Converting Food Waste to Biogas: Sustainable Gator Dining

Winner of the AASHE Award for Student Research on Campus Sustainability

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Editor's note:

An earlier version of the following paper was the winner of the Association for the Advancement of Sustainability in Higher Education (AASHE) Award for Student Research on Campus Sustainability. This AASHE award recognizes outstanding student research that advances the field of campus sustainability, explains Julian Dautremont-Smith, associate director of the Lexington, KY-based association. The papers are judged by a panel of experts assembled by AASHE. All submissions are posted in AASHE's resource center at www.aashe.org/resources/research.php. The winning paper was written by Ryan Graunke as his honors thesis. The version printed here has been modified with the assistance of Professor Ann Wilkie for publication in **Sustainability: The Journal of Record**. *The original paper is available online at www.aashe.org/resources/documents/Graunke2008.pdf. The abstracts that follow this paper are from the runners up in the competition.*

Abstract

Biogas is a renewable source of natural gas produced by the microbial degradation of organic matter in a process called anaerobic digestion. While any organic material may be a feedstock for anaerobic digestion, waste organic matter represents a vast potential for sustainable energy production. Food waste, in particular, is a relatively untapped resource. Large amounts of food waste are produced at campus dining halls and other food service facilities. A case study was undertaken to determine biogas production and implementation potential at the University of Florida's Broward Dining Hall. Food waste quantity and current disposal methods were determined. The waste was analyzed for organic matter content and potential biogas yield. Food waste was digested in a small-scale anaerobic digester. The study demonstrated that converting food waste to biogas could provide significant supplemental energy to the dining hall and provide a closed-loop system for sustainable food waste management. By using biogas produced from anaerobic digestion of food waste, in place of fossil fuel, the energy footprint and carbon emissions at Broward Dining Hall would be reduced. Further, energy use and carbon emissions associated with current disposal methods would be reduced, and valuable nutrients in the food waste would be recycled for use as organic fertilizer. Establishing a biodigester at Broward Dining Hall would contribute to meeting the University of Florida's sustainability goals by simultaneously reducing solid waste and producing carbon-neutral, renewable energy. If biogas technology were adopted throughout the food service industry, this would significantly advance campus and societal sustainability.

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Introduction

It is increasingly evident that human activity is causing global climate change. One of the principal causes of this change is the atmospheric accumulation of carbon dioxide released by the burning of fossil fuels. *Fossil fuel is fossil thinking.* As human development continues to increase and fossil fuels continue to be depleted, it is an undeniable fact that sustainable, alternative energy must replace fossil fuels in order for society to maintain its quality of life. Rather than a single energy source taking the place of fossil fuels, the sustainable energy future must rely on an integrated suite of renewable energy technologies. One sustainable energy technology with great promise is biogas production from organic waste.[1]

Biofuels in general have come under much scrutiny in recent years. The energy obtained from some biofuels, such as corn ethanol, is almost equal to the energy put into the production process. In some cases, there is a net loss of energy. Current biofuels utilize feedstocks that require significant input of land, water, and fertilizer resources. Some biofuels have been linked to rain forest destruction. Biofuels have become the subject of a "food versus fuel" debate. By growing crops specifically for fuel production,

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there is direct competition between food and fuel demands. This inevitably raises the price of food and, in a global economy, is devastating to developing nations. This scenario does not hold true for biogas derived from waste material. Rather than using land and crops to grow fuel, biogas energy is captured from material that is otherwise a burden to society.

Biogas is considered carbon neutral because all of the carbon released during combustion has been recently taken from the atmosphere through photosynthesis.

Biogas technology is essentially the bio-digestion of any organic material under anaerobic conditions[1,2] (Fig. 1). The process does not require large expenditures of energy, as it is biologically driven by a mixed culture of bacteria in the absence of oxygen. Anaerobic digestion produces a gaseous product, called biogas, which is composed mostly of methane and some carbon dioxide. The biogas fuel can be collected and combusted for cooking, heating, or to produce electricity. Biogas is considered carbon neutral because all of the carbon released during combustion has been recently taken from the atmosphere through photosynthesis, unlike fossil fuels that have stored carbon for millions of years. Thus biogas is a sustainable alternative to natural gas. Since anaerobic digestion only releases carbon to the gas phase, the other nutrients (nitrogen, phosphorus, and micronutrients) remain in the effluent, which makes it a high-quality organic fertilizer and soil amendment.[2]

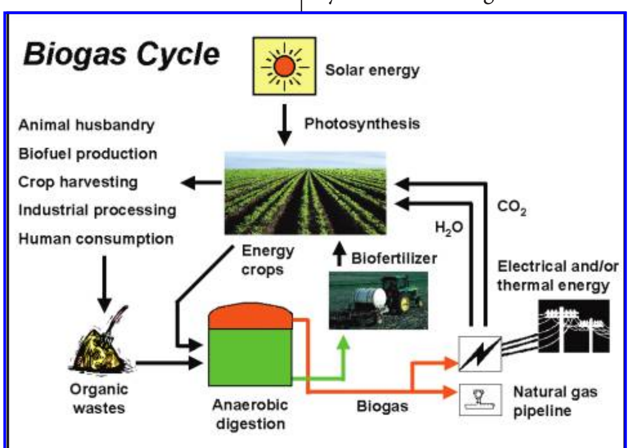

Fig. 1. Biogas from organic wastes.

Beyond making a carbon-neutral, renewable alternative to natural gas, biogas production offers a sustainable method for disposing of organic wastes. Discarded food is a major component of municipal waste. In fact, Americans throw away about 25 percent of the food they prepare, equal to 96 billion pounds annually, which comprises 12 percent of the municipal waste stream.[3] *What a waste!* The true cost of wasted food also includes the water, energy, nutrients, and labor that are used to grow, harvest, transport, process, and prepare the food. The vast majority of this food waste is disposed of in landfills, with less than three percent recovered.[3] Landfills require transportation energy, human labor, and land. They release methane, a potent greenhouse gas, into the atmosphere and lock up nutrients that could otherwise be used to grow crops.

Food waste can also be disposed of in an aerobic sewage treatment facility, but this process requires a large expenditure of energy for wastewater aeration. Two other methods of food waste disposal are composting or combustion. However, with composting, the nutrients are retained but the energy is lost; with combustion, energy is captured but the nutrients are lost. In anaerobic digestion, both the energy and the nutrients can be captured and recycled, providing a closed-loop system that minimizes environmental impact and maximizes resource recovery. Food waste makes an ideal feedstock for biogas production; it is readily biodegradable and is available in large amounts from point sources (e.g., restaurants, grocery stores, food processing plants).

An initial study investigating campus food waste as a possible source of renewable energy was conducted by interns from the UF-IFAS Bioenergy School in the summer of 2006.[4] The current research entailed a more comprehensive study to analyze the food waste stream from Broward Dining Hall (BDH), a campus dining hall at the University of Florida in Gainesville, and to assess the potential for biogas production from the food waste.

Experimental Methods

Food waste collection

Pre- and post-consumer food waste was collected separately for each waste stream over 12 days. Employees sorted the food waste into labeled garbage bins. Nondigestible materials were separated from both kitchen waste and plate scraps. The waste was weighed periodically throughout the day. Postconsumer drink waste was collected separately in three categories: soda/juice, milk, and coffee. Daily customer counts were obtained to standardize results on a per capita basis. Plate and kitchen waste was homogenized using a paint mixer connected to an electric drill. Subsamples were analyzed for organic content and bulk density.

Digester design and operation

The biogas reactor used in this study was a 30 gallon daily-fed anaerobic digester constructed from

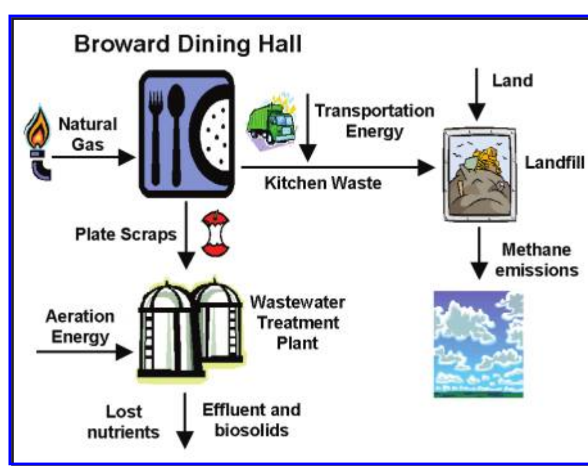

Fig. 2. Open-loop system of food waste disposal.

reused polyethylene drums. The digester was fed homogenized plate scraps daily and mixed with a manual stirring mechanism.[5] Biogas production was measured by water displacement. The digester was sited in an open field with full exposure to the sun. It was painted Gator blue to increase solar absorption and maintain average digester temperature at 30°C. The pH was monitored to ensure approximate neutrality (pH 7.0), which is ideal for methanogenesis. Detailed operation of the digester is described in an online video.[6]

Results

Broward Dining Hall is managed by Gator Dining Services (GDS), a subsidiary of the Aramark Corporation. Current methods of food waste disposal at BDH were determined by site visits and interviews with dining hall managers and supervisors. The facility uses natural gas for cooking. Data on customer numbers and energy use were obtained for the 2007 year. In 2007 average daily gas use and customer counts were 3,885 cubic feet and 1257 customers, respectively.

There are two different food waste streams at the dining hall: preconsumer or kitchen waste (KW) and postconsumer or plate scraps (PS) (Fig. 2). There is also liquid waste (unconsumed drinks) that is discarded with the PS. The KW includes raw kitchen scraps and leftover prepared food. It is disposed of in garbage bins along with other nonfood waste, placed in a trash receptacle and trucked to the landfill in a neighboring county. The PS waste stream consists of uneaten food left on plates, along with napkins and paper cups with plastic lids. The dining hall uses reusable flatware and dishes; therefore the vast majority of the PS stream is food waste. Nondigestible materials (cups, lids, pieces of plastic) comprise a minimal portion of the PS and are separated out by BDH employees. The final PS stream is ground in a mulcher and flushed with water to the on-campus sewage treatment facility.

Over the 12-day study period, the average daily food waste (KW + PS) totaled 576 pounds, or 0.35 pounds per customer. The KW averaged 258 pounds per day (0.15 pounds per customer) and the PS averaged 318 pounds per day (0.19 pounds per customer). Average daily drink wastes totaled 0.43, 0.5, and 0.2 gallons for soda/juice, milk, and coffee, respectively.

The organic content of the food waste averaged 95 percent and demonstrated a high biodegradability. The fermentation was stable and robust, producing a high BTU content biogas. Based on digester performance using PS, biogas production extrapolated to the total food waste would be 1413 cubic feet of methane biogas per day or 918 cubic feet of methane (CH_4) per day.

Discussion

Broward Dining Hall is a good candidate for a biogas reactor because the waste stream is relatively free from nondigestible material. Nondigestible materials are already being separated from the PS fraction of the waste stream by dining hall employees. The non-digestible material present in the KW can also be easily separated by sorting the food waste from the nonfood waste.

This study demonstrates that converting food waste to biogas could provide significant supplemental energy to offset natural gas use at BDH.

This study is an ongoing project, with the eventual goal of establishing a functioning biogas reactor on site at BDH. Further studies will include evaluating the food waste using a biochemical methane potential (BMP) assay. This will measure the total convertibility of the food waste to methane, which predicts the maximum amount of methane the waste could produce. The BMP assay will show how close the actual yield is to the theoretical yield and if adjustments can be made to increase the efficiency of biogas production. Another important study would be to experiment with different loading rates to find the optimum rate at which to load the digester. Because soda, juice, coffee, and milk have a high concentration of soluble organic material, they are energy dense and readily digestible. Therefore, analyzing the drink wastes would also be important in assessing the total biogas potential of the facility.

A limitation to this study was the length of time that food waste collection occurred at BDH. Ideally, waste collection and measurement would take place over several weeks spaced throughout the year to get a true representation of the waste stream. Another limitation was that the separation of the food waste relied upon employees who were not in the routine of separating the kitchen waste. When initiating a behavior change, there will always be an adjustment period before the new behavior becomes habitual. Also, the length of digestion time was a limitation. Running the digester for several months would result in a more accurate assessment of biogas yield. However, this was not possible within the timeframe of the study.

There are many far-reaching benefits to building a biogas reactor at BDH. Gator Dining Services, the University of Florida, and the community as a whole would benefit. Overall economic benefits include savings on solid waste disposal, wastewater treatment, and energy costs. The direct energy value of biogas may prove to be an even more significant asset in the future as natural gas prices have risen over the past few years and will likely continue this trend.

Food waste anaerobic digester.

The true cost of wasted food also includes water, energy, and nutrients that are used to grow and prepare the food.

Plate scraps—waste or bioenergy?

If biogas technology were to spread throughout the food service industry, it would represent a significant stride towards a sustainable economy.

Gator Dining Services will benefit from a positive public image resulting from reduced food waste and lower carbon emissions from its operations. By implementing biogas technology, the dining hall will become a model for sustainable facility management. Aramark is a worldwide dining service facility management corporation. By demonstrating a successful biogas reactor at BDH, GDS would help make the case for other Aramark dining halls (including the other dining hall at UF) to implement anaerobic treatment of their food waste.

The University of Florida will also benefit from undertaking this project. In order to meet its goal of zero waste by 2015, the university needs to develop a sustainable alternative to the current food waste disposal practices at its dining halls. Because the dining hall currently sends the PS portion of its food waste to the on-campus aerobic sewage treatment plant, there is an unnecessary burden on the plant. Aerobic treatment is a costly, energy-intensive process. By diverting the PS to a biogas reactor, a waste stream to the treatment plant will be removed, which will also reduce the costs associated with hauling biosolids from the treatment plant. If the KW portion of the food waste is also processed in the biogas reactor, less solid waste would go to the landfill, providing savings in landfill tipping fees and trucking costs, as well as reducing energy use and carbon emissions associated with transporting solid waste.

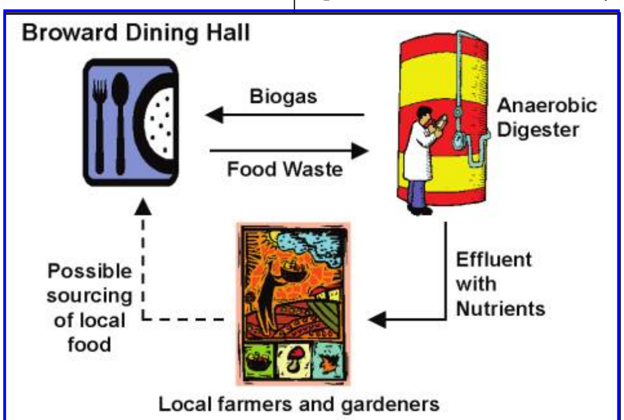

Fig. 3. Closed-loop system for sustainable food waste management.

At the community level, the general public will benefit from reduced carbon emissions. Local gardeners and farmers could utilize the effluent as an organic fertilizer in place of commercial fertilizers that are produced using less sustainable methods. Local food production also reduces greenhouse gas emissions produced during shipping. Students too can use the biofertilizer in the on-campus student organic garden.

Implementing a biogas reactor at BDH will enable sustainable management of food waste and produce a renewable carbon-neutral fuel. *Gator dining* will be converted from an open-loop resource-intensive system (Fig. 2) to a sustainable closed-loop system (Fig. 3) that conserves energy and nutrients, and requires less external sources for energy and fewer sinks for waste. If biogas technology were to spread throughout the food service industry, it would represent a significant stride toward a sustainable economy.

Acknowledgments

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