anaerobic
DIGESTION
in the Pacific Northwest

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Concerns about climate change have increased interest in anaerobic digestion (AD), a commercially available technology increasingly used to treat livestock manure on concentrated animal feeding operations (CAFOs). AD can provide climate benefits because it generates and captures methane, a powerful greenhouse gas\(^1\), in a controlled environment. In the absence of AD, methane is generated from manure as organic materials decompose in oxygen-deprived conditions, and is released directly to the atmosphere (Mosier et al., 1998). By enhancing methane generation and capturing it, methane emissions are avoided. When burned, the methane-rich biogas can replace fossil-fuel generated energy, generating additional positive climate impacts. These two climate benefits can generate financial returns through the sale of carbon credits for manure management and renewable energy generation offsets.

AD technology creates an environment without oxygen (anaerobic) in which naturally-occurring microorganisms convert complex organic materials in manure and other wet organic wastes such as food processing wastes to biogas, a source of renewable energy (US-EPA, 2006), as well as fiber and a liquid effluent (Figure 1). Value-added products may also be produced if appropriate and economical technologies can be developed. In addition to reducing greenhouse gas (GHG) emissions, the process can reduce odors, stabilize waste, and decrease pathogen counts, greatly enhancing manure management efforts (Martin and Roos, 2007; US-EPA, 2004; US-EPA, 2005; US-EPA, 2008).

AD technologies are much more widely used in Europe than in the U.S., where concerns about high capital costs and poor return on investment have led to low adoption rates. In 2004, only two farms in the Pacific Northwest (PNW) had operational anaerobic digesters. Washington State University’s Climate Friendly Farming (CFF) Team, in collaboration with industry, non-

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\(^1\)Methane has 25 times more global warming potential than carbon dioxide over 100 years (IPCC, 2007).
governmental organizations, and government agency partners, launched a comprehensive program to evaluate existing and develop new AD technology, support installation of a commercial digester on a PNW dairy farm, analyze the financial drivers for AD in our region, improve the management of AD systems (including improved understanding of the benefits of co-digesting manure and food processing wastes), research and develop co-product technologies to increase financial returns, and support the development of effective public policy to encourage deployment of AD technology.

This article focuses on two aspects of the research of particular interest to producers in the West: our financial assessment of a commercial scale digester with a special focus on co-digestion of food processing wastes, and ongoing research to develop technologies to recover nutrients from AD effluent.

Financial Assessment

To help prioritize technology development efforts, the economics of digester operation were analyzed using financial data from a commercial scale anaerobic digester installed with CFF support on a dairy farm in northwest Washington State.\(^2\) The analysis considered a scenario based on actual construction costs (with grants covering a portion of these costs), manure from a 500-cow on-farm herd and 250 cow herd one mile away, and co-digestion of pre-consumer food processing wastes (16 percent by volume). Revenues were generated from electricity sales, tax credits for renewable energy generation, greenhouse gas offsets, tipping fees from food processing wastes, and fiber. The majority (85 percent) of fiber was used on farm as a bedding replacement, while 15 percent was upgraded for sale as a soil amendment after pretreatment by a patented process developed through the CFF Project (MacConnell, 2006; MacConnell et al., 2007; Liao et al., 2010).

Previously, the most documented and studied revenue stream from AD was electrical sales from power production. However, in the PNW, where received prices for produced electricity are well below the national average of $0.09/kWh (US-EIA, 2010), our analysis confirmed that other revenue streams are important to financial viability and stability. With only revenues from electricity produced from manure from 500 cows on farm, the project had a negative net present value -$644,556, and a modified internal rate of return of only 1.8 percent, lower than the discount rate (Bishop and Shumway, 2009).\(^3\) This negative financial picture is partly attributable to the “oversizing” of the project (designed for 1,500 cows), resulting in high total construction costs of $1,136,364. Sizing was done to allow for possible future farm expansion, use of trucked-in manure from nearby farms, and utilization of other imported organic materials. A similar analysis carried out by the U.S. EPA (2004) noted that for digesters dependent on the sales of electricity, economic feasibility was dependent upon proper digester sizing and adequate electricity prices, both of which were more positive in their study.

When all additional revenue streams were considered, the economics of the project became quite positive. Operating revenues were significantly larger than operating expenses (Figure 2), and the entire project had a net present value of $1,375,371, and a modified internal rate of return of 9.9 percent (Bishop and Shumway, 2009). Surprisingly, further analysis indicated that trucking in manure from a neighboring farm had a negative impact on project economics in the case of the test digester, despite the relatively short travel distance of one mile (Bishop and Shumway, 2009). This finding may have important implications for projects that plan to transport liquid manure by truck, suggesting that economic feasibility should be carefully considered.

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\(^2\)The digester was a patented modified plug-flow digester with axial dispersion and sludge recycling.

\(^3\)For investment in the digester to be considered feasible, the net present value (NPV) must be positive, meaning that the rate of return on the investment is greater than the cost of the capital (i.e., the interest rate). The modified internal rate of return (MIRR) is a modification of the internal rate of return (IRR) that corrects for the fact that internal rate of return (IRR) calculations assume that any potential revenue can be re-invested in the project and earn equal returns, an assumption that is often considered overly optimistic. For the project to be considered economically feasible, the MIRR must be greater than the minimum acceptable rate of return, normally the discount rate (Kay and Edwards, 1999).

\(^4\)For their analysis, Bishop and Shumway set the discount rate to 4.0%, based on the average of the 4.3% rate of return to U.S. farm assets reported by Blank for the period 1960-2002 and the 3.4% rate or return to U.S. farm equity based on ARMS data (USDA) for the period 1996-2006.
Figure 2. Breakdown of average projected annual operating revenues (top) and expenses (bottom) for anaerobic digester installed in northwest Washington, carrying out co-digestion of 16 percent pre-consumer food processing wastes with dairy manure. Financial data was collected from 2004-2007. For details of data collection and assumptions underlying financial analysis and digester performance, see Bishop and Shumway (2009) and Frear et al. (2010).
Co-digestion was by far the strongest contributor to financial performance, accounting for 63 percent of average annual project revenues (see green shaded portions of revenues chart in Figure 2). Food wastes roughly doubled methane production (and therefore electricity and tax credit revenues), because of the higher energy content of food processing wastes compared to manure. These results are consistent with other commercial and laboratory-scale studies indicating that biogas production can be enhanced by 25–400 percent, depending upon the type, concentration, and flow rate of the organic waste stream (Alatriste-Mondragon et al., 2006; Braun et al., 2003). Meanwhile, tipping fees received by accepting the wastes was the largest single project revenue source. Based on these results, locating digesters in areas where strong relationships can be formed with food processors may be important to project success.

The sale of carbon credits did contribute to overall project revenues, but made a relatively minor contribution. This may be important, because the prices of carbon credits through the Chicago Climate Exchange have been quite volatile over the past few years, and at times quite a bit lower than they were when the data underlying this analysis was gathered in 2004-2007. However, even without the consideration of carbon credits, the net present value of the project (considering all other revenue streams) was $1,185,416, and the modified internal rate of return was 9.3 percent (Bishop and Shumway, 2009).

Nutrient Management

While the financial analysis included many revenue streams, it did not incorporate analysis of the potential impact of refining biomethane into transportation fuel, or producing fertilizer-grade nutrients. Each of these technologies is still in development, with ongoing efforts by CFF Project researchers.

However, several considerations indicated that technology development for nutrient products was particularly important. First, farms that accept food processing wastes for co-digestion with manure import additional nutrients to the farm, exacerbating existing nutrient management concerns (Figure 3). Managing these additional nutrients has the potential to create additional costs (costs not captured in our financial analysis), as dairies need to manage the nutrients in compliance with applicable regulations.

Second, communication with dairy industry leaders in the PNW made it clear that nutrient management is a key concern for dairy farmers in our region. As one Washington dairy farmer stated, “We don’t necessarily want to be energy producers. We want to milk cows. But...if an anaerobic digester can help us solve our manure...”
problems, help with nutrient management, and keep us in the business of producing milk, then...producing energy and mitigating GHG emissions will be welcome side benefits." Thus, a key focus of current research is the development of cost-effective methods for recovering marketable nitrogen and phosphorous from the AD effluent.

Our research has developed an integrated process for removing ammonia and phosphorous from the liquid effluent through the simple addition of heated air, forced into the pre-heated liquid effluent with blowers. After phosphorous and ammonia removal, the pH of the resulting low-nutrient effluent can be re-adjusted using the AD biogas, allowing for field application without additional chemical costs, though sulfuric acid is required to sequester the released ammonia in a stabilized ammonium sulfate solution. This process also removes some impurities from the biogas, improving biogas quality. A series of bench and pilot tests have confirmed that the integrated process is viable, with economics that could be cost-effective (Zhang et al., 2009; Zhang et al., 2010; Jiang et al., 2008; Jiang, 2009). The process generates two important bio-fertilizer products: an ammonium sulfate solution and a phosphorous rich organic solid.

Commercial-scale evaluation is ongoing with industry partners at two Washington dairies, and we are working with additional industry partners on product formulations that will meet fertilizer purchasers’ needs. Future results will be available from WSU’s Center for Sustaining Agriculture and Natural Resources. We plan to develop marketable fertilizer products that will further spur AD adoption and aid in nutrient management on dairy farms. Because the industrial processes currently used to manufacture fertilizers (particularly nitrogen fertilizers) may require large amounts of energy, these nutrient products also have the potential to create additional climate benefits if they are used in place of other fertilizer products (IFA, 2009; Zaher et al., 2010).

In addition, we hope that our research will help change the perception of AD technology, from a more limited view of AD as a manure management tool or an “energy technology”, to a view that sees AD as a bio-refinery that can produce a number of different products from multiple organic feedstocks. Taken together, this variety of projects has the potential to provide financial stability and enhanced financial returns to dairies and other CAFOs, as well enhancing the beneficial impacts on the climate and rural communities.

References


RECOMMENDED READING

Climate Friendly Farming Information on the website of Washington State University’s Center for Sustaining Agriculture and Natural Resources: csanr.wsu.edu/pages/

U.S. Environmental Protection Agency

AgStar: epa.gov/agstar/