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Towards energy self-sufficiency at a wastewater treatment plant

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Wastewater treatment plants are a classic application for CHP, as the fuel, power and heat loads are all present. Here, Ed Ritchie reports from one plant which has also added solar PV, on-site wind and hydro power to reach the point where it supplies all its energy requirements.

The Gresham Waste-water Treatment Plant in Oregon, US, missed an important anniversary in January 2011. That was when the utility had expected its six-year old CHP system to have paid back its cost and to start turning a profit. There was no celebration, but no disappointment either, because the system actually hit that break-even date about 19 months earlier, in May of 2009.

But this is more than a financial success story. This is a story about a city, a utility, a multinational water company, and a shared vision for achieving sustainability.

The city's planners took some of their first steps on the path to sustainability in the late 1980s, with the commissioning of a biogas-fuelled CHP system at the wastewater treatment plant. It was a respectable effort for a plant serving just about 108,000 customers. The plant treated from 13-20 million gallons per day (as it still does today), and at that point the 250 kW reciprocating engine used 59% of the available gas, leaving the rest to be flared off, rather than entering the atmosphere as raw methane. Exhaust heat from the system found use in displacing the natural gas that was burned to heat the treatment plant's anaerobic digesters.

Unfortunately, by 2003 the corrosive nature of biogas had taken its toll. It's not surprising because biogas is typically composed of 60% methane and 40% carbon dioxide, with just enough trace amounts of hydrogen sulphide to wreak havoc on gensets that haven't been designed to resist the abusive fuel. For Gresham's engineers, the frequent outages plus expensive repairs made it more than apparent that a new CHP system was needed. At least the timing was fortunate, as the City of Gresham happened to be doing a master plan to upgrade the facility.

Aerial view of the solar PV installation
Source: City of Gresham, SunEdison and REC Solar

AIM FOR A SELF-POWERED FACILITY

Having earned high marks in biogas from the 'school of hard NOx', Gresham's team applied their lessons to the master plan, developing the design, procurement, financing and technology, with the intent of delivering a project that would be the foundation of the plant's ultimate (and lofty) goal - a 100% self-powered wastewater treatment facility based on renewable energy.

To start, the firm of R&W Engineering, Beaveron, Oregon, performed a preliminary study and evaluation of biogas potential, and determined that, by adding the flared gas, the plant could almost double the output, with a 395 kW CHP system. But that was just the beginning.

With fresh memories of the short and expensive life of the first CHP system, engineers opted for a fuel treatment system designed to remove harmful moisture and contaminants from the digester gas. The hardware specifications called for a chiller to condense moisture, a packed-bed reactor to remove hydrogen sulphide, and two packed bed reactors to capture a relatively new intruder to wastewater treatment plants - siloxanes - the catch-all category for consumer product chemicals that can leave harmful deposits with plenty of sticking power on the metal surfaces of gensets.

A Caterpillar model G3508 eight-cylinder engine generator package won the honour of fulfilling the power and heating requirements at Gresham. 'We have evolved this engine starting with the G3516A model,' explains Nick Kelsch, gas application consultant at Caterpillar. 'That was our first low energy or landfill biogas genset package, and was purpose-built to run on this type of fuel.'

As is typical in a biogas environment, the engine runs in a 'lean burn' mode that has proven to be the optimum method to satisfy US and Canadian regulations for NOx emissions. 'With the technology we use on all of our low-

energy or biogas projects we can get under the maximum allowable emissions regulations without having to employ exhaust after treatment, which is sometimes tricky to do because of the elements that come along with biogas.'

Lean burn helps, but Kelsch notes that his company's definition of a purpose-built engine includes modifications to a host of other operating parameters, and design upgrades. For example, the engines operate at much higher than normal jacket water temperatures to prevent the condensation of corrosive elements, and with higher tolerances in components such as exhaust valves.

Of course, the exhaust has a job to do, and along with heat from the above-normal heat jacket water, is harnessed to a heat recovery system that produces 82°C water to maintain a temperature of 33°C, thus keeping the bacteria's biological reaction ideal for the two digesters. Finally, everything connects to a SCADA system to run the plant, and even to switch the CHP to back-up mode to keep critical components on-line in the event of a grid failure. With such good specs, only two questions remained: how much will it cost, and how can it be funded?

The engine-based CHP plant

Source: City of Gresham

In all, for consulting, design-build, permits and inspection, substation relays, plus internal engineering and administration, the total cost was $1,352,000, while the estimated payback period stood at 8.1 years, based on energy savings of $203,000, and system maintenance costs of $36,500. A respectable return on investment, but Gresham's planners thought they could do better, and found help from two sources. The Oregon Energy Trust offered $82,000 in return for retaining the rights (and financial benefits) of the project's green tags (environmental attributes). Then the project qualified for a Business Energy Tax Credit from the Oregon Department of Energy, valued at $288,000. Together, the two contributed a total of $370,000, reducing the budget by 27% and shortening the payback period to just 5.9 years.

PUBLIC-PRIVATE SECTOR PARTNERSHIP

The project was completed in 2005, but its impact on the plant and the green momentum was just beginning. Along with the new CHP system, the City of Gresham took another significant step in 2005, by selecting Veolia Water North America, to manage the wastewater plant's operations. (In 2008, the City of Gresham and Veolia Water received a Public-Private Partnership Award from the National Council of Public-Private Partnerships for their collaboration on this innovative, renewable energy solution.)

A primary goal of the new relationship was to ensure an optimum level of performance from the CHP unit. In fact, as part of a seven-year, $21 million contract with Gresham, Veolia agreed to guarantee a minimum of 90% up-time performance for the cogenerator. In something of a nod of confidence to all the parties involved in the project, the guarantee was made before the new system was installed. Did the confidence pay off?

It paid with dividends according to Alan Johnston, senior engineer at the City of Gresham. 'We've had some of our best production in 2010 and it was about $275,000 in savings over one calendar year,' says Johnston. 'I think our runtimes were 95% to 96% and that's about as high as we can output with our operation.'

Gresham would like to increase its CHP capacity with another unit
Source: City of Gresham

Not only has the project exceeded the minimum output levels, but Gresham's operations team also managed to exceed repair and replacement expectations for both the fuel treatment system, and the Caterpillar genset. Furthermore, the city's efforts have garnered numerous awards.

Getting more life out of the fuel treatment system's filtration media was relatively simple and involved modifying the hydrogen sulphide sponge media and discontinuing the addition of caustic soda ash. That extended the life of the media to meet Gresham's goal of 100 days' usage before replacement.

For the Caterpillar engine, maintenance is a matter of hours on the clock, but according to Richard Ludlow, Veolia facility asset manager, sometimes it's better to rely on what's in the crankcase. 'Instead of the Caterpillar-recommended hourly period of oil changes we determine the oil change cycle based on oil sample test results,' says Ludlow. He credits the oil testing and fuel treatment with getting double the manufacturer's lifecycle out of the Caterpillar before it required a major overhaul. 'They recommended 9,000 to 13,000 hours and we have made it to double their times between manufactured recommended top-end overhauls,' he adds.

MORE CHP CAPACITY, ALSO PHOTOVOLTAIC

With such performance, it's not surprising that Gresham would like to increase its CHP capacity with another unit. In fact the current system doesn't use all the biogas from the digesters, and monitoring is in progress to determine how much is available.

While this biogas is insufficient to run a matching Caterpillar genset, another source of biogas could make up the balance, according to Alan Johnston. 'Initially the data we looked at showed that we were flaring about 15% of the gas we produce,' Johnson explains. 'But now we're designing a fats, oils and grease (FOG) receiving facility that will probably increase our gas production by 50% with no more than 15,000 gallons per day. From there we would be looking at scaling up the CHP system.'

A preliminary study showed that a FOG and green waste project to process 3000 gallons of grease and 20 tonnes of food scrap per day could be built for about $1.1 million. It would generate enough digester gas to run three microturbines at 1600 MWh/year, one fuel cell at 80% capacity for 1400 MWh/year, or one Caterpillar engine at about two-thirds capacity for 900 MWh/year.

Although the FOG project is still in the planning stage, renewable energy from a photovoltaic array is a reality, and it required no capital investment from Gresham. The 420 kW peak capacity system is owned by SunEdison, Beltsville, Maryland. Gresham buys the array's power at rates below that of the local utility, Pacific Gas and Electric (the initial rate was 25% below the PGE rate). SunEdison operates and maintains the ground mounted system, which covers almost an acre of land.

Ludlow says, 'In 2010 our solar array was in production for the whole year for the first time, and did about 450 MWh and that's about 8% of the plant's needs. We had anticipated about 420 MWh.' As with the CHP project, the Energy Trust of Oregon provided some financial incentives. Over a 20-year period, the array is projected to generate more than 8 GWh of renewable energy.

Gas treatment plant
Source: City of Gresham

The combination of the existing CHP system and the solar array supplies 56% of the wastewater treatment plant's needs. That leaves a fairly significant gap to bridge if Gresham truly wants the plant to be 100% off the grid. But the FOG project will boost onsite energy production to 89%. Just 11% to go and, not surprisingly, there are two more renewable energy sources with projects ready to complete the plant's path to sustainability.

NEW ON-SITE WIND AND HYDRO POWER

The first is a small wind project that could close the gap by an additional 5%. Most likely the power would be generated by roof-mounted units of the 20-100 kW variety. In its search for funding, the city is applying for a grant from the Oregon Business Department. And, finally, Gresham has the opportunity to take advantage of hydropower by tapping into a 122 cm water outfall pipe. A study has been completed and shows that a 50 kW micro-hydro generator would fit nicely and supply the last 5% needed to total 100% self generation.

Then too, as part of Veolia's charter with Gresham, there are gains to be made in energy efficiency upgrades. Among them: replacing four existing motors with premium efficiency motors, reducing the system's pressure, and replacing the aeration diffusers with newer more efficient fine bubble diffusers. 'We are under construction on those projects related to energy,' says Johnston, 'And we have taken advantage of fine bubble diffusers to replace some of the 30-year-old technology. We'll also change our digester mixing to a more efficient system.'

All told, Gresham's efforts cover a wide range of solutions for on-site power production. Moreover, the city has garnered many awards acknowledging its efforts in sustainability. Cogeneration and photo-voltaics make for a firm foundation, and the future holds opportunities for wind and hydro-power. The city demonstrated tenacity in using creative financing, power purchase agreements and incentives to fund the projects. With that kind of track record, it wouldn't be surprising to see the wastewater treatment plant take its sustainability goals beyond energy independence and ultimately become a net exporter of power.

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