Turning Onion Juice Into a Power House

BY LYN CORUM

With an anaerobic digester and 600 kW of fuel cells, Gills Onions is now on the cutting edge of California's drive to transform the state into the renewable capital of the country.

Rising energy and waste disposal costs are plaguing California's vibrant and valuable food processing industry. Gills Onions invested time and research to identify technologies that will eliminate and reduce those costs.

Steven Gill and his brother David have been growing onions on 15,000 acres of their family-owned land in southern California for 25 years, along with other vegetables. Moreover, Steven Gill has a special affinity for finding technologies that can grow the business and manage it more effectively.

Looking to eliminate the hauling of onion waste to his fields, he began a search six years ago, for an anaerobic digester that could turn onion waste into digester gas that could, in turn, be burned in an onsite power generator. That search culminated in the startup of fuel cell operations in December 2008. The state-of-the-art anaerobic digester will start operating by summer 2009. What Gill saw as a business opportunity may provide the food processing industry a new set of tools to reduce costs and join California's drive to convert one-third of the state's power resources to renewable resources.

Natural gas and electricity prices have become a significant cost factor in California's fruit and vegetable processing industry, valued at $50 billion a year. Furthermore, coproduction of wastes and its associated liabilities has become a significant cost factor, and a limiting factor to the growth of operations, Gill testifies.

To put all of this in perspective, according to the California Institute of Food and Agricultural Research at the University of California, Davis (UC Davis), food processing is the third largest industrial energy user in the state. As such, it is an important, diverse, and dynamic sector of California's economy. Furthermore, California is the nation's leading producer of fruit and vegetables in the US.

Using Technology to Grow the Business

When the Gill brothers decided to grow and process onions at their Oxnard, CA, plant at the request of La Victoria—which wanted diced onions for its salsa—there was no way to wash, skin, slice, and dice onions outside a kitchen counter. "Nobody knew anything about onions, and learning how to shred onions took a long time," says Steven Gill. It took them two years to develop the equipment through trial and error. "Now this is the largest fresh onion processing plant in the world," he remarks.

Gill's onions are skinned, diced, sliced, or bagged whole, and shipped in small and large packages all over the country—some to wholesalers, and a lot to retail stores such as Ralphs. The Gill brothers also grow tomatoes, lettuce, and peppers on their Rio Farms, but those vegetables are picked and immediately shipped out to wholesalers and retailers.

A tour through the plant, which looks quite modest from the outside, revealed workers overseeing peeled onions traveling through chutes to the slicers or dicers and on to packaging, through sulfur-laden air. (Gill says the eyes get used to it over time.) A large, refrigerated warehouse attests to major cooling needs that keep stacks of red, yellow, and white onions, as well as small and large packages of diced or sliced onions waiting to ship to supermarkets, just-above-freezing temperatures.

Gill explains that they've never sent the onion waste to the landfill. Instead, until about a year ago, they would spread it in their growing fields to compost it—a great organic solution. But as the company grew, this effort became too expensive and unmanageable. They needed a better approach. About six years ago, Gill began looking at anaerobic digestion as a way to dispose of the waste. The methane produced could be used to create electricity. However, he discovered digesting onion waste had never been tried.

When Gill started researching anaerobic digestion, he hired Bill Deaton, a chemical engineer and consultant, as project manager. Deaton says they first sought advice from UC Davis, to determine how onions would work as feedstock in an anaerobic digester. Researchers there were doing biomass research on agriculture produce waste. They studied the onion waste issue for two years—the debate was between using onion skins or the juice. Juice was the winner, because it has higher sugar content, making it ideal for conversion to methane.

Enter Biothane and Fuel Cell Energy

Next, Deaton began looking for an equipment vendor and, after looking at eight or

10, settled on Biothane, which specializes in the design, engineering, and construction of compact anaerobic and aerobic wastewater treatment plants. He explains that a high methane conversion rate was needed for Gill's specific feedstock, "and that's what we got from Biothane."

Biothane is an international company based in the Netherlands, and has an office in Camden, NJ. It is a subsidiary of the French company, Veolia Water Solutions & Technologies. According to Deaton, Biothane designed an anaerobic digester specifically for onion juice. Furthermore, about a year ago, the plant began separating the juice from the onion skins. Gill's workers now spread juice, rather than all the onion waste, on the fields. The leftover press cake, a product of squeezing out the juice, is shipped to Bakersfield, CA, for cattle feed.

While quality and reliability of power has been of great concern for the food processing industry, Gills Onions offers an exception. Its processing lines do not depend on sensitive microelectronic controls, and, therefore, power quality disturbances have not been an issue, says Gill. However, power interruptions during the 2000–01 energy crisis led Gills Onions to buy and install a GE emergency generator.

Once the Gills decided on anaerobic digestion, the question then was what to do with the methane gas. As Steven Gill explains, there were several options. One was to burn it in internal combustion engines to generate electricity. However, the company did not want to go with this option, because they did not want to deal with emissions and the requisite air quality permits. The next option was microturbines, but they produced some emissions, although very low, and in the end could not compete with fuel cells.

Gills Onions chose the Direct FuelCell—manufactured by the Danbury, CT-based FuelCell Energy—for several reasons. First, they wouldn't need any air quality permits, because fuel cells are virtually emissions-free. Second, not only are fuel cells not noisy, they have high fuel-to-electricity conversion rates of 47% to 50%. Two 300-kW units began operating on natural gas in December 2008 and will start burning methane once the anaerobic digester is operating and reaches a steady state production of methane gas, sometime in mid- or late 2009. The $9-million project will have a six-year payback, says Gill. Southern California Gas will be presenting Gills Onions a $2.7-million check from California's Self-Generation Incentive Program, and the company will receive $3,000 per kilowatt in federal tax credits.

Hauling the onion waste to the fields cost the company $400,000 annually in hard costs for diesel fuel, tractors, spreaders, and labor. These expenses will be reduced to zero once the anaerobic digester is operating. The company spends $120,000 to $160,000 a month on electricity, mostly for air conditioning. These bills will be cut by $700,000 annually, based on Southern California Edison's current rates, with the fuel cells contributing about 35% of the plant's baseload electrical needs. Deaton says if you size the generation unit to cover more than the baseload, "the economics are not good as you go higher to cover peak loads."

Gill has more plans. He and Deaton will be looking at how the water can be recycled after being discharged from the anaerobic digester once the onion juice is processed. The water is currently being discharged into city sewers. Gill also wants to explore developing another product from onion juice. "We learned how to extract downstream" an antioxidant named quercitin, found in the outer skin of onions, he says. This antioxidant has anti-inflammatory characteristics, and Gill will be looking at incorporating it into cattle feed.

Waste Heat Recovery Adds Another Element

Refrigeration is required to cool the processing plant and to store onions at 34°F before they are washed in cold water and processed. Recently, the company installed five new MyCom ammonia compressors, totaling 900 horsepower, to provide refrigeration and air conditioning for the plant. The heat, generated by the compressors, is currently sent to the cooling tower to drop its temperature before going back to the evaporator. Another 850-horsepower Caterpillar air compressor blows skins off the onions.

Heat transfer loops are being installed to reach from one end of the plant to the other to pick up the heat generated by the compressors and by the fuel cells, once they are operational. The heat will be transferred through heat exchangers to warm washdown water, aerobic wastewater treatment, and other uses. Heat will also be injected into the anaerobic digester once it is operating.

The aerobic wastewater treatment equipment treats the water being discharged from the plant. It has been operating at 55°F to 60°F without supplemental heat, but adding heat will make it operate more efficiently and reduce contaminants. Deaton explains that every 10°C (50°F) can increase the rate of digestion. Originally sized to handle cold water, increasing the rate of digestion will increase the capacity of the equipment. The treated water then goes to Oxnard's water treatment plant.

GTI Researches Contaminant Removal

Cleaning up the methane will be a particular problem because of the high sulfur content in onions. This is the subject of a $106,000 California Energy Commission (CEC) grant awarded to the Gas Technology Institute (GTI) to study the biogas produced at Gills Onions. GTI is to demonstrate high-sulfur biogas cleaning and conditioning to FuelCell Energy's stringent gas quality specifications, in order to displace natural gas as a fuel source for the direct fuel cell power plant.

Ted Barnes, principal engineer for advanced energy systems at GTI, says there

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is no current commercial way to clean up onion waste, so research is necessary to determine the best way to remove the sulfur. The fuel cell is very particular about the quality of the fuel it is fed, so this research will be critical, he says.

Barnes explains that the implications for this research go far beyond onions. If a method to clean up onions is found, it will be applicable to other vegetable wastes as well. The CEC funded the research, acknowledging California's agriculture industry is a very large grower and exporter of vegetables. Furthermore, biofuels fit into the state's drive to develop renewable resources.

The research is in the preliminary design state, says Barnes. There is much laboratory work to be done before researchers know the quality of gas the anaerobic digester will produce. He says it will take six months to one year to evaluate the gas coming out of the digester and fine-tune the cleanup system. To begin with, researchers will do some small-scale bench testing, and a computer simulation model is being built to test alternatives. Barnes says Biothane has estimates of gas contents that can be created to do the testing. Gill mentions iron sponges and carbon filters, and Barnes says these are first guesses as to what will work.

Gill says the goal is to run on 100% biogas, but it may need to be mixed with natural gas, at least initially, with methane contributing 75% to 90% of the mix. Construction of the site for the anaerobic digester is under way. A very large hole has been dug near Gills' plant headquarters to accommodate a 150,000-gallon tank. The digester equipment, newly designed for onion juice, has been delivered and is in storage; it is expected to begin operating in April or May 2009. Once both the fuel cell and digester are operating, over 30,000 tons of carbon dioxide now being produced by decomposing onion waste will be eliminated. The company is already registered with the California Climate Action Registry and will be selling greenhouse gas credits in a future cap-and-trade program California will eventually develop.

Tony Leo, vice president of applications and original equipment manufacturer engineering at FuelCell Energy, is optimistic about cleaning out the sulfur produced by the onion juice at Gills Onions. "This is not a technical challenge," he says. "It's an economic challenge and can be helped by state funding. Since Gill bought the fuel cells, it tells me there is a value proposition in it for him."

Leo says those interested in pursuing the anaerobic digestion/fuel cell combination at their facility should figure out how much digester gas can be produced and what its composition will be. His company will then be able to determine how much electricity can be generated and how many fuel cell units will be needed.

Fuel Cell Energy Adapts to Biogas

Leo says the company developed its Direct FuelCell products, assuming they would be burning natural gas, but the first unit—shipped to Kirin Beer in Japan, in 2003—was to generate power using biogas. As noted in a July 2008 FuelCell Energy paper on the subject, the company became aware that as commercialization proceeded, biogas—in particular, anaerobic digester gas—was one of the most important alternative fuels that needed to be considered in the product mix.

While the main ingredient in anaerobic digester gas is methane, it is usually diluted with carbon dioxide to 30–40% of the level seen in natural gas, according to Leo. In comparison, wastewater treatment biogas is 60% methane, while beer plant biogas contains about 70% methane. Biogas also contains, as has been discussed, high levels of sulfur contaminants.

As of July 2008, more than 20 FuelCell Energy power plants had been installed at biogas sites, and additional applications were in production at the time. The biogas sector has become one of the company's most important markets, and FuelCell Energy has produced product design changes to accommodate biogas fuels. The approach taken by the company has been to design the power plant for the more common natural gas fuel and provide an auxiliary fuel cleanup system to deal with the wide variety of biogas compositions and their contaminants. Furthermore, the July 2008 FuelCell paper notes that the company's fuel cells are uniquely qualified to efficiently utilize digester gas, because they are insensitive to the amount of carbon dioxide in the methane.

FuelCell Energy first evaluated the implications of using digester gas in its power plants, when a 1-MW fuel cell power plant was installed at the King County Wastewater Treatment Plant in Renton, WA. The plant processed natural gas, digester gas, and scrubbed gas from raw digester gas. At times, it was necessary to mix the three gases, which created rapid increases in Btu content—an event the plant was not designed to respond to. An automatic system was devised to allow a controlled switch from the primary fuel to a secondary fuel while on full load. As the paper notes, this capability is very useful in applications where the fuel supply may not be stable.

FuelCell Energy has developed a fuel-blending feature that is being used at Sierra Nevada Brewing Co., in Chico, CA. The amount of digester gas available from the wastewater digester at the site can support approximately 25% of the 1-MW total fuel cell power generation capacity. The fuel-blending feature allows the power plant to use all of the available digester gas, and then blend in enough natural gas to make full power output.

The Kyoto Eco-Energy Project, which began operating in 2006, is FuelCell Energy's first project that is fueled by biogas from recycled food waste. The project is part of an 850-kW minigrid, consisting of the fuel cell, a wind turbine, photovoltaics, and gas engines connected in parallel to the local electrical grid. It combines intermittent power from solar and wind systems with firm power produced full time by the 250-kW fuel cell plant. Heat energy produced by the fuel cells is provided to the food waste digestion process, as it will be at Gill's plant. Japan's New Energy and Industrial Technology Development Organization support the project.

As Gills Onions begins operating its anaerobic digester, studying the quality and quantity of its biogas, and begins feeding it into its power plant, it will be backed up by a tool box of technologies already developed, allowing it to confidently adapt to operating realities. DE

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Fuel Cells and Power Quality

A variety of critical load industries —including information technology, telecommunications, and the medical field—require high power quality. Although conventional power quality solutions include UPS and emergency generators, fuel cells have the potential to mitigate short-term power quality problems with new technological advances that fine-tune dynamic responses, to aid voltage sags and momentary power interruptions. The added benefit of a fuel cell system is that it has the potential to deliver high quality power efficiently and without greenhouse gas emissions, making a truly "green" power source.

Several companies have already begun work on a new generation of fuel cells designed for the mission critical facility. GenCore, for example, has designed a fuel cell system that uses a proton exchange membrane and a single-phase inverter, so that its fuel cell can operate off grid or as backup power for a high power quality system. GenCore's fuel cell fulfills the need for high power quality, because it is combined with a high performance inverter made up of four IGBT (insulated gate bipolar transistor) power switches, a step-up power transformer, and a LC output filter.

By integrating a hydrogen storage tank, thermal management controls, and ultracapacitors, Hydrogenics' HyPX Fuel Cell Power can capture and release regenerative power, in order to provide higher power in short bursts as required by the load profile of a specific application. Along the lines of a traditional UPS system, the Hydrogenics Fuel Cell Power Pack form fit and function product of traditional large battery packs often found in powered equipment. According the Hydrogenics' Web site (www.hydrogenics.com), one of the many benefits of its Fuel Cell Power system is "instantaneous response and peak power in excess of HyPM rating" and increased power quality.

Altergy Systems has focused on combining its fuel cell engines with Eaton Electrical's electrical control and power distribution products to create a hybrid power distribution system designed to delivery high quality power to telecommunications and other mission-critical customers. The hope is that Altergy's collaboration with Eaton will allow the company to provide fuel cells engineered to delivery reliable, high quality power with low maintenance and startup costs.

Finally, Proton Energy Systems Inc. has responded to the challenge of creating a fuel able to meet the demands of the mission-critical industry, by developing a 10-cell UNIGEN regenerative fuel cell continuous power system. The Proton fuel cell is configured to respond to electrical interruption by picking up the load within less than one microsecond (0.000001 second), a response time far and above the 4,000 microseconds considered adequate for digital electronics backup systems.

The Proton UNIGEN makes its own hydrogen fuel and stores a portion of that fuel in a fuel cell stack that is chemically ready to react back through the fuel cell at any time, thereby providing instantaneous electrical energy. Proton's UNIGEN regenerative fuel cell continuous power system is aimed at sophisticated digital systems that are vulnerable to electrical interruption and, therefore, require backup protection that can deliver high quality power.

The idea that fuel cells can be a high quality power source is gaining ground. According to the National Fuel Cell Research Center, the ability to configure fuel cell electrical output to be computer grade is key. As an example, they note that fuel cell systems "have been configured to provide 99.9999+% uptime." Additional individual fuel cells can be arranged in a series to respond to increasing load demands, and even fuel cell power plants can be set up in a range of electrical outputs. In fact, it could be quite possible that in the near future, fuel cells will be used in conjunction with the grid and as a standalone source of high quality power.