Technical Education and Analysis for Community Hauling and Anaerobic Digesters
TEACH AD

February 15, 2023

Daphne Hulse
Zero Waste Coordinator
Facilities & Services | University of Illinois Urbana-Champaign

Dear Daphne,

Thank you for your recent inquiry regarding an initial economic feasibility assessment of a new Anaerobic Digester (AD). According to our discussion, a micro-digester could be installed on the UIUC campus to divert the campus food waste and create an educational opportunity for students. A second option would be the installation of a larger digester capable of processing the campus food waste and the animal waste generated by the farms of the Department of Animal Sciences.

Anaerobic digestion is a process through which bacteria break down organic matter—such as animal manure, wastewater biosolids, and food wastes—in the absence of oxygen. Anaerobic digestion for biogas production takes place in a sealed vessel called a reactor (digester), which is designed and constructed in various shapes and sizes specific to the site and feedstock conditions. Anaerobic digestion produces two valuable outputs: biogas, which is rich in methane and can be used as a fuel, and digestate, the residual material left after the digestion process, which is rich in nutrients and can be used as a fertilizer and in many other beneficial applications.

The Technical Education and Analysis for Community Hauling and Anaerobic Digesters (TEACH AD) is a Program funded by the Environmental Protection Agency with the goal of helping communities and water resource recovery facilities in the Midwest region divert food waste from landfills by providing education and no-cost technical assistance to explore the increased adoption of anaerobic digestion and renewable energy biogas technologies.

This analysis should be considered a screening for initial evaluation as real feedstock will have specific characteristics that will affect digester system performance. The analysis provides an initial look at the economic and physical feasibility of organic waste digestion at the UIUC campus with the food waste currently processed with a Grind to Energy (G2E) system as well as with the potential maximum food waste generated on campus. The analysis has been performed using the equipment specifications from a micro-digester vendor for a similar project, and it is based on limited site information and the best current data of organic waste anaerobic digestion projects in the U.S. The analysis compares the relative merits of hauling food waste off campus compared to anaerobic digestion on site to generate electricity, utility savings, and reduce campus carbon emissions. Two scenarios have been considered and the simple payback analysis including initial capital costs, annual costs, and annual savings, have been calculated for each scenario. Each of the two scenarios considered have been analyzed using the current amount of food waste the University processes with the G2E and pays to have hauled off campus to the Urbana Champaign Sanitary District (UCSD) as well as the maximum organic waste generated on campus that was identified through a Waste Stream Characterization Study in 2015. It was estimated that in fiscal year 2015, the Urbana-Champaign campus generated and landfilled 5,568.78 tons of solid waste of which 22% consists of food scraps. Also, in 2022, 322 tons of food waste have been processed through the G2E.

In addition to these two scenarios, a third scenario has been evaluated where the food waste from the campus is co-digested with animal waste. Information about the quantity and the characteristics of the animal waste have been collected from the South Farms Anaerobic Digester Feasibility Study conducted in 2013. For this scenario the analysis has been performed using the EPA's Co-Digestion Economic Analysis

Tool (Co-EAT). The analysis compares the relative merits of three uses of biogas: Combined Heat and Power generation (CHP), Renewable Compressed Natural Gas (R-CNG) for vehicle fuel, and Renewable Natural Gas (RNG) for pipeline injection.

Please see the attachment for the results of the AD qualification screening. The results of the analysis suggest a more detailed analysis should be pursued to continue the evaluation of anaerobic digestion on UIC campus. Further analysis of AD at your site may include one or more of the following:

- Detailed Equipment Modelling
- Detailed analysis of market pathways for digestate
- Evaluation of feedstock availability and biomethane potential (BMP) and anaerobic toxicity assay (ATA) testing of feedstocks
- Obtaining Budgetary Pricing Specifications

Moving forward, we would like to discuss the potential next steps with you. If you have any questions or comments, please contact me at 312-358-4950 or mpibir2@uic.edu

Regards,

Marcello Pibiri
Program Manager

Feedstock for the Digester

Feedstock	Quantity	Units/day	Specific Gravity	Total Solids (%)	VS/TS Ratio
Scenario 1: Food Scraps from Dining Halls	1.36	Ton	1.10	30	0.85
Scenario 2: Food Scraps (Campus wise)	4.1	Ton	1.10	30	0.85
Scenario 3: Food Waste + Animal Waste	143	Ton	1.06	12.66	0.58

Food scraps hauling cost: based on information found in the Waste Stream Characterization Study, in 2015 the cost per ton to haul trash (including the organic fraction) to the landfill was $67.14/ton. This analysis uses $85.26/ton to account for inflation and this cost has been applied to the waste hauled to the landfill as well as the G2E slurry hauled to the UCSD.

Scenario 1: Food Scraps from Dining Halls

This scenario analyzes a micro-digester capable of accepting 500 tons/year of organic waste. The feedstock for this scenario are 322 tons/year of food scraps currently processed through the G2E plus an additional quantity (178 tons/year) of food scraps to meet the maximum capability of the digester.
The avoided hauling and tipping fee costs would be equal to $42,630/year.
The biogas production estimated is equal to 2,285,507.25 cf/year that can be used to produce 127,098 kWh/year of electricity, worth $10,167.84 of savings.

The second valuable output from the digester, other than energy, is the digestate, the residual material left after the digestion process, which is rich in nutrients and can be used as a fertilizer and in many other beneficial applications. The digester can generate a liquid and or a dry fertilizer with the liquid generation rate estimated in 112,500 gallons per year and the dry product generation rate estimated in 23 tons per year (if 100% is dried). The larger source of revenue for this project is the value given to this digestate, equal to $203,906.25/year. The economy of the project is very sensitive to this value: without this revenue stream, the project won't be economically feasible. The simple payback of this scenario, including the value of the digestate, is 5 years (see appendix A for the details about the market value, market opportunities and nutritional value of the digestate).

Scenario 2: Food Scraps (Campus wise)

This scenario analyzes a micro-digester capable of accepting 1,500 tons/year of organic waste. The feedstock for this scenario are 1,225 tons/year of food scraps generated on campus as estimated in the 2015 Waste Stream Characterization Study, plus an additional quantity (275 tons/year) of food scraps to meet the maximum capability of the digester.

The avoided hauling and tipping fee costs would be equal to $127,890.00/year.

The biogas production estimated is equal to 6,855,072.46 cf/year that can be used to produce 381,213 kWh/year of electricity, worth $30,497.08 of savings.

The second valuable output from the digester, other than energy, is the digestate, the residual material left after the digestion process, which is rich in nutrients and can be used as a fertilizer and in many other beneficial applications. The digester can generate a liquid and or a dry fertilizer with the liquid generation rate estimated in 337,500 gallons per year and the dry product generation rate estimated in 70 tons per year (if 100% is dried). The larger source of revenue for this project is the value given to this digestate, equal to $611,718.75 /year. The economy of the project is very sensitive to this value: without this revenue stream, the project won't be economically feasible. The simple payback of this scenario, including the value of the digestate, is 3.5 years (see appendix A for the details about the market value, market opportunities and nutritional value of the digestate).

Scenario 1&2 Financial Analysis

	Current Hauling Program: Food Scraps from Dining Halls	Current Hauling Program: Food Scraps (Campus wise)	Scenario 1	Scenario 2
Food Waste (Tons/year)	500	1,500	500	1,500
Tipping and Hauling Cost	($42,630.00)	($127,890.00)	($0)	($0)
Digester O+M			($38,000.00)	($104,000.00)
Total Annual Operating Cost	($42,630.00)	($127,890.00)	($38,000.00)	($104,000.00)
Biogas Generation (cf/year)			2,285,507.25	6,855,072.46
Electricity Generated (kWh/year)			127,098.03	381,213
Annual Electricity Savings ($)			$10,167.84	$30,497.08
Annual net Income from Biofertilizer			$203,906.25	$611,718.75
CO2e Reduction (Metric Tons)[1]			82	245
UIUC Carbon Cost Savings[2]			$4,904.25	$14,696.41
Net Annual Operating Cost/Revenue	($42,630.00)	($127,890.00)	$180,978.34	$552,912.24
Annual Savings			$223,608.34	$680,802.24
Installation Cost			($1,142,000.00)	$(2,385,000)
Utility Incentives			$10,676.23	$32,021.93
Simple Payback with Incentives (yr)			5.06	3.46
Net Present Value[3]			$1,178,978.10	4,681,494.44

[1] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator
[2] $60/ton CO2e
[3] 15 years period and 5% Discount Rate

Scenario 3: Food Waste + Animal Waste

CHP Scenario

The biogas production estimated by the model is equal to 57,488,617 cf/year, enough to run a 327 kW Combined Heat and Power (CHP) unit on a continuous basis. The CHP scenario does not show favorable financials: the revenues generated are not enough to overcome the capital costs and the O&M costs.

R-CNG Scenario

The renewable compressed natural gas for vehicle fuel (R-CNG) scenario show more favorable financials compared to the CHP scenario: the larger source of revenue for this scenario is the value given to the vehicle fuel produced. We also attempted to estimate the value of the environmental attributes of the renewable gas produced. Assigning $1.00 to each Renewable Identification Number (RIN)[4] generated, an additional $ 315,360/year[5] revenue is available. RINs credit values are highly volatile and difficult to predict due to the political uncertainty surrounding the Renewable Fuel Standard Program[6]. Qualifying for the program requires a thorough registration process designed to prevent fraud. This option also requires the use of the R-CNG produced in vehicles equipped for CNG. Further development of this option would require the use of an experienced consultant with familiarity with renewable fuel markets.

RNG Scenario

This scenario consists of installing gas conditioning and gas metering equipment to produce pipeline quality natural gas that meets Utility's gas quality requirements. The conditioned gas would then be sent to the nearest high load transmission pipeline. UIUC or the Gas Utility (or both) would be responsible for constructing and operating the pipeline from the digester gas transmission pipeline. The cost of such a scenario is highly impacted by the distance of an available high load transmission pipeline, by the contribution of the Gas Utility and by several other variables.

Similar to the R-CNG scenarios, injecting digester gas into a natural gas pipeline could generate value through the trading of RINs. In addition, by injecting the gas into a utility pipeline, other renewable energy markets can be considered, such as state-level low carbon fuel exchanges (e.g., California's Low Carbon Fuel Standard program and Oregon's Clean Fuel Program) and other voluntary markets (i.e., fixed price markets that offer longer term contracts). Further development of this option would require the use of an experienced consultant with familiarity with renewable fuel markets.

In addition to R-CNG and RNG sales, associated environmental credits, gas and electric savings, the "effluent" that remains in the digester vessel following anaerobic digestion is also a potential source of revenue. This material, known as "digestate," consists of a liquid and a semi-solid stream, each of which can be turned into a finished product such as fertilizer or soil amendments. The model estimated a production of 46,916 tons/year of digestate at 10% TS. The market value of these products has not been investigated but it can play a role in the economy of the project. Finally, several other services and benefits to the environment and surrounding community, such as reduced GHG emissions, reduced food waste sent to landfill, reduced odors from land applying raw manure should be taken into consideration when evaluating this project.

[4] https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rin-trades-and-price-information
[5] https://americanbiogascouncil.org/resources/rin-calculator/#gf_3
[6] https://www.epa.gov/renewable-fuel-standard-program

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Co-EAT: Co-digestion Economic Analysis Tool: BETA

An analysis tool to assess the economic feasibility of co-digestion at a Water Resource Recovery Facility **2/15/2023**

U.S. EPA

Scenario 3

Purpose: Compare econmics and plant operations between current and future scenarios and analyze results

The numbered worksheets contain assumptions and default values that provide the underlying functionality of the Model. Once familiar with the inputs, outputs, and data used to calculate values, users can customize the Model by modifying data in the rest of the worksheets. Be sure to save a copy of the tool prior to making any changes. All worksheets' defualt values can be restored using the "Resotre Default Formulas & Values" button.

	CHP	R-CNG	RNG
Biogas Produced (cf/yr)	57,488,617	57,488,617	57,488,617
Total Biogas Heating Energy (MBTU/yr)	16,739	26,154	0
Total Energy Needed for Heating (MBTU/yr)	5,563	5,563	5,563
Max Capacity of Digester (gal)	0	0	0
Feedstock Feed Rate (gal/day)	32,351	32,351	32,351
% Solids of Feedstock Fed to Digester (%)	12.7%	12.7%	12.7%
Percent Volatile Solids Reduction (%)	50%	50%	50%
Actual Hyraulic Retention Time (days)	0.0	0.0	0.0
Target Hydraulic Retention Time (days)	20.0	20.0	20.0
Available Capacity (Gal/day)	0	0	0
Additional Volume Needed to Treat Feedstock (gal)	647,030	647,030	647,030
Mass of Digestate (Tons/yr)	46916	46916	46916
Digestate Cost ($/yr)	$0	$0	$0
Digestate Revenue ($/yr)	$0.00	$0.00	$0.00
Tipping Fees ($/yr)	$0.00	$0.00	$0.00
Avoided Natural Gas Costs ($/yr)	$134,110	$0	($66,756)
Avoided Electricity Costs ($/yr)	$228,931	$0	$0
Avoided Vehicle Fuel + RINS ($/yr)	$0	$994,465	$0
Revenue from RNG pipeline injection	$0	$0	$1,061,528
Annualized Cost of Plant Upgrades ($/yr)	($560,569)	($649,633)	($910,720)
Annual Operations and Maintenance ($/yr)	($255,849)	($333,552)	($298,439)
Net Annualized Value ($/yr)	($453,377)	$11,280	($214,387)
Simple Payback	71.1	11.5	17.8

Return to Inputs/ GUI

Restore Default Formulas

Print Input Values

CHP Use biogas in CHP to heat digester and incomming feedstock and generate electricity. Value is given to the electricity generated and excess heat. If digester heating demand is not met, expense for natural gas will incur.

R-CNG Use biogas to heat the digester and convert the rest to vehicle fuel. If digester heating demand is not met, no biogas will be available for CNG and an expense for natural gas will incur.

RNG All biogas is converted into Renewable Natural Gas. Cost of natural gas to meet the heating demand of the digester and incomming feedstock will incur.

For a detailed review of the calculations and assumptions, please observe the "4. Biogas Use" worksheet.

Analysis

Percent increase in heating demand =	**#DIV/0!**	
Percent increase in biogas production =	**#DIV/0!**	
Percent increase in biosolids =	**#DIV/0!**	
Additional volume needed to treat feedstock =	**647,030**	[gal]
Size of CHP =	**327**	kW

APPENDIX A

Digestate Analysis for Micro-digester

Net Income from Biofertilizer (Annual)	Distribution	Qty/Month	Qty/Year	Units	Price/Unit	$'s/Year
Liquid Biofertilizer Retail Value	0%	-	-	gallons	$ 7.00	$ -
Per unit cost of packaging & handling					$ 1.30	$ -
Liquid Biofertilizer Wholesale Value	75%	7,031	84,375	gallons	$ 3.50	$ 295,312
Per unit cost of packaging & handling					$ 1.30	$ (109,687)
Liquid Biofertilizer Bulk Wholesale Value	25%	2,343	28,125	gallons	$ 0.75	$ 21,093
Per unit cost of packaging & handling					$ 0.10	$ (2,812)
Dry Biofertilizer Retail Value (w supplements)	0%	-	-	lbs	$ 10.00	$ -
Per unit cost of packaging & handling					$ 2.00	$ -
Dry Biofertilizer Wholesale Value (w supplements)	0%	-	-	lbs	$ 5.00	$ -
Per unit cost of packaging & handling					$ 2.00	$ -
Dry Biofertilizer Bulk Wholesale Value (wo supplements)	0%	-	-	lbs	$ 10.00	$ -
Per unit cost of packaging & handling					$ 0.18	$ -
Net Biofertilizer Income per Ton:	*$ 400*		**Sub-total Biofertilizer Annual Net Income**			$ 203,906

Liquid Plant Food – as it exits the digester (un-modified)

Liquid un-modified digestate has four beneficial qualities: soil carbon, nutrients, water, and live beneficial microbes. It can be used un-modified. We have even better results by adding biochar and water at 1:1 by volume. This makes the digestate more pleasant to handle (less agricultural odor) and less mineral concentration for the soil and plant root zone.

Raw untreated digestate characterization

		2018	2018	2017	2017	2017	
		IS	SCH	BA	FR	AU	AVG
Solids	**percent**	1.0%	1.1%	3.8%	1.4%	2.3%	1.9%
Water	**percent**	99.0%	98.9%	96.2%	98.6%	97.7%	98.1%
pH		8.1	7.9	7.7	8.3	7.7	7.9
Salts	**E.C.**	16.8	12.0	25.3	21.0	22.5	19.5
Density	**lbs/gal**	8.39	8.51				8.5
C:N ratio		2.1	3.0	10.0	2.5	5.1	4.5
Sodium	**mg/kg/day**	17.9%	13.5%	9.2%	23.5%	15.1%	15.8%
Total Nitrogen	**percent dry**	20.3%	11.2%	4.2%	14.1%	6.3%	11.2%
Total Phosphorus	**percent dry**	1.3%	1.5%	0.5%	0.9%	0.6%	1.0%
Total Potassium	**percent dry**	10.8%	9.9%	2.0%	6.6%	2.2%	6.3%
Total Carbon	**percent dry**	42.0%	33.1%	41.9%	34.5%	32.2%	36.8%
Total Sulfur	**percent dry**	0.7%	0.6%	0.2%	0.4%	0.3%	0.4%
Ammonia Nitrogen	**mg/kg dry**	136,900	59,000	31,310	102,813	43,340	74,673
Nitrate Nitrogen	**mg/kg/day**	900	818	106	355	131	462
Iron	**mg/kg dry**	1,700	5,909	12,292	1,179	1,995	4,615
Total Nitrogen	**percent wet**	0.20%	0.12%	0.16%	0.20%	0.14%	0.17%
Total Phosphorus	**percent wet**	0.01%	0.02%	0.02%	0.01%	0.01%	0.01%
Total Potassium	**percent wet**	0.11%	0.11%	0.08%	0.09%	0.05%	0.09%
Total Carbon	**percent wet**	0.42%	0.36%	1.59%	0.49%	0.74%	0.72%
Total Sulfur	**percent wet**	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Ammonia Nitrogen	**mg/kg wet**	1369	649	1,186	1,447	991	1,128
Nitrate Nitrogen	**mg/kg wet**	9	9	4	5	3	6
Iron	**mg/kg wet**	17	65	47	17	46	38

Dried Plant Food

Dried digestate (Avg 11-1-6 NPK dry basis) can be used as a dry product at 100% content, or it can be blended into a balanced organic fertilizer to further add value/fertility. We have been successfully marketing "mix 5" in Seattle.

Mix 5	N	P	K	Ingredients
	5	4	1	brew dew/bone meal/feather meal/biochar/frass

Benefits

1. Production of continuous, onsite, renewable energy. The energy can be stored at night and used during the day if necessary. It does not depend upon sunlight or wind for production.
2. Elimination of foodwaste dumpsters with the associated odor, birds, flies, rodents, insects, and leakage that commercial foodwaste can produce.
3. Elimination of the hauling, fuel use, and traffic impacts associated with trucking waste from the city to a distant processing facility. This reduces urban traffic congestion as well as truck exhaust emissions.
4. Conversion of the organic materials into valuable plant food, compost, and fertilizer. This can be returned to the soil to improve the sustainability of local gardening.
5. New employment of people in the conversion of waste to bioenergy, commercial products, and the local food supply chain industry.
6. Collaboration with local educational curriculums such as culinary arts, horticulture, sustainable agriculture, viticulture and wine technology, engineering, environmental science, business, biology, and education.
7. Achieving significant diversion of waste from disposal, moving the city closer to zerowaste goals.
8. Improving the local soil-water-air ecosystem by returning carbon to the soil and displacing the need for chemical fertilizers, pesticides, and herbicides.
9. Improving the opportunities for farm-to-table food production and healthy food networks which will improve the well-being of its communities.

Beneficial Uses of Digested Food Waste

There are a number of market pathways for digestate. Some of them are complimentary to compost and mulch sales. The list below shows a few that can and should be considered:

1. Liquid fertilizers or soil amendments
2. Dried organic fertilizers
3. Dried and pelleted organic fertilizers
4. Dried and pelleted fuel
5. Constructed wetlands, forests, bogs, and other high-carbon soil banking projects
6. Constructed pasture and cropland
7. Constructed high organic matter crop land
8. Integrated farming systems in greenhouses and vertical farms
9. Hydroponic farming systems

Some of these produce heat and some require heat. Several of these systems can be combined to make a more robust and sustainable system. Employment opportunities are associated with all these pathways. These examples illustrate how diverse the options are for recycled product marketing. When combined with composting and gasification the list can also include these pathways:

10. Gasified biochar and charcoal products
11. Prepared (shredded and screened) and dried wood fuel
12. Integrated surface water treatment systems and living roofs
13. Non-traditional systems like vermiculture, aquaculture, black soldier fly cultivation

APPENDIX B

Example Layout for Microdigester