International Food and Agribusiness Management Review
Volume 13, Issue 3, 2010

Industry Speaks

Carbon and Energy Life-Cycle Assessment for Five Agricultural Anaerobic Digesters in Massachusetts on Small Dairy Farms

Chelsea Morris[①a], William Jorgenson[b], and Sam Snellings[c]

[r]*Researcher, AGreen Energy LLC, 580 Harrison Ave Suite 404, Boston, Massachusetts, 02118, U.S.A.*

[b]*Managing Partner, 580 Harrison Ave Suite 404, Boston, Massachusetts, 02118, U.S.A.*

Researcher, AGreen Energy LLC, 580 Harrison Ave Suite 404, Boston, Massachusetts, 02118, U.S.A.

Abstract

In the United States anaerobic digestion units are in place on several farms, but primarily handle manure and very small fractions of other organic material. AGreen Energy's business model aims to increase the profitability of dairy farmers and the food processing industry by utilizing organic feedstocks produced in urban areas, while reducing the risk to investors by installing an expensive technology which better meets the needs of environmental regulators.

An assessment is conducted that quantifies environmental impact through estimates of useable energy produced and carbon emissions avoided by AGreen Energy's project to install anaerobic digesters on five Massachusetts farms. The analysis shows the anaerobic co-digestion of manure and source separated organics under project conditions results in a net energy gain of 1:2.9 and a GHG emissions reduction of 50% over business as usual, justifying the technique as a sustainable residual management tool for dairy operations as well as food industry businesses.

Keywords: anaerobic digestion, co-digestion, dairy operations, food processing, greenhouse gas emissions, net energy gain

[①]Corresponding author: +1 617.510.5245
Email: contact@agreenenergyllc.com

Introduction

The dairy industry continues to face challenges and changes from increasing energy costs, tightening environmental standards for air and water emissions, and volatile milk prices. These changes are especially difficult for smaller dairy operators who buck the trend of the 5,000+ cow mega-dairies. AGreen Energy, LLC, a management company of five farmers and businessmen in the Northeast United States, plan to demonstrate that the viability of the small farm can be improved while meeting stricter environmental standards through the on-farm co-digestion of farm manure and off-farm SSO.

Anaerobic digestion of manure and other organic material is a widely accepted practice in many European Union nations and an emerging one in the United States. Dairy waste is carted off from the milking parlor floor and to a large sealed container where it is heated and mixed with other organic material, such as SSO, for a period of 15-35 days. Naturally occurring bacteria break down the organic matter, or digestate, under anaerobic conditions (without oxygen) to produce methane gas. The methane gas is burned in a generator to produce electricity used on site or sold to the electrical grid. After the digestate is fully stabilized by the process it has several secondary uses including bedding for cows and fertilizer for crops.

In the United States anaerobic digestion units are in place on several farms, but primarily handle manure and very small fractions of other organic material. AGreen Energy's business model aims to increase the profitability of dairy farmers and the food processing industry by utilizing organic feedstocks produced in urban areas, while reducing the risk to investors of installing an expensive technology and better meeting the needs of environmental regulators.

Dairy farmers see the most benefit from handling their waste with a turn-key anaerobic digestion unit. Income is earned from savings on energy usage from the methane driven generator, reduced fertilizer costs from use of a better homegrown product, and a less expensive alternative to sawdust bedding material. In addition to replacing the electricity demand at the farm, excess power will be sold to the grid and used in the local community. The farmer becomes not only a source for milk and dairy products, but provides the community with renewable energy. Exhaust heat from the generator, after satisfying existing farm heat demand, can be used to heat hoop houses with vegetable crops in the winter. Demand for local produce in the Northeast during the winter greatly outstrips the supply. After processing, the digested manure is used as a cheap, sustainable fertilizer. This will reduce the need for additional chemical or organic fertilizers. Additional digested product not used on crops can be sold to other local farmers or used as a bedding alternative to sawdust. The dairy operator also enhances his or her standing with surrounding community by eliminating unpleasant odors originating from traditional lagoon style manure storage and raw manure spreading.

The food processing industry stands to gain considerably with agricultural anaerobic digestion presently and in the future. In our model, AGreen Energy provides an additional revenue stream to the farmer through contracts to accept food residuals from processing facilities. These fees are priced to compete with current fees paid by generators for landfill or composting disposal. From a food processor's viewpoint, the disposal route runs nearly the same as before. Liquid haulers pick up the food residuals at regular intervals (daily, weekly, biweekly) and the disposer is charged at a per volume basis. The price is competitive to other disposal methods, but the service renders greater benefits.

Waste streams from soup-making, seafood processing, and other food products can be challenging, or expensive, to dispose of properly, often ending up in the municipal wastewater stream or landfilled. These streams can be diverted for inclusion in an anaerobic digestion "recipe" where they are stabilized and returned to the soil. SSO producers partnering with dairies secure present and future diversion opportunities ahead of state and federal regulation of organic materials in landfills. State yard-waste landfill bans are already supported by the US Environmental Protection Agency, and general organic material bans have been adopted by several European nations.

Contracting with a renewable energy source can be a communication platform to consumers on how a supplier's product supports sustainable environmental efforts. Food processors partnering with AGreen Energy enhance their supplier credentials by meeting retailer's requests to recycle all by-products from production. They become a source of sustainable procurement, which many companies including Unilever and Wal-Mart have adopted as part of their operational philosophy. Long-term contracts with AGreen Energy to remove organic waste will reduce processor energy expenses and the overall carbon footprint.

State and Federal Regulators will find agricultural anaerobic digesters can be used to meet several environmental needs. The technology can be used to improve air and water quality for existing and expanding herds in a quantifiable way. When agricultural materials such as milk-house waste and manure, and food residuals are treated as waste, they are often handled and disposed of at the lowest cost. On the farm, this has in several cases led to the construction of inadequately sized or maintained manure lagoons. If an organic material waste stream is reframed as a valuable feedstock, it is handled more carefully with additional funding is available for their handling and storage.

Anaerobic digestion is a tangible technology implementation allowing smaller farms to become more economically sustainable while affordably meeting state environmental guidelines. Generating power with agricultural anaerobic digestion is a way to meet Renewable Power Standards existing in 39 states and join the USDA effort to meet the 40% reduction of greenhouse gases by the year 2020. Finally, agricultural anaerobic digesters can help local and state agencies meet their long-term goal of solid waste reduction and efforts towards zero-waste facilities.

Investors find the organized entity, a management LLC, reduces the risk of any one digester investment through pooling of operations using sophisticated process controls with professional management. A steady return business of 9 to 15% IRR is attractive to those seeking utility-like investment returns. The business operates like any other utility, with the added benefit of meeting the most stringent of green standards. These standards for air and water are easily audited and verified to meet environmental desires in investments. Social responsibility and sustainable practices can be demonstrated through a codified method for investors seeking this class of investment. The business model is also replicable to expand geographically as more States adopt Renewable Power Standards and similar regulatory measures.

In this assessment we aim to quantify the positive energy benefit and carbon reduction for the Massachusetts project. It is important to note that this model of resource sequestering is made possible by the unique geography of the Northeast. Small and medium-sized dairies located near a large metropolis make SSO feedstock available for diversion to farm digesters as well as the premium renewable-electricity price paid possible. Small dairies are a strong and vocal force in New England. Their willingness to test new ideas and remain innovative and independent is integral to their success.

Scope

This assessment models the useable energy produced and carbon emissions avoided by AGreen Energy's project to install anaerobic digesters on five Massachusetts farms. The emissions model quantifies the greenhouse gas (GHG) emissions in carbon dioxide equivalents incurred on each farm for the current manure management system (baseline) and the anaerobic digestion system (project). The energy model estimates the net energy gain, a ratio of energy expended to energy consumable. This is the commonly used notation for comparing renewable and non-renewable fuels.

Methodology

The carbon emissions model is based on the Organic Waste Digestion Project Protocol developed by the Climate Action Reserve for quantifying greenhouse gas (GHG) emissions. This is a peer-reviewed model used to quantify and normalize avoided emissions for the purpose of carbon credits. The model is a comparison of GHGs generated under business as usual conditions, landfilled SSO and lagoon-style manure management regimen, to the anaerobic co-digestion of these two materials. The manufacture and construction of the digester unit produces negligible emissions over the lifetime of the facility in this analysis and thus are not included in the model (Sanders 2002, Finnveden 2004). Emissions occurring when the digestion effluent is spread on agricultural fields were not calculated because of the difficulty in modeling. However, it is recommended that the farmers use a trailhose versus a sprinkler when applying the effluent to minimize nitrous oxide emissions (Edelmann). Transportation was not considered in this part of the analysis because the anaerobic digestion of these materials does not require additional transportation of the materials over the business as usual case. Note that the Organic Waste Digestion Project Protocol does not have a prescribed method for estimating transportation emissions.

The energy model has been constructed specifically for this project. It is a sum of the generated energy and input energy for processing, transporting, and pumping materials. The parameters for this study extend to the SSO collection plant in near Boston, Massachusetts to include the transportation. The transportation model is a simplified variation of the US Department of Energy's GREET model for transportation fleets. Transportation was considered in this model to attempt to include as much of the system as possible and provide an accurate estimation of net energy gain. Unlike the carbon emissions analysis, the energy model is not a comparison of two processes, but rather an estimation of a system with the boundaries expanded to include as many components as reasonably possible.

Data used for both models are a combination of data types. Project specific data was used when possible, such as mass flows of manure and SSO. In absence of specific data, such as chemical oxygen demand, published values with nearly identical circumstances were used. Additionally, the Organic Waste Digestion Project Protocol assumed universal values for microbial kinetics and methanogenesis variables. Figure 1 outlines the assessment boundaries for both the emissions and energy models. Most activities were included in both types of assessments (emissions and energy), however in the comparison format of the emissions model, the activities generating GHG at the landfill and on the farm manure lagoon were included. The energy assessment only included activities related to the production of biogas and therefore did not include activities at the landfill or manure lagoon.

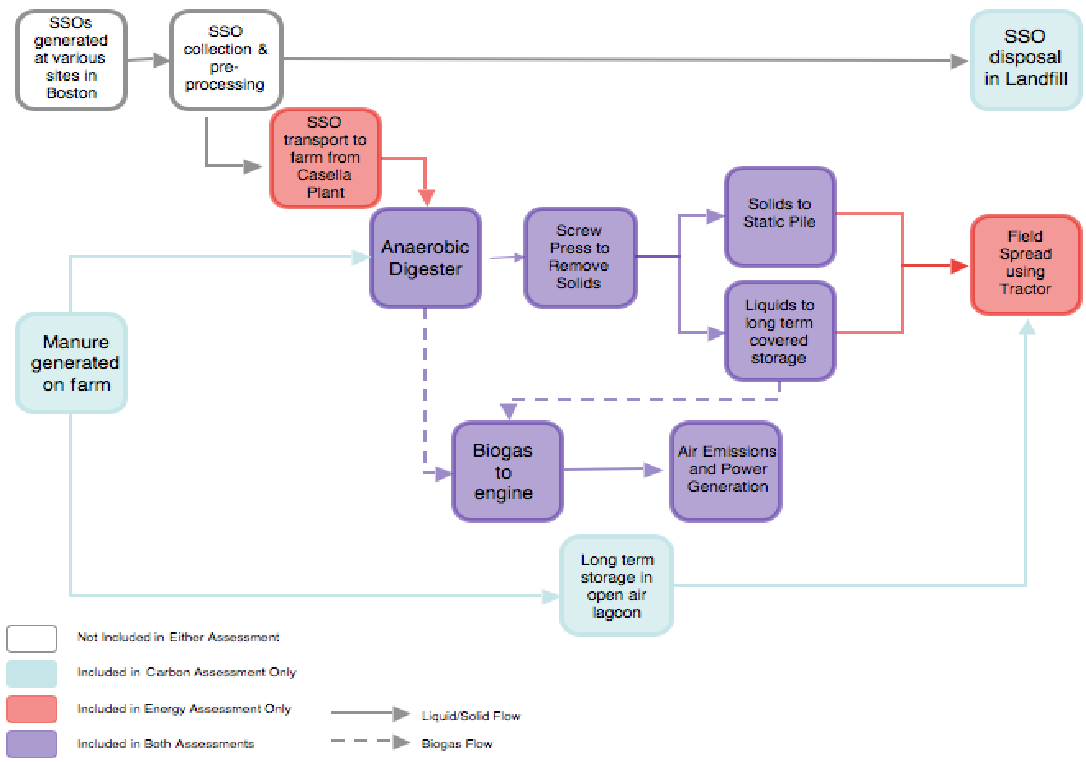

Figure 1. Assessment boundaries and system schematic for project and baseline cases

Results and Discussion

In total, the five-farm project will avoid 27,000 metric tons of carbon dioxide equivalents per year, about half of the emissions produced on the farms today. This is roughly equivalent to the GHG emissions created by about 5,000 passenger vehicles per year.

In the baseline case, landfilling the SSO created the largest source of emissions (94%). The model assumes the food waste decomposes uncovered for three years in the landfill before it is enclosed. The carbon dioxide equivalent emissions during these three years represent 80% of SSO emissions. Anaerobic degradation at landfills is common as waste is piled and open to atmosphere before the section is capped. Food waste streams in many cities are also diverted to incinerators and composting facilities. The landfilling scenario was chosen for this model based on the reasonable expectation that without the project, Casella would be sending SSO to landfill and in time, composting facilities. Composting provides a significant reduction in GHG emissions in comparison to landfilling due to discouraged anaerobic growth. Anaerobic digestion however, sequesters all emissions from the decomposition of SSO and offsets the use of non-renewable sources of energy. A 2004 life cycle assessment (LCA) conducted in Sweden found anaerobic digestion of food wastes preferable to composting, landfilling, and incineration for GHG emissions and consumption of non-renewable energy (Finnveden). In the Finnveden study, food waste treated with anaerobic digestion decreased GHG emissions assuming the biogas replaced electricity generated by coal and heat generated by natural gas. For simplicity in calculations, the LCA assumed the unlikely case that all waste would be treated with the same process.

The energy input to the anaerobic digestion process represents only 34% of the total output of the system, a net energy gain of about 1: 2.9. For every 1 unit of energy used, 2.9 units of energy from biogas were produced. This is a significant gain for each farm annually. In comparison to other agricultural fuels such as ethanol from corn (1:1.3, currently best accepted value, USDA 2002), biogas from co-substrates recovers much more energy per initial input. However, the energy balance is greatly dependent on the operation of the system. Therefore, during start-up and other less biogas-productive months, the whole system may see this gap shrink. It is not uncommon for the energy input to grow to 50% of the total output.

Many scientific studies recognize the reduction anaerobic digestion has on environmental impact. Environmental impact is a quantified measurement of effects on human health and ecosystems from a particular activity. In a comprehensive environmental impact study, biofuels produced from methane waste streams result in the lowest impacts when compared with biodiesel, alcohol, and fossil fuels (Zah et al. 2007). This is largely because the waste is considered a raw material to be used in agriculture as fertilizer and as an energy source to replace non-renewable sources.

The project specific models as well the published literature, place anaerobic digestion of manure and food waste at the top of the list of environmentally sound biofuels, in terms of energy, emissions, and environmental impact. The project generates energy for a community, reduces carbon emissions for a region, and protects human health and local ecosystems.

Conclusion

Co-substrate anaerobic digestion technology addresses the waste management challenges of dairy operators, SSO producers, and waste treatment facilities in an economical and environmentally sustainable manner. Cost effective organics management by co-substrate anaerobic digestion grants stakeholders additional benefits. Dairy operators temper volatile milk prices with steady income from contracts with SSO producers. SSO producers easily dispose of their food residuals while meeting and improving their environmental sustainability standing. Consumers and retailers concerned with environmental impact recognize and reward the producer's corporate responsibility efforts. Methods to quantify environmental impacts are readily available to the SSO producer for use in marketing materials and corporate sustainability goals. The processor stays ahead of federal and state environmental standards and secures disposal contracts at competitive prices. USEPA has placed state adoption of numeric nutrient criteria high on their list of priority goals. Partnering with emerging technology ensures that SSO produces will not see fallout from cost increases at waste treatment facilities.

The project specific models, as well the published literature, place anaerobic digestion of manure and food waste at the top of the list of environmentally-sound biofuels, in terms of energy, emissions, and environmental impact. The project generates energy for a community, reduces carbon emissions for a region, and protects human health and local ecosystems. Partnering with agricultural digesters can be an easy and effective statement to clients of your commitment to a sustainable prosperous environment for all.

References

Audsley E., ed. 1997. *Harmonisation of Environmental Life Cycle Assessment for Agriculture.* European Commission, DG VI Agriculture, Brussels.

Berglund, Maria, and Pal Borjesson. 2006. Assessment of Energy Performance in the Life-Cycle of Biogas Production, *Biomass and Bioenergy,* 30(3):254-266.

Edelmann W, U. Baier and H. Engeli 2005. Environmental Aspects of the Anaerobic Digestion of the Organic Fraction of Municipal Solid Wastes and of Agricultural Wastes. *Water science and technology* 52(1-2):203-208.

Finnveden, G., J. Johnasson, P. Lind and A. Moberg 2004. Life Cycle Assessment of Energy from Solid Waste—Part 1: General Methodology and Results. *Journal of Cleaner Production* 13(3):215-229.

Sanders, D.L., E. Audsley, C. Cañete, T. R. Cumby, I. M. Scotford and A. G. Williams 2003. Environmental Benefits of Livestock Manure Management Practices and Technology by Life Cycle Assessment, *Biosystems Engineering.* 84(3):267-281.

Shapouri, H., J.A. Duffield, and M. Wang. 2002. *The Energy Balance of Corn Ethanol: An Update*. AER-814. Washington, D.C. http://www.usda.gov/oce/reports/energy/aer-814.pdf (Assessed January 21, 2010)

Zah et al. 2007. *Life Cycle Assessment of Energy Products: Environmental Assessment of Biofuels,* 2007. http://www.bioenergywiki.net/images/8/80/Empa_Bioenergie_ExecSumm_engl.pdf (Assessed May 20, 2010).

