Life Cycle Assessment of Food Waste Management Techniques: Loyola University Chicago Lake Shore Campus

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Abstract

Global food waste and loss accounts for about 8% of total anthropogenic greenhouse gas emissions. Targeting and eliminating these man-made emissions will play a critical role in fighting global climate change. At Loyola University Chicago (LUC), climate action and sustainability are key values held by students, faculty, staff, and administrators alike. The goal of this project is to provide a theoretical impact comparison of food waste management techniques proposed for LUC's Lake Shore Campus. Created by the International Organization for Standardization (ISO), life cycle assessments are a methodology used for assessing the environmental impact of a process throughout its entirety. For this study, three processes – commercial composting, anaerobic digestion, and aerobic digestion – were compared based on their global warming potential which was standardized to carbon dioxide. Data for each process was supplied by literature, informal interviews and laboratory research. Sensitivity testing will be implemented to determine the significance of any assumptions made. Our work may serve as a reference for future decisions made at the University-level related to food waste management and diversion.

Introduction

- The degradation of food waste in landfills contributes significantly to anthropogenic greenhouse gas emissions, especially via methane gas[1]
- Targeting these emissions is essential for any climate action plan, including LUC's which aims to eliminate directly controlled emissions by 2025[2]
- Comparing waste mitigation techniques – including anaerobic digestion, aerobic digestion and commercial composting – will allow for robust decisions made at the University-level related to management

Definitions

Life Cycle Assessment – a methodology for assessing the environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service[3]

Anaerobic Digestion – a process through which bacteria break down organic matter in the absence of oxygen; this process produces biogas and liquid digestate by-products[4]

Aerobic Digestion – a process through which bacteria break down organic matter in the presence of oxygen; reduced volatile solids concentration through endogenous respiration in which microbes consume dying cells[5]

Windrow Composting – a process of recycling organic nutrients through the decomposition of organic waste; occurs in long 'windrow' piles that are periodically turned[6]

Global Warming Potential – a metric used to compare the global warming impacts of different gases[7]

Carbon Dioxide Equivalent (CO_2e) – a unit of measurement used to standardize the effects of various greenhouse gases[8]

Figure 1. Photographs of Food Waste Management Technologies. Commercial windrow composting[8] (L) facility with windrow turner that provides oxygenation for the organic waste piles. Renovare Environmental Revolution Sprout aerobic digester[9] (R) unit degrades organic waste into a slurry for disposal into existing wastewater infrastructure.

Methods

There are four broad phases in a life cycle assessment (LCA) study

- Goal and scope definition phase
- Inventory analysis phase
- Impact assessment phase
- Interpretation phase

As an example of the larger project, the following methodology breaks down the first two phases of LCA for anaerobic digestion.

Figure 2. Impact Bioenergy High-solids Organic-waste Recycling System with Electrical Output Anaerobic Digester 25 (HORSE AD25).[11] The HORSE AD25 provides a scalable solution to food waste – converting it into liquid digestate and biogas.

Step 1: Determine functional unit and processes

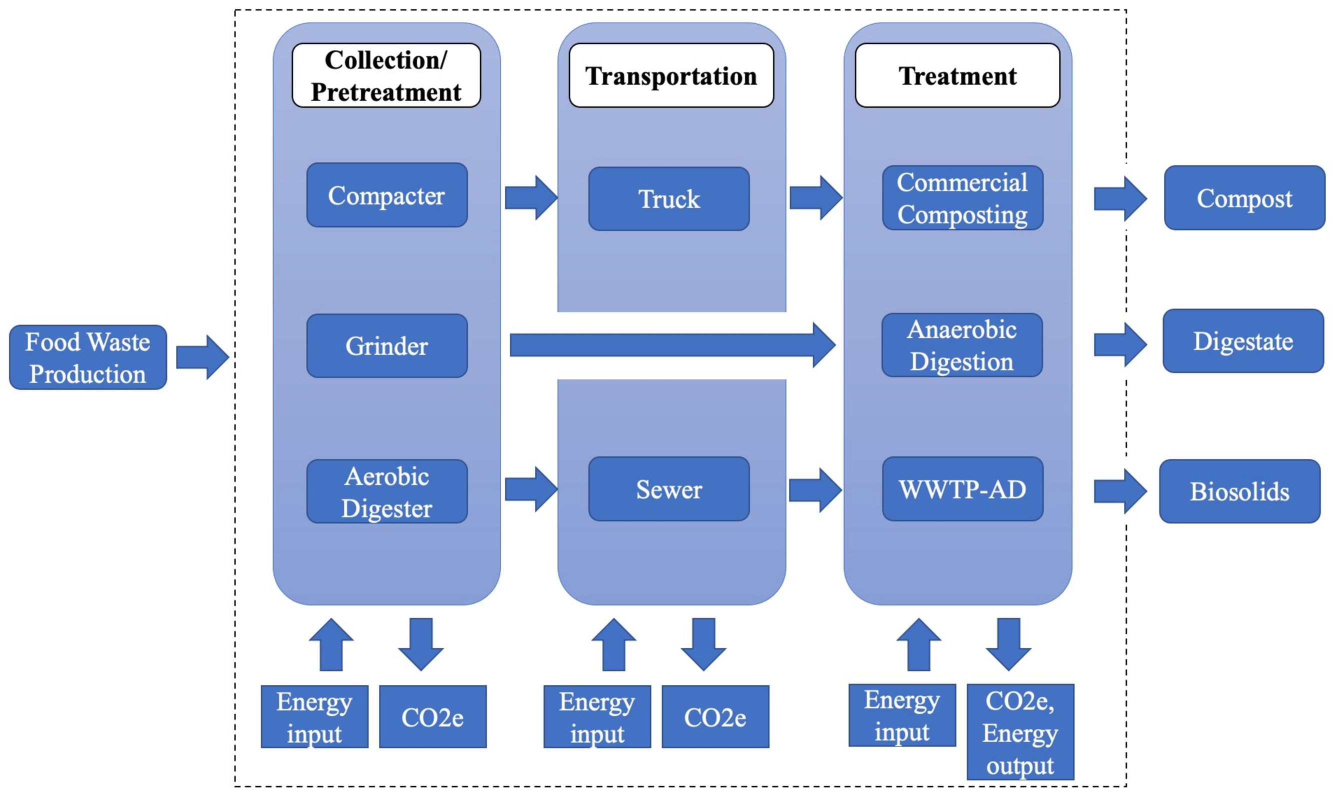

Figure 3. Comparative systems scope for commercial composting, anaerobic digestion and aerobic digestion. The dotted box represents the processes included within the assessment scope.

Step 2: Establish process scopes

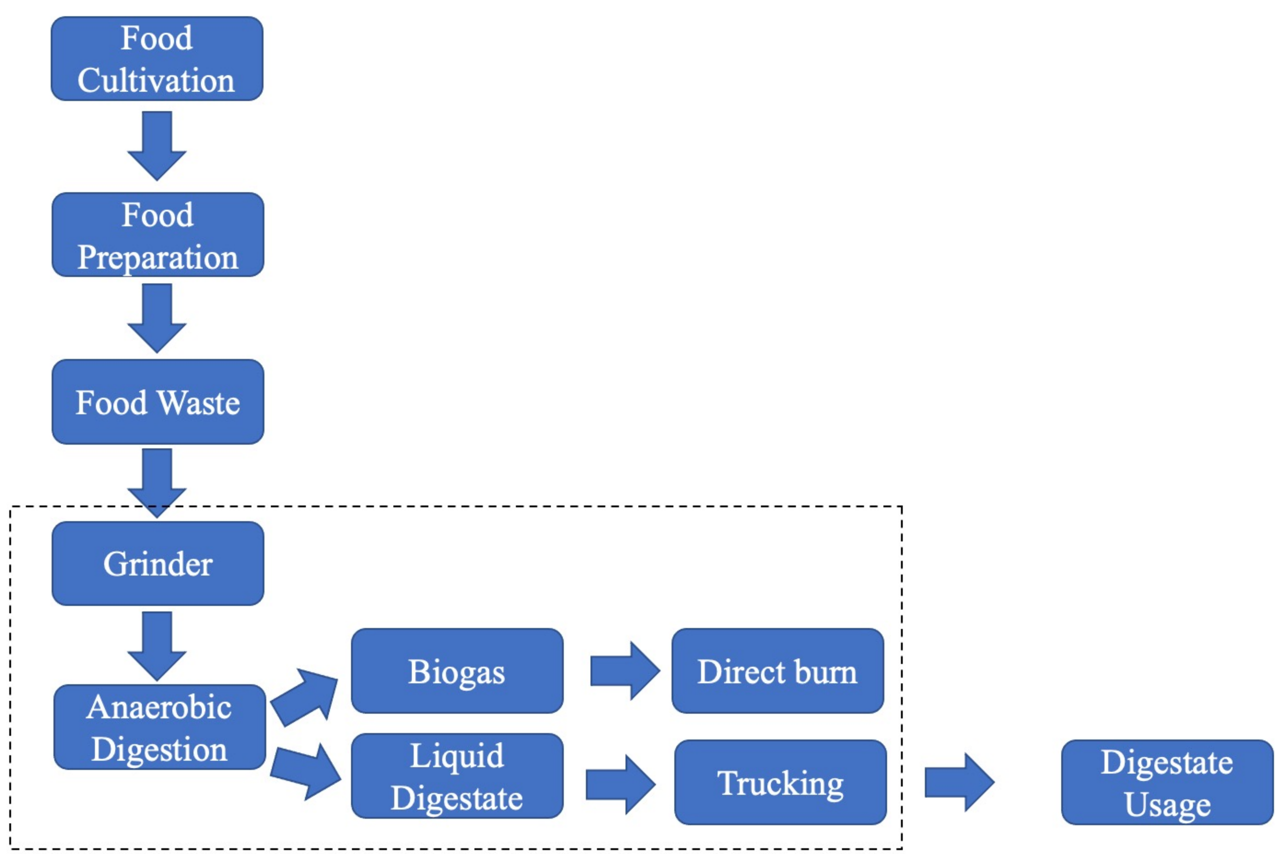

Figure 4. Scope for on-campus anaerobic digestion system. The dotted box represents the critical components included within the assessment scope for this specific process.

Step 3: Conduct life cycle inventory analysis

Collection	Conversions	Impact	Units	Reference
Grinder Electricity				
		---		Aaron Durnbaugh
Digester Electricity				
		---		Aaron Durnbaugh
Potable Water				
Digester Consumption Rate		135	lbs/day	Impact Bioenergy
Unit Conversion	0.4535924		kg/lbs	Mark's Mechanical Engineering
Digester Consumption Rate		61.234974	kg/day	Impact Bioenergy
Functional Unit		1000	kg	
Time to Digest Functional Unit		16.33053686	days	
Grinder Water Consumption		30	gal/day	Assumption Based on Aerobic Digester
Water Consumption Functional Unit		489.9161058	gal	
Electricity for Potable Water		0.00000052	MWh/gal	Aaron Durnbaugh
Greenhouse Gas for Potable Water		0.566	MT CO2e/MWh	Aaron Durnbaugh
Negative Emissions		0.000144192	MT CO2e	
Digester Water Heating				
Digester Consumption Rate		135	lbs/day	Impact Bioenergy
Unit Conversion	0.4535924		kg/lbs	Mark's Mechanical Engineering
Digester Consumption Rate		61.234974	kg/day	Impact Bioenergy
Functional Unit		1000	kg	
Time to Digest Functional Unit		16.33053686	days	
Grinder Water Consumption		30	gal/day	Assumption Based on Aerobic Digester
Water Consumption Functional Unit		489.9161058	gal	
Unit Conversion	8.33		lbs/gal	Don McLauchlan
Temperature Rise (delta T)		50	F	Don McLauchlan
Unit Factor		1.0	BTU/lbs/delta T	Don McLauchlan
Boiler Efficiency Factor		0.85		Don McLauchlan
Natural Gas Needed		240058.8918	BTU	
Unit Conversion	116.65		lbs CO2/BTU	EIA
Negative Emissions		28002869.73	lbs CO2	
Unit Conversion	0.4535924		kg/lbs	Mark's Mechanical Engineering
		12701888.89	kg CO2	
		12701.88889	MT CO2e	
Net Negative Emissions		**12701.88903**	**MT CO2e**	

Figure 5. Life cycle inventory analysis for anaerobic digestion. This datasheet displays calculations related to greenhouse gas emissions of anaerobic digestion throughout collection and processing. Data was collected via literature, informal interviews and laboratory research.

Step 1 lays out the functional unit of comparison between differing systems

- The functional unit is 1,000 kg of food waste over a 100-year event horizon. Each system is assessed based on the GHGs produced during this processing.

Step 2 describes critical components of each process

- Components like food cultivation, food preparation and food waste lie outside of the scope because they are processes shared by all the techniques. System-specific components represent distinct impact.

Step 3 prescribes and compiles the CO_2e impact of each critical component

- The green rows in Fig. 5 represent components that do not contribute to the overall CO_2e of the process. Processes occurring on LUC's Lake Shore Campus are green due to the assumption of 100% clean energy attained through a structured retail transaction.
- The red rows in Fig. 5 represent components – such as potable water and water heating – that contribute to the overall CO_2e of the process.

Next Steps

- Following the same methodology described from anaerobic digestion, greenhouse gas impacts of commercial composting and aerobic digestion will be assessed
- Converting all greenhouse gas emissions to CO_2e will allow for the comparison of distinct management techniques
- Sensitivity analysis will be run on assumptions to test their overall impact on the results
- The results from the sensitivity analysis will inform recommendations on areas of focus for sustainability work related to food waste on LUC's Lake Shore Campus

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