Costa Rica

Evaluating Digester Design For Electricity Generation

Low-tech digesters alleviate environmental degradation and produce high-quality biogas, but technological improvements are needed.

Joaquín Viquez, Stephanie Lansing and Helen Martínez

IN DEVELOPING countries, electricity generation is achieved through fossil fuel consumption or hydroelectric dams, both of which have a high environmental impact, including greenhouse gas emissions and ecosystem alteration. In many developing countries, the price of electricity is relatively high, making it inaccessible to portions of the population. In Costa Rica, the average household electricity price is $0.13 kW h⁻¹.

In addition, the discharging of wastewater into water supply areas has a large environmental impact. Due to the inability of many governments in developing countries to enforce environmental laws and the high cost of implementing wastewater treatment plants, wastewater from animal production facilities passes largely untreated into water supply areas.

Considering both issues are key for sustainable development, anaerobic digestion of livestock manure is a reduction in the negative impacts of wastewater on air and water quality.

Conventional anaerobic digestion using complete-mix or plug-flow technologies has not been shown to be practical or economical for developing countries. Studies have shown that the Taiwanese model-biodigesters can produce biogas with methane concentrations above 60 percent, with temperatures at or below the mesophilic range (25 to 35°C or 77°F to 95°F) (Lansing et al, 2007).

The Taiwanese-model biodigester is a simple flow-through reactor consisting of a double tubular polyethylene bag and PVC piping. The construction, materials and labor costs of an 8-meter long (26-foot) Taiwanese-model digester, with a volume of 10 m³ (353 ft³), in Costa Rica is approximately $200.

A 10 m³ digester can treat waste from 20 pigs, offering up to 3 m³ (106 ft³) of biogas per day with methane content above 60 percent. The digester requires little lifetime maintenance. There are approximately 1,000 of these digesters in Costa Rica, 5,000 in Colombia and around 20,000 in Vietnam.

In Costa Rica, at EARTH University, an international private, nonprofit undergraduate university specializing in the study of sustainable agriculture, a research team evaluated the possibilities of using this low-cost technology for electricity generation. The produced biogas would supply energy to the university's dairy and swine farm and at the same time be a learning component for students, government, private organizations and the community.

Description

This case study evaluated an electricity generation plant using biogas from a Taiwanese-model biodigester as the fuel source. The study was conducted at EARTH University, located in the humid tropics of Costa Rica, at an elevation of 50 m (164 ft), with an average temperature of 25°C to 30°C (77 °F to 86 °F).

The electric generator received biogas from two biodigesters: a 102 m³ (3602 ft³)
The dairy farm and swine facility produced biogas with a methane concentration of 62.3 percent ± 0.7 (n = 15) and 76.6 percent ± 1.4 (n = 16), respectively, and had hydrogen sulfide concentrations of 246.2 ppm ± 29.6 (n = 6) and 324.3 ppm ± 7.8 (n = 10), both of which are less than 0.05 percent of the produced biogas. Both digesters produced on average 0.25 m³ of biogas per m² of digester, with a total of 44.5 m³ of biogas produced per day.

The EARTH University farm, which includes the dairy farm and swine facilities, has an electricity demand of 12.9 ± 1.05 kW h⁻¹ during the eight hour work day. Considering that the demand of the farm is only 32 percent of the generator potential (40 kW), there is an efficiency of only 7.0 percent, with 2.2 m³ of biogas being used to generate each kW h⁻¹ of electricity. If the generator were used at the full 40 kW capacity, running at the manufacture-stated efficiency rate of 35 percent, only 0.44 m³ of biogas would be used to generate each kW h⁻¹. At full capacity, the produced biogas from the EARTH University digesters would provide 40 kW h⁻¹ for 2.53 hours a day.

The concentration of organic matter in the wastewater was significantly reduced during the digestion process. At the dairy farm, there was a 78 percent decrease in COD and a 63 percent decrease in TS. At the swine facility, there was a 91 percent decrease in COD and a 64 percent decrease in TS (Table 1). This decrease in organic loading will reduce the environmental impact of the wastewater on aquatic life in the receiving waters.

The impact of wastewater on the rivers in Costa Rica has resulted in new laws and regulations governing the handling and disposal of manure, resulting in fines of $0.22 for every kilogram of COD discharged above the 500 mg L⁻¹ limit. The effluent from the digester at the swine facilities fall below the legal limit without any further treatment. The dairy farm, however, is above the legal limit due to a high COD levels in digester influent. Currently, the effluent from both digesters undergo further treatment in tertiary lagoons, which results in the effluent waters being well below all legal limits.

During the anaerobic treatment process, nutrients are converted from the organic form to the dissolved form, which increases the fertilizer value of the digester effluent.

The EARTH University electricity generation project had a capital cost of $60,000, which included the cost of both biodigesters (including piping and roofing) ($12,000), the electric equipment ($43,000), and the hydrogen sulfide absorption tower ($50,000). Cummins Power Generation donated the electric generator to EARTH University.

Considering only the income from the savings in the electricity bill, all the installation costs would be recovered in 14 years, with an internal rate of return of 5.44 percent for a 20 year period. If the generator were run at full capacity and the biogas production was doubled using codigestion (Lansing et al., 2008), the capital costs would be recovered in 5 years with an internal rate of return of 22 percent.

**Conclusions**

With almost no maintenance or internal control, this system produces high quality biogas, reduces over 50 percent of the organic matter in the wastewater, and increases the fertilizer quality of the manure (effluent). EARTH University’s dairy farm has 36 milking cows that are kept in the milking parlor for only 2 hours a day, thus the digester receives only a fraction of their daily manure. The swine facility has 80 pigs that have an average weight of 50 kg and are kept in the corrals 100 percent of the time. The size of this farm is relatively small, but the amount of biogas offered is sufficient to supply for the farm with its energy needs.

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Although the system is likely still inaccessible for small farmers in developing countries, with cheaper engines and codigestion, this system can become more accessible, especially for medium to large-scale farmers, in a way that could contribute to Costa Rica's electricity production.

J. Viquez is based in Costa Rica and can be contacted at: jsviquez8@gmail.com; S. Lansing is at The Ohio State University's Department of Food, Agricultural and Biological Engineering and can be contacted at: lansing.10@osu.edu; H. Martinez can be contacted in Guatemala at helenmichellemartinez@gmail.com.

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The pilot food waste program started in December 2007, once funding was in place. Collection is scheduled to start for the six participating companies (four restaurants, a supermarket, and a private school) in early February 2008 (see sidebar).

“We will track the amount of food waste generated by each participant, and total costs,” says Buk. “Since our employees will be collecting the material, we will be able to inspect the containers and, if they contain too many contaminants, we will leave it with the trash. We will provide regular feedback to the customers, and are also providing written training programs and signage customized for each business.”

Buk is looking at systems for enclosed, year around composting for larger quantities of organic waste, due to cold winters and concerns about attracting bears. “It will take time to establish boundaries of what will work, and it will be a costly upgrade,” he says. “What needs to occur is a commitment from the county to create a waste management strategy over the next 10 years, because the financial investment is so large for Terra Firma that a payback has to be guaranteed through long-term contracts. If Teton County is not on board, you can be certain that organics diversion will not progress, but so far the county has been very support-

Penny McBride is a consultant to, and former employee of, Terra Firma Organics. She is a Leadership in Energy and Environmental Design Accredited Professional (LEED-AP) and works as a sustainable building consultant on a variety of projects in Jackson, Wyoming. Robert Spencer, a Contributing Editor to BioCycle, is an environmental planner in Vernon, Vermont.