, and cooling. One or more of the six fuel cells has operated continuously during that entire period, meeting all energy requirements without interruption except for small grid supplements.

INTRODUCTION

In 2000, the State of Connecticut undertook action to expand its juvenile detention facilities. At the time, the most appropriate site available for the facility was a large section of land located on the Connecticut State Hospital grounds. While the proposed construction site satisfied many of the project's criteria, it was also situated above an aquifer, subjecting any project to extensive environmental permitting and wetlands protection constraints. As part of the facility design, the State decided to supply heating, cooling, and electricity for the site from an "Energy Center," a central power plant located just outside the secured area, using buried pipes and cables to distribute the energy to each building on site. Once constructed, the Energy Center would provide all the heating, cooling, and electrical power needs for CJTS's 227,000 square feet of buildings on 35 acres, including residences, office buildings, and other campus facilities.

With this conceptual design in place, the project's construction and operation phases were offered for competitive bid to energy services companies. As part of its bid, SESI offered a unique alternate. SESI proposed to design, build, and maintain a freestanding Energy Center that would deliver a guaranteed supply of "green power" through an innovative configuration of new technology—fuel cells—interconnected with the regional electric power grid and emergency generators for seamless system backup. Based on extensive life-cycle cost analysis and the environmental benefits related to using green power at the site, the fuel cell option was chosen. SESI was selected to build the Energy Center and operate it for the next 30 years.

Since its installation, the Energy Center has operated through four seasons, providing all of CJTS's heat, cooling, and electrical energy for the entire period. All of that electricity and cooling, and some of the heat, were produced by the fuel cells themselves. (They are "base loaded," using the grid as backup, and power centrifugal chillers as well as a small absorption chiller.) The two backup sources giving CJTS triple electric redundancy (normal grid power and emergency generators) have not been required except for a small percentage of power (less than 300 kW) needed for synchronization and occasional "tripping." (There were a few instances when the fuel cells were tripped off by external problems or minor problems with controls or electrical/mechanical components.)

The nominal power capacity of each fuel cell (200 kW) has proven to be available when needed. Because CJTS is a 24-hour institution, its power needs are continuous, although variable. Last summer's peak demand was less than 80% of the fuel cells' combined capacity. The six fuel cells have delivered between 400 and 900 MWh of electricity each over their first 14 months of operation. Availability, relative to CJTS's demand, has been 100% for four of the cells and over 95% for the other two. Each cell is taken off line quarterly for minor maintenance and annually for about a day of maintenance, then returned to service. After

5 years or 40,000 hours of use, a general overhaul, including new "stacks," will be performed, one cell at a time. This is expected to require less downtime than that required for an engine or turbine of equivalent capacity.

Operation of the Energy Center has proven simpler than engine-based cogeneration plants, because the fuel cells have been at least as reliable, requiring no lubrication and little scheduled maintenance. Because their emissions consist of only water vapor and carbon dioxide, no stack tests or other code compliance procedures are needed. They have essentially no moving parts and make no noise.

MAKING THE DEAL

To bring a project this unique to life, many parties had to contribute extensive time and effort in their areas of expertise. The State of Connecticut called on the Department of Public Works (DPW), the Department of Children and Family, the Department of Environmental Protection, the Department of the Treasurer, the Governor, and many others. The private sector called on energy services companies, engineers, lawyers, equipment manufacturers, and builders.

Two primary agreements were used to structure the deal: an engineering, procurement, and construction (EPC) contract, and an operations and maintenance (O&M) contract. The EPC contract addressed the specifications, equipment capacities, schedules, terms, and other details relating to the Energy Center's engineering and construction. The O&M contract documented the duties, responsibilities, and requirements of the 30-year operating period.

The EPC contract was a fixed-price contract to construct the Energy Center. Equipment capacities and performance were specified and guaranteed by SESI. For example, the fuel cells were required to meet a 1.2-megawatt electrical capacity test, the chillers had to produce 680 tons of cooling, and the boilers had to produce 9 million Btuh of hot water. Representing the State of Connecticut, the DPW maintained project oversight, approving all major equipment selections. The State's motto was "No change orders." SESI met this challenge.

The O&M contract, which has a 20-year term with a 10-year renewal, covers staffing and operational responsibilities for the Energy Center. Chilled water, hot water, and electricity must be provided 24 hours per day, 7 days per week. Failure to provide these services would result in significant liquidated damages. To ensure that these services are reliably provided, the plant is staffed with an operating crew to monitor the equipment and provide routine maintenance. The operator has full responsibility for repair or replacement of equipment.

The O&M contract also includes fuel purchasing for the plant. An innovative approach was devised whereby the State and SESI meet annually to determine the gas purchase strategy to be used for the coming year. Based on input from the State's energy purchasing representative, annual or multi-year commodity purchases can be made. Increases and decreases in the unit cost of fuel are passed to the State.

FINANCING

The State chose to pay for the project over 30 years. SESI financed the project through a combination of project financing and U.S. Department of Defense fuel-cell grants. The fuel-cell grants were obtained by SESI in the amount of $200,000 per fuel cell, and were used to buy down the price paid by the State. For the balance of the project cost, the State entered into a 30-year lease agreement with a limited liability company established by SESI for the sole purpose of holding the lease for the Energy Center. Under the terms of the lease, the State makes fixed semi-annual payments and owns the plant at the end of the lease. SESI raised the money to build the Energy Center by selling tax-exempt certificates of participation (COPs) in the lease. Each certificate represents the right to a proportionate interest in the lease payments from the State. COPs may be traded and sold, and therefore are more marketable, typically carrying lower interest rates

than a private placement of a project loan. In addition, Standard & Poors rated the COPs A+. Obtaining this rating required extensive discussions regarding fuel cell technology, the State's need for the facility (lease payments are subject to appropriations), and the structure of the transaction.

Some strings were attached to the lower tax-exempt interest rate. Connecticut's Department of the Treasurer spent considerable time on the transaction, prescribing terms of the transaction. In addition, under Internal Revenue Service rules, using tax-exempt financing for the Energy Center imposed limits on the operation and maintenance fees. SESI worked within these requirements to preserve the economics of the transaction.

THE SCHEDULE

One of the project's biggest challenges was achieving construction schedule milestones. After SESI was selected in June/July 2000, the first set of milestones focused on providing temporary electricity, chilled water, and hot water to the site. Because some school buildings had already been under construction for several months, utilities were needed immediately to keep the construction schedule on track. SESI's project managers and electrical engineers designed and managed construction of a 13,200-volt temporary power line. The line was energized within 2 weeks, preventing a possible slowdown of construction on the main fa-

cility. Chilled water was provided by August 1, a full 2 weeks ahead of schedule. Chilled water was required during construction to dehumidify the interior space to allow painting and other interior finish work to be completed on schedule. Later that year, in October, the temporary boilers were on site and started up to provide heat. There have been no outages or interruptions since these services started.

The next set of milestones involved installing and completing major components of the Energy Center. The building was constructed during the fall and winter of 2000; at the same time, equipment vendors were filling orders for equipment with long lead times. Although the final Notice to Proceed was not issued until March 2001 because of contractual issues related to the financing, the Energy Center still retained a functional-use date of September 2001, with final completion by December 2001. The September date was met with power generated by all six fuel cells.

The State of Connecticut will confirm that SESI exceeded expectations by meeting very aggressive deadlines during construction. These included extensive environmental permitting and wetlands protection provisions. Since the start of power production in July 2001, all services have remained on line and available to meet the needs of the CJTS facility.

THE ENERGY CENTER

The Energy Center is a freestanding building located outside the high-security area of CJTS. It provides electricity, chilled water, and hot water to the entire campus through underground distribution. Physically, it is configured as follows:

Building and Site

The building is approximately 4,000 square feet, housing all equipment and offices. Because it is outside of the secured area, the building has its own parking and admission area separate from CJTS. The fuel cells are located outside the main structure, as shown.

Electricity

Providing reliable power is the most important mission of the Energy Center. To ensure reliability, the electric supply has three levels of redundancy: (1) the fuel cells, which are the primary power source; (2)

backup power provided by the local utility; and (3) gas-fired emergency generators. Because there are six individual fuel cells, there is minimal chance of total equipment failure. If the fuel cells should malfunction, the local electric utility will serve the facility with 13,200 volts from a relatively new line fed from a single substation and provided with state-of-the-art automatic reclosures. In the event of catastrophic failure, two 1,500-kW emergency generators are available to supply all the power needs of the facility for extended periods of time.

Chilled Water

Chilled water is produced in the Energy Center and distributed to the facility. Over 1,000 tons of installed chilling capacity is available to serve a projected load of 680 tons. To maximize energy efficiency, an absorption chiller was installed to use waste heat from the fuel cells to capture "free cooling" when conditions permit. During the spring and fall, the absorption machine will provide most of the chilled water. During peak summer months, two centrifugal chillers will also produce chilled water. These chillers are equipped with variable-speed drives to track the load efficiently.

Hot Water

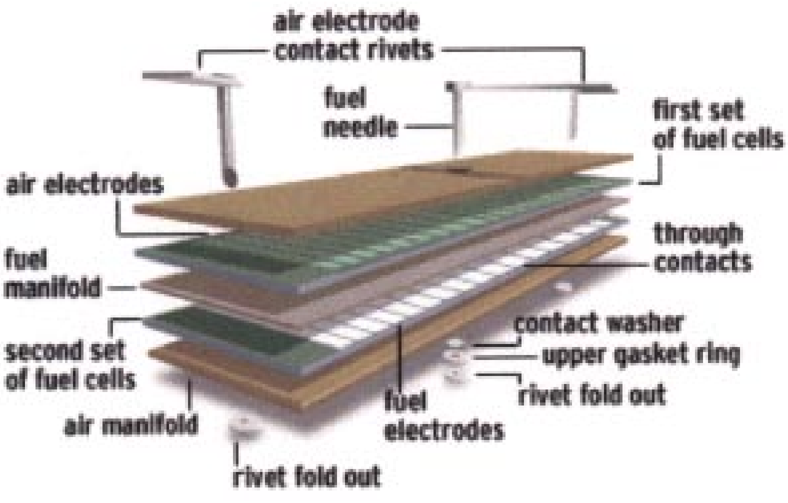
In the course of normal operation, the fuel cells generate waste heat that can be used to heat the building during most periods. However, a fully redundant fire-tube boiler system is installed to ensure that heat is available under all circumstances. The building automated control system is designed to maximize waste heat use before using the boilers.

Building Automated Control System

A fully automated control system has been installed to monitor and control the systems. This provides the system operator with information and scheduling inputs. Separate, integrated control systems operate the fuel cells and the rest of the mechanical systems.

FUEL CELL TECHNOLOGY TODAY

A fuel cell operates much like a battery: fuel cells produce power from chemical reactions rather than combustion, and thus do not produce air pollutants. However, unlike batteries, as long as fuel is supplied to a fuel cell, it will continue to operate. Inside each fuel cell are 256 "cell stacks," which are stacked graphite plates containing phosphoric acid. Natural gas is processed through an external reformer, which converts it to hydrogen and carbon dioxide. By causing a



Fuel cell illustration and details

Courtesy of International Fuel Cells, Inc.

chemical reaction between the hydrogen and the oxygen in the air, each fuel cell produces 200 kilowatts of electricity at 480 volts.

International Fuel Cells (IFC) is the largest company in the world devoted solely to fuel cells. IFC has manufactured more than 250 PC25 power plant systems (165 of which are the PC25C model installed at CJTS) that are installed in approximately 100 locations throughout the world. Installed PC25 commercial fuel cell power plant systems have accumulated more than 3 million hours of in-service operation.

LESSONS LEARNED

- Innovative approaches can bring unique projects to life.
- Fuel cells are commercially available and can be used in suitable applications.
- Long-term build/operate contracts can provide economic solutions to state needs.
- Institutions need financially stable companies for these innovative projects.
- Green power is still somewhat more expensive than commercially available alternatives.
- The future is bright for the environment and for alternate power sources.

ABOUT THE AUTHOR

James B. Redden, P.E., is president and chief operating officer of Select Energy Services, Inc. (SESI), an unregulated subsidiary of Northeast Utilities Systems. Mr. Redden has over 25 years of progressive experience in energy services fields, including founding an energy services contracting firm in the late 1970s, providing project engineering on some of the world's largest buildings, providing project management on cogeneration projects, managing utility demand-side management programs, and profitably growing energy services busi-

nesses. His career has extensively involved project development and strategic planning. He has provided management and technical leadership on utility demand-side management programs, facility conservation programs, cogeneration systems, central plant improvements, fire safety upgrades, and diverse equipment retrofits at hundreds of facilities around the country. Active in professional societies, he has helped to promote energy efficiency as a career and an important part of today's energy mix. Mr. Redden earned his BS from Cornell University, College of Engineering. Mr. Redden may be reached at *jredden@selectenergysi.com.*