Fuel Cell System Turns Waste into Electricity at the Tulare Wastewater Treatment Plant

Since September 2007, the Tulare, California, Wastewater Treatment Plant (WWTP) has been finding a more productive use for the byproduct anaerobic digester biogas it used to flare. The project has reduced the plant's electricity bill by over $1 million per year, by generating 1.2 megawatts (MW), or 45 percent of its electricity needs, with on-site molten carbonate fuel cells.

Original Installation of Three FuelCell Energy Fuel Cells and Gas Pretreatment Unit at Tulare Wastewater Treatment Plant.

PROJECT SUMMARY

Location	Tulare WWTP, Tulare, CA
Primary Objective	Cost-effective power
Incumbent Technology	Electric power grid
Systems and Manufacturer	Applied Filter Technology gas pretreatment system. Four DFC300MA molten carbonate fuel cells rated at 300 kW for a total capacity of 1.2 MW manufactured by FuelCell Energy.
Fuel Supply	Approximately 500,000 cubic feet of biogas per day
Fuel Cell Startup Date	September 2007, 2011
Availability	99.45% in 2010
Efficiency	Electrical efficiency of 47% Combined heat and power efficiency of 90%
Systems Installation Cost	Total cost of fuel cell power plant: $9.39 million Funding: approximately $4.95 million from Southern California Edison as part of California's Self-Generation Incentive Program
Avoided Costs	An estimated one-time cost of $600,000 was avoided in Emission Reduction Credits (ERCs) that would have been required for combustion technologies; an average of $3,500/day is saved in electricity costs
Avoided Emissions	6,200 tons CO_2 per year
Facility Size	Average daily wastewater flow of about 11.5 MDG (4.4 MDG domestic wastewater, 7.1 MDG industrial wastewater)
Hours of Operation	95,086 hours from September 2007 through July 2011

Background

Many WWTPs use anaerobic digestion to stabilize sludge generated during the treatment process. Microorganisms break down organic material, releasing biogas, a mixture composed of methane and carbon dioxide, trace gases, and water. Typically, WWTPs flare biogas to dispose of it, but this renewable fuel can be used in fuel cells to generate heat and electricity. Using biogas in this way reduces emissions that otherwise would be generated by flaring and eliminates emissions that would be generated by using traditional power sources. There are currently 12 WWTPs in California operating almost 10 MWs of fuel cell systems.

The Tulare WWTP requires about 2.7 MW of electricity to treat an average of 11.5 million gallons per day (MGD) of wastewater from domestic and industrial sources. The county has a large agricultural processing community with many dairy facilities contributing high organic loads in the wastewater. The facility's anaerobic digester produces about 500,000 cubic feet of biogas per day.

The fuel cells at the Tulare WWTP qualify as an ultra-clean technology by meeting strict standards established by the California Air Resources Board. As a result, Tulare qualifies for preferential rate treatment by the California Public Utilities Commission. The decision to use fuel cells for onsite power has also reduced the facility's reliance on the electric grid—substantially decreasing the amount of utility-generated emissions and easing the strain on Southern California's already stressed power grid.

Project Planning and Evaluation

The rising cost of electricity in California prompted the City of Tulare to consider alternatives to electric grid power for its WWTP. City officials analyzed bids by Carollo Engineers for several cogeneration technologies, including generators and micro-turbines, and concluded that a fuel cell power system would be the most cost-effective option. Primary considerations in selecting the technology were lifecycle and capital costs, and state emission-reduction credit requirements. Substantial financial incentives in California make fuel cells cost competitive with alternative combustion technologies, especially considering added benefits such as superior electrical efficiency and negligible emissions.

Project Implementation

In 2007, the Tulare WWTP installed three 300-kW molten carbonate fuel cells manufactured and installed by FuelCell Energy (FCE), based in Danbury, Connecticut. The success of the initial installation led to the addition of a fourth fuel cell in 2011, bringing the entire system up to 1.2 MW. The high operating temperature of the molten carbonate fuel cells facilitates internal conversion of methane to hydrogen, virtually eliminating criteria pollutant emissions. The fuel cells operate primarily on biogas from the facility's anaerobic digester but also are designed to operate on natural gas. Natural gas is used only when the gas treatment system is out of service for maintenance, which enhances the system's availability.

Four FuelCell Energy Fuel Cells at Tulare Wastewater Treatment Plant. Photo courtesy of Tulare Wastewater Treatment Plant.

System Configuration

The fuel cell power plant is modular in design, containing four separate fuel cell units and separate systems for electrical and mechanical balance, biogas pretreatment, and heat recovery. FCE manages the fuel cell operation and maintenance remotely, and the company provided onsite training to Tulare WWTP personnel to familiarize them with the

technology.

The fuel cell power plant has maintained an electrical efficiency of about 47 percent and a combined heat and power efficiency of 90 percent during the 95,086 hours collectively logged from September 2007 through July 2011. The fuel cell power plant boasts availability of 99.45 percent providing reliability and assuring consistent energy savings. The fuel cells also produce waste heat that is recovered and use in the anaerobic digester.

To avoid damaging sensitive components, trace contaminants and moisture are removed from the biogas prior to use in the fuel cells using a pretreatment unit developed and installed by Applied Filter Technology. The gas pretreatment unit (GPU) is housed on a skid separate from the fuel cell system and is designed to reduce concentrations of water, hydrogen sulfides, particulates, siloxanes, and non-methane volatile organic compounds present in the biogas. Applied Filter Technology samples the biogas at regular intervals to ensure there is no contaminant breakthrough.

Installation

During the initial stages, challenges arose surrounding the design-build approach. Alliance Chico Energy managed the design-build, which was a new process for the city and provided added complexity for city attorneys. A lack of familiarity with design-build contract language delayed the project by several months. A conventional design-bid-build approach would have been less complicated; however the design-build approach gave the city better control over managing the project's timeline and budget.

FCE's DFC300MA fuel cells meet the IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems as well as California's Rule 21 for distributed energy resource generators. In contrast to the design-build challenges, connecting the fuel cell system to the grid was relatively simple. Because the WWTP's fuel cells meet the standards' criteria, electric power grid interconnection was accomplished without complication. Although fuel cells are exempt from most air quality permits, they are not exempt from all. The plant had to apply for some permits, but the process was relatively simple.

> "The combined heat and power capability of FuelCell Energy's power plant has been ideal for us. The fuel cells generate clean electricity and heat that we use in our anaerobic digester, making this system the most efficient and cost-effective for our needs."
> **- Lew Nelson, Tulare's Director of Public Works**

Maintenance

The City of Tulare has a five-year operations and maintenance agreement with FCE for the fuel cells. The system design allows FCE to provide continuous remote routine maintenance and restart of the fuel cells. The maintenance contract was amended to include the fourth fuel cell. The city plans to extend the maintenance contract so the maintenance needs won't fall on the staff of the WWTP. The city signed a separate five-year agreement with Applied Filter Technology to operate and maintain the GPU. This agreement includes routine biogas sampling to ensure the effectiveness of contaminant-removal media. The two operation and maintenance agreements collectively totaled $514,000 for the first year.

Cost

The total initial construction cost of the Tulare WWTP fuel cell system was about $7 million. The plant was able to apply $4.05 million received from Southern California Edison as part of California's Self-Generation Incentive Program toward that cost. Considering operations and maintenance costs, electricity cost savings, and other factors, the City of Tulare estimates that the initial three fuel cells will pay back the city's $2.95 million share in less than 5 years. Purchasing the fourth fuel cell brought the total cost up to $9.39 million and qualified for an additional $900,000 in incentives. The return on investment for the fourth fuel cell will be longer, as there were fewer incentives, and the maintenance contract is higher. The cost savings associated with the fuel cells at the Tulare WWTP are substantial. Based on the average electricity rate paid to the utility over a period of several months, the City of Tulare estimates that the fuel cell power plant generates an average of $3,500 in electricity per day.

Project Results

There are always challenges associated with new projects, and the Tulare WWTP fuel cell power plant is no exception. In addition to difficulties with using the design-build approach, the project team encountered issues with the GPU (including a small pump failure), but these have been relatively minor and were resolved by Applied Filter Technology. Another challenge is that occasional power interruptions to the WWTP cause the fuel cell power output to trip offline. The first three fuel cells do not have load banks and go into "hot standby" when the grid power fails, and it takes 10 hours to return to full electricity production. The response to this was that the newly added fourth fuel cell has a resistive load bank, which ensure homogeneous power flow from the fuel cells and reduce the risk of shutdown. Having this load bank ensures constant power from the fuel cell, even when grid power fails.

The Tulare WWTP's fuel cell installation is a crowning example of how fuel cells can be used to solve a variety of problems. Tulare's fuel cells cut the plant's emissions by efficiently using gas that used to be flared, and by avoiding emissions that would be created through the use of grid electricity. The fuel cells take waste by-product, and turns it into useful energy. WWTPs across California are beginning to turn to fuel cells to provide clean, reliable heat and power to run their facilities.

For more information on how fuel cells work and additional resources please visit the Fuel Cells 2000 website www.fuelcells.org.

The case study can be downloaded at: www.fuelcells.org/info/TulareCaseStudy.pdf