Phase II Bioenergy Production from MSW by High Solids Anaerobic Digestion

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2017 Quarterly Report # 4

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

B	Biosolids
BS	Baking Soda
$CaCO_3$	Calcium Carbonate
CH_4	Methane
CHP	Combined Heat and Power
FW	Food Waste
HS-AD	High Solids Anaerobic Digestion
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
LCI	Life Cycle Inventory
MSW	Municipal Solid Waste
NH_4^+	Ammonium
$NaHCO_3$	Sodium Bicarbonate (Baking Soda)
OFMSW	Organic Fraction of Municipal Solid Waste
OS	Oyster Shells
S/I	Substrate to Inoculum
PV	Present Value
TS	Total Solids
VFA	Volatile Fatty Acids
VS	Volatile Solids
WTE	Waste to Energy
YW	Yard waste

QUARTERLY REPORT #4

PROJECT TITLE: Phase II Bioenergy Production from MSW by High Solids Anaerobic Digestion

PERFORMANCE PERIOD: October 7, 2017-December 31, 2017

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The overall goal of this project is to improve the environmental and economic sustainability of High Solids-Anaerobic Digestion (HS-AD) of Organic Fraction of Municipal Solid Waste (OFMSW) in Florida. Specific objectives for Phase II are to:

1. Investigate the performance of HS-AD of OFMSW with varying substrate ratios (yard waste [YW], food waste [FW], biosolids [B]) and temperatures (35, 55 °C).
2. Apply life cycle analysis (LCA) to guide the selection of waste sources and operating conditions for HS-AD.
3. Compare HS-AD with other waste management options (e.g., landfilling, waste to energy (WTE), composting) to ensure economic and environmental sustainability.

WORK ACCOMPLISHED DURING THIS REPORTING PERIOD

Objective 1: Investigate HS-AD performance with varying substrates and temperatures

Bench-scale experiment with addition of biosolids in HS-AD of FW+YW: Additional experiments were conducted to quantify the effects of biosolids addition in HS-AD of FW and YW. In this experiment, different Substrate to Inoculum ratios (S/I ratio=1) were applied to avoid the risks of AD failure. Also, crushed Oyster Shells (OS) and sodium bicarbonate ($NaHCO_3$) as additional alkalinity sources were used to prevent acidification in the first 10 days. Figure 1 (a) and (b) shows the cumulative methane (CH_4) production and CH_4 yields for HS-AD with FW+YW and FW+YW+B. Both FW+YW and FW+YW+B digester sets were not able to produce methane in the first 10 days due to high Volatile Fatty Acid (VFA) production, which resulted in low pH (Table 1). After 10 days, CH_4 production and yield increased in both digestion sets.

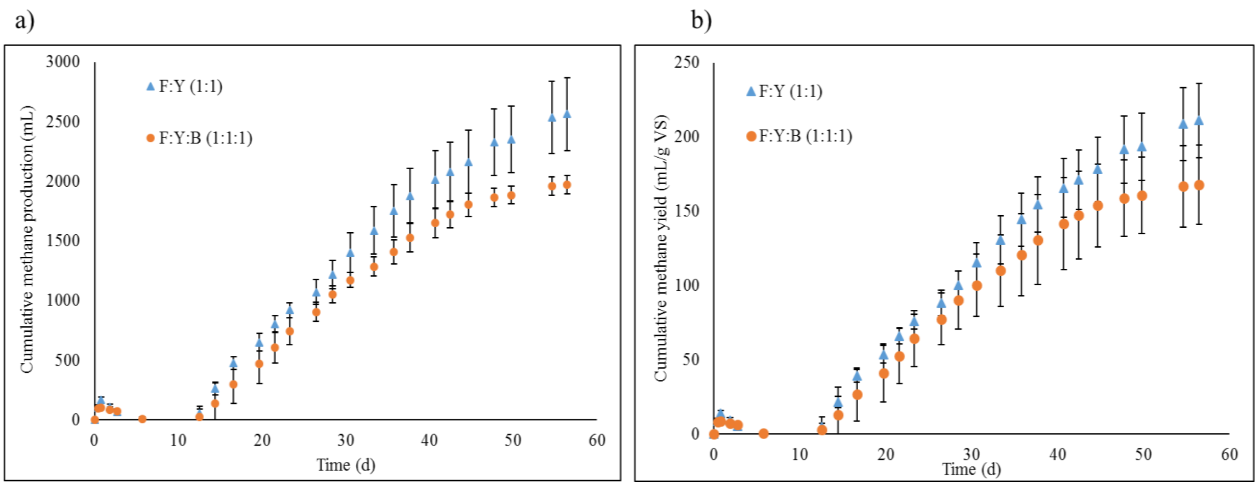

Figure 1. Cumulative Methane (CH_4) production (a) and CH_4 yield (b) for HS-AD of FW+YW and FW+YW+B

Table 1. Digestate and leachate characteristics for HS-AD of FW+YW and FW+YW+B.

Item	**FW+YW**				**FW+YW+B**			
	Day 0	**Day 6**	**Day 28**	**Day 56**	**Day 0**	**Day 6**	**Day 28**	**Day 56**
Total Solids (g/g)	0.20 ±0.001	0.20 ±0.01	0.18 ±0.004	0.18 ±0.01	0.20 ±0.01	0.20 ±0.01	0.17 ±0.02	0.17 ±0.01
Volatile Solids (g/g)	0.15 ±0.01	0.13 ±0.002	0.12 ±0.01	0.11 ±0.01	0.15 ±0.01	0.13 ±0.004	0.11 ±0.003	0.11 ±0.004
pH	8.41 ±0.01	6.40 ±0.04	8.50 ±0.07	8.53 ±0.03	8.20 ±0.11	6.86 ±0.12	8.51 ±0.04	8.59 ±0.06
VFA (mg/L)	1,788 ±7	22,036 ±2,040	9,310 ±221	1,803 ±305	1,303 ±8	16,511 ±1,625	5,292 ±522	1,118 ±300
Alkalinity (mg $CaCO_3$/L)	11,669 ±217	9,220 ±439	12,591 ±620	14,347 ±2,430	6,657 ±40	7,698 ±503	11,400 ±964	11,318 ±2,716
soluble COD (mg/L)	21,280 ±25	41,636 ±4,926	25,950 ±565	10,665 ±1,582	12,047 ±527	32,767 ±3,174	19,072 ±2,256	7,339 ±4,576
NH_4^+-N (mg/L)	1,197 ±34	2,115 ±272	2,359 ±75	2,175 ±200	1,629 ±67	2,193 ±198	2,261 ±220	2,139 ±426
VFA/Alkalinity	0.15	2.39	0.74	0.13	0.20	2.14	0.46	0.10

VFA/alkalinity ratios, which are a common stress indicator for anaerobic digestion, were highest on day 6 and then gradually decreased in both digestion sets (Table 1). Generally, a ratio of < 0.4 is considered as optimal for anaerobic digestion. Both digestion sets were able to maintain optimal conditions after 28 days. As shown in Figure 1, digesters inoculated with FW+YW had a higher cumulative CH_4 production and yield than digesters with FW+YW+B, likely because digesters with FW+YW had a larger amount of biodegradable substrates than FW+YW+B. Volatile Solids (VS) reductions for HS-AD with FW+YW and FW+YW+B are shown in Figure 2. Over 28 days, VS reductions for FW+YW and FW+YW+B were 18.0% and 28.1%, respectively. As shown, the biosolids addition to the FW+YW increased VS reduction by 1.6-fold for 28 days. After 56 days, both digester sets were achieved approximately 31% VS reduction.

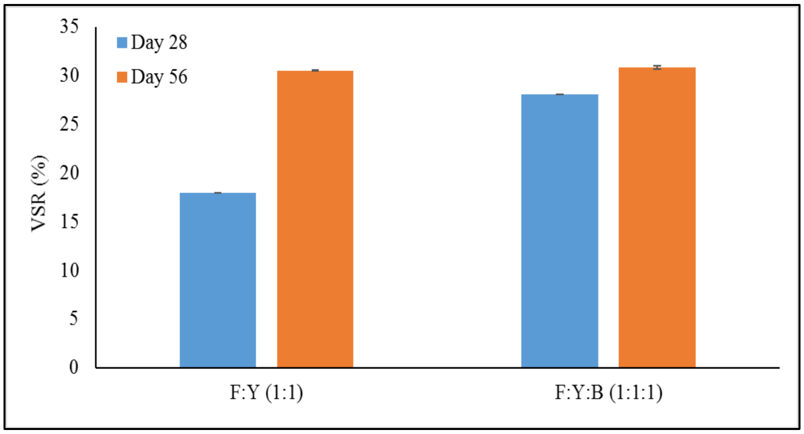

Figure 2. Volatile Solid Reduction (VSR) for HS-AD of FW+YW and FW+YW+B

Bench-scale experiment with varying substrate ratios (FW+YW+B): The results of the first bench-scale experiment with varying substrate ratios were described in the third quarterly report. However, a challenge related to acidification was encountered during that study and the results were inconclusive. Thus, the bench-scale studies for HS-AD with varying substrate ratios were repeated. Unlike the previous reactor set-up (S/I ratio=2.7), S/I ratios for both sets were maintained at 1, and crushed OS and $NaHCO_3$ were both used as alkalinity sources to provide both long (OS) and short term ($NaHCO_3$) pH buffering.

Figure 3 shows the cumulative CH_4 production and yield of each substrate as a function of digestion time. Table 2 shows leachate characteristics of both sets. As shown in Figure 3, after 10 days, CH_4 production and yield from both digesters significantly increased. The digester set with FW+YW+B (1.4:3.1:1) had higher CH_4 production and yield than the digester set with FW+YW+B (1:1:1) before 36 days because the FW+YW+B (1:1:1) had higher VFA/alkalinity values (above 0.4, Table 2). After that time, CH_4 production and yield of the digester set with FW+YW+B (1:1:1) exceeded those of the digester set with FW+YW+B (1.4:3.1:1).

In Table 2, the VFA/alkalinity values for the digester set with FW+YW+B (1.4:3.1:1) was less than 0.4 which means that the digesters maintained optimal conditions for 56 days. During the digestion, the digestion sets with FW+YW+B (1:1:1) had higher NH_4^+-N concentrations than those of the digestion sets with FW+YW+B (1.4:3.1:1). Figure 4 shows VS reduction for the HS-AD of FW+YW+B (1:1:1) and FW+YW+B (1.4:3.1:1). The digestion sets with FW+YW+B (1:1:1) had higher VS reduction than the digestion sets with FW+YW+B (1.4:3.1:1) during the first 56 days because the digestion sets with FW+YW+B (1.4:3.1:1) contained larger amounts of YW. YW typically contains lignin, which is a complex organic substance that is difficult to degrade by anaerobic bacteria.

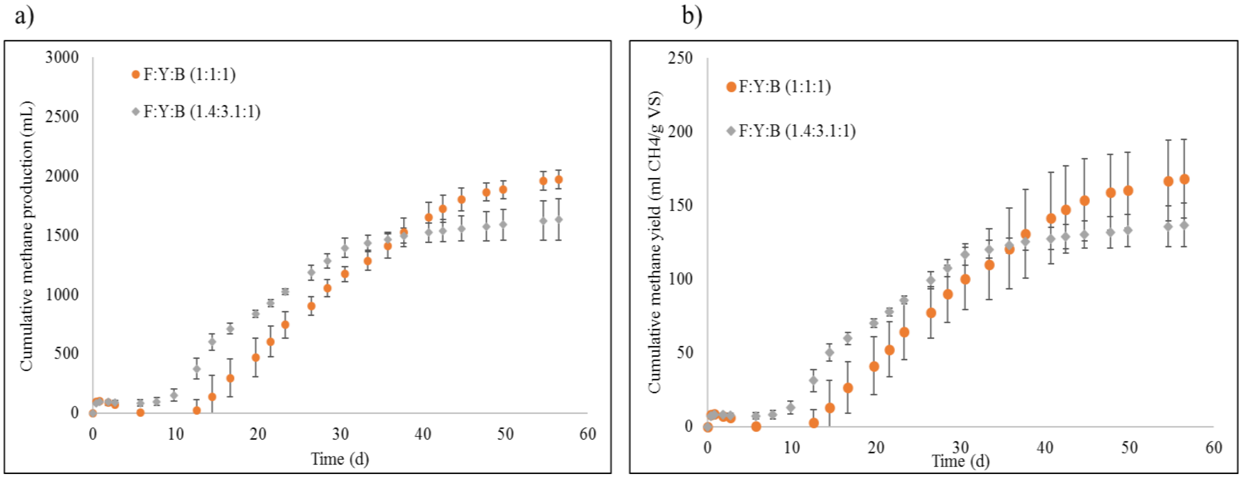

Figure 3. Cumulative Methane (CH_4) production (a) and CH_4 yield (b) for HS-AD with different substrate ratios

Table 2. Digestate and leachate characteristics for HS-AD with different substrate ratios

Item	**FW+YW+B (1:1:1)**				**FW+YW+B (1.4:3.1:1)**			
	Day 0	**Day 6**	**Day 28**	**Day 56**	**Day 0**	**Day 6**	**Day 28**	**Day 56**
Total Solids (g/g)	0.20 ±0.01	0.20 ±0.01	0.17 ±0.02	0.17 ±0.01	0.20 ±0.01	0.20 ±0.01	0.18 ±0.02	0.17 ±0.01
Volatile Solid (g/g)	0.15 ±0.01	0.13 ±0.004	0.11 ±0.003	0.11 ±0.004	0.15 ±0.01	0.14 ±0.004	0.13 ±0.003	0.11 ±0.004
pH	8.20 ±0.11	6.86 ±0.12	8.51 ±0.04	8.59 ±0.06	8.14 ±0.01	7.78 ±0.08	8.51 ±0.02	8.41 ±0.05
VFA (mg/L)	1,303 ±8	16,511 ±1,625	5,292 ±522	1,118 ±300	1,511 ±135	12,598 ±1,408	3,626 ±525	949 ±275
Alkalinity (mg $CaCO_3$/L)	6,657 ±40	7,698 ±503	11,400 ±964	11,318 ±2,716	8,853 ±455	7,409 ±1,153	11,336 ±316	9,866 ±2,271
soluble COD (mg/L)	12,047 ±527	32,767 ±3,174	19,072 ±2,256	7,339 ±4,576	12,680 ±829	25,475 ±4,299	14,751 ±1,781	7,210 ±2,067
NH_4^+-N (mg/L)	1,629 ±67	2,193 ±198	2,261 ±220	2,139 ±426	1,395 ±106	1,654 ±296	2,030 ±77	1,747 ±383
VFA/Alkalinity	0.20	2.14	0.46	0.10	0.14	0.09	0.28	0.38

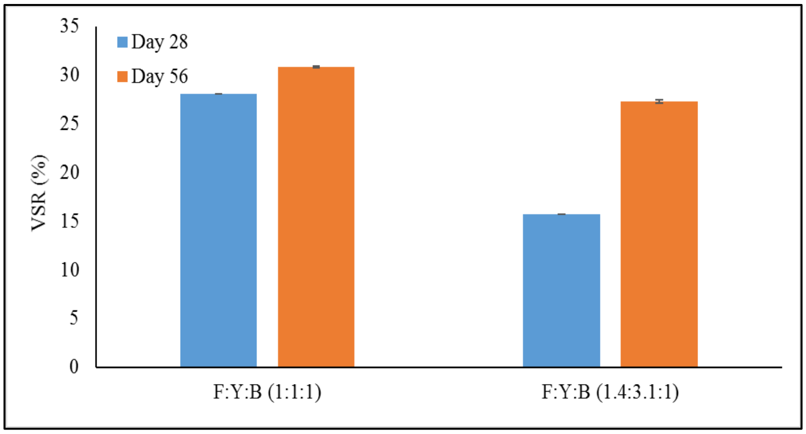

Figure 4. Volatile Solid Reduction (VSR) for HS-AD with different substrate ratios

Bench-scale experiment with different S/I ratios and alkalinity sources (fast and slow release): HS-AD reactor studies with FW+YW+B at varying S/I ratios and with different alkalinity sources (fast and slow release) were carried out. In this study, crushed OS and $NaHCO_3$ were used as slow and fast release alkalinity sources, respectively. Two different S/I ratios (1.0 and 1.9 by VS) and three alkalinity options (no alkalinity addition, OS addition, OS+$NaHCO_3$ addition) were applied for the HS-AD of FW+YW+B (Figure 5).

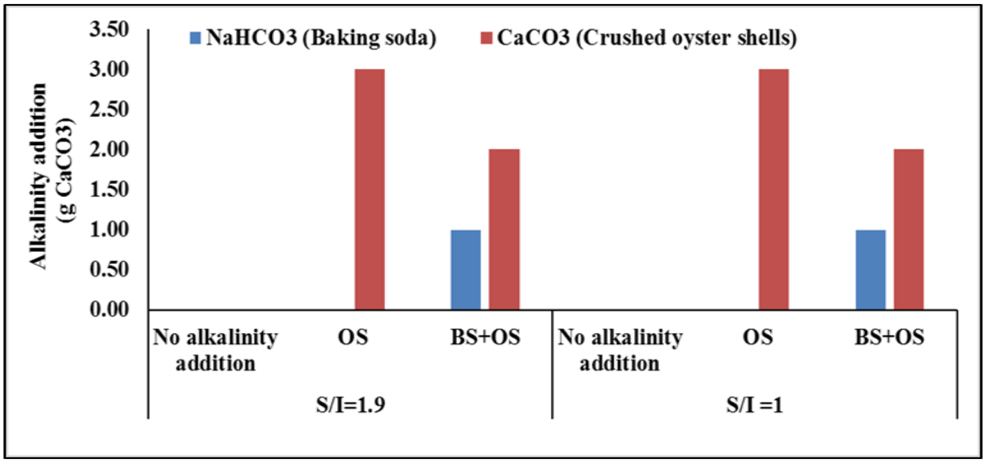

Figure 5. Applied different S/I ratios and alkalinity options for digesters (OS = oyster shell; BS = baking soda ($NaHCO_3$))

Figure 6 shows cumulative CH_4 production and CH_4 content in biogas for HS-AD with different S/I ratios and alkalinity options. All digestion sets with S/I ratio=1 gradually produced CH_4 over 80 days. Among sets with S/I ratio=1, the mixture of OS and $NaHCO_3$ resulted in the highest CH_4 production rate, followed by OS only. However, the sets with S/I ratio=1.9 without BS had low CH_4 production over the entire period. This may have been due to inhibition of methanogenic activity by acidification. Comparing the sets with S/I ratio=1.9 and 1, reduction of S/I ratio improved CH_4 production as well as CH_4 content in the biogas. CH_4 production of the digester set with S/I ratio 1.9 with the mixture of OS and BS gradually increased after 20 days and this set had a similar CH_4 production trend as the digester with S/I ratio=1 without additional alkalinity. The results indicate that $NaHCO_3$ addition can help overcome the pH drop at the beginning stage of digestion.

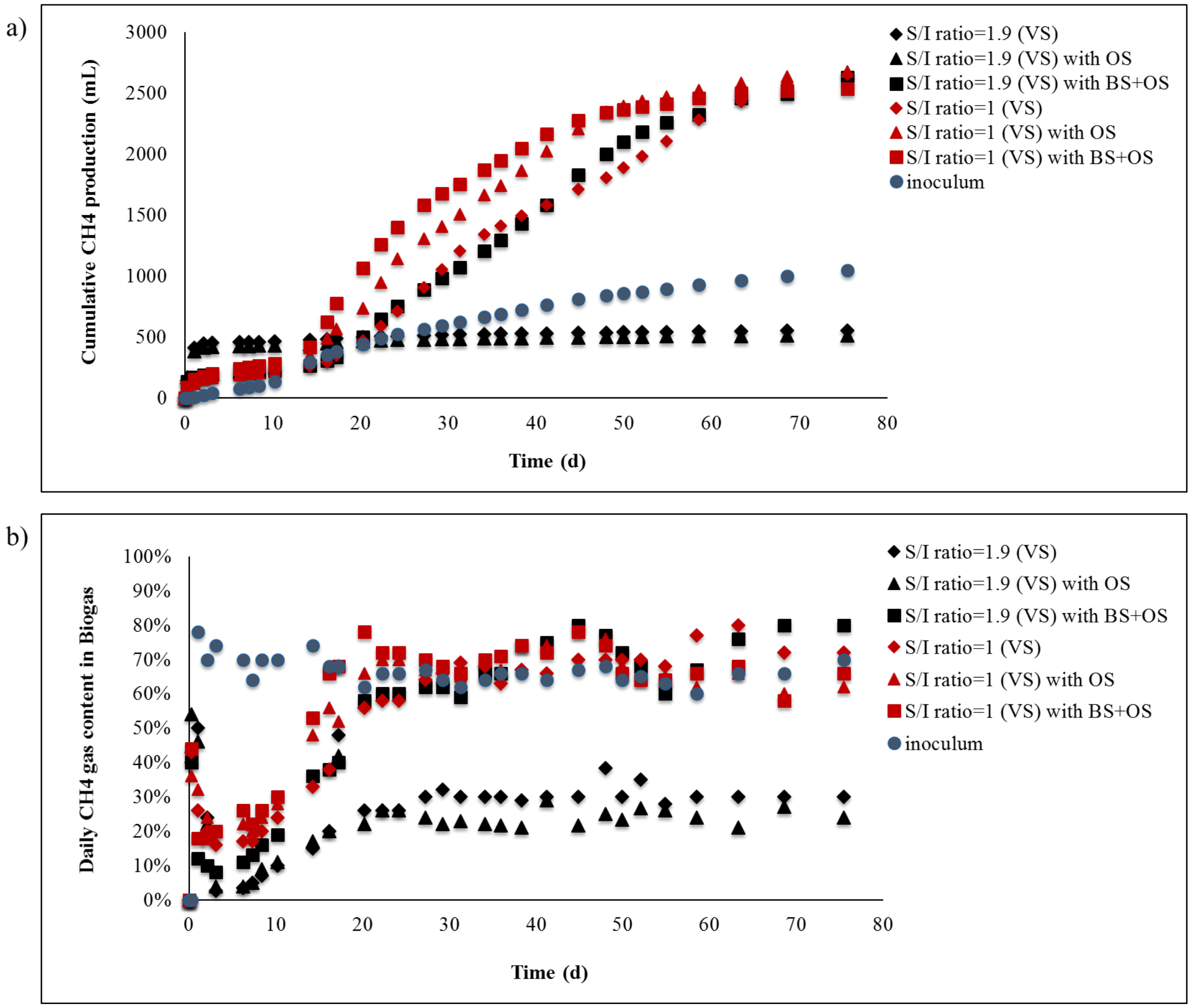

Figure 6. Cumulative CH_4 production (a) and CH_4 content in biogas (b) for HS-AD with different S/I ratios and alkalinity options.

Objective 2: Apply life cycle assessment (LCA) to guide the selection of waste sources and operating conditions for HS-AD

To the previously completed Life Cycle Inventory (LCI) (mesophilic operation mode and annual capacity of 60,583 MTPY) two new important considerations were added: first, construction and operation of the coupled CHP-unit; second, collection and transportation data for food waste (FW), yard waste (YW), and Biosolids (B). With these new additions, the Life Cycle Assessment (LCA) for the HS-AD of FW, YW, and B (1:1:1), as well as the collection of FW and YW, and the transportation of FW, YW, and B was completed. The LCA software SimaPro 7 was used to accomplish this.

CHP Unit: Data for performing the construction LCI for the CHP unit came from the Ecoinvent database (Ecoinvent, 2013). This database considered a CHP unit with annual capacity of 1,000 kW (Ecoinvent, 2013). For the aforementioned waste composition, the total volume of CH_4 produced per year was verified experimentally (92.89 L CH_4/ kg VS, obtained from the first quarterly report). Assuming a constant flow-rate of CH_4 to the CHP unit (295 m^3/hr), and a lower heating value for CH_4 of 33,943 kJ/m^3 (Engineering Toolbox, n.d.), the annual power of the CHP unit was estimated to be 2,778 kW. The conversion to electrical energy efficiency was assumed as 35%, and that of heat efficiency as 45% (Li et al., 2017), giving 972 kW of electricity and 1,250 kW of heat, annually. Thus, it was determined that a single 1,000 kW CHP unit would suffice for the given annual waste capacity.

Having established the required number of CHP units, the inventory from Ecoinvent, version 3.01, was used to calculate the material requirements for building the CHP unit, per functional unit (1 L of CH_4 produced). The inventory for CHP operation was taken from the electricity and heat produced. For the purposes of inputting data into SimaPro, it was considered that all heat and electricity inputs (for operating digesters, pumps, leachate tank, etc.) would come from the grid, while all heat and electricity outputs (produced from the process) were considered avoided products in the form of electricity from the grid. In addition, since the available processes in SimaPro did not have heat processes, all inputs/outputs of heat were assumed to have been converted from or into electricity with an efficiency of 80%.

Collection and Transportation: Collection data considered residential door-to-door collection of FW and YW using single unit trucks, fueled by diesel (EIA, 2017), and a daily average distance traveled by each truck of 100 miles/day/vehicle (national average taken from Sandhu et al., 2014). To assess the impact of the collection process, the freight carried, measured as distance traveled times mass (tkm), was computed. The average daily distance traveled by each truck (100 miles/day) was used as the distance, and the assumed annual mass of FW and YW (27,121 MTPY) was used as the mass, yielding 0.00507 tkm/L CH_4. The choice of using the average daily distance traveled by each truck, rather than the total annual distance traveled by the whole fleet of collection trucks, was based on the idea that every portion of the total waste, each collected by individual trucks, travels, on average, the same distance to the transfer station. An additional assumption, for simplicity, was that the trucks traveled the whole distance carrying their maximum capacity (when in reality the freight carried by the trucks continually increases per distance traveled, until the maximum capacity is reached).

Similar calculations were performed for the transportation of FW,YW, and B. For the case of FW and YW (27,121 MTPY), the transportation distance was assumed to be from the transfer station to the HS-AD plant, while for the B case (33,462 MTPY), it was assumed to be from the Wastewater Treatment Facility to the HS-AD plant. These distances were estimated to be 35 miles each, and the corresponding freight carried were 0.00177 tkm/L CH_4 and 0.00219 tkm/L CH_4. It is important to point out that since this report considers a hypothetical HS-AD plant, the estimated distances are not real, existing distances. When inputting the inventory into SimaPro, the transport process chosen considered a generic, single unit truck, powered by diesel, so it was not possible to account for truck capacity.

LCA results: Based on the inventory presented in the third quarterly report and additional inventories of the CHP, collection, and transportation, four impact categories (global warming, acidification, eutrophication, and ecotoxicity) were calculated through SimaPro using the TRACI 2 v3.03 method. Figure 7 shows the percent contribution of each process (transportation, collection, construction of HS-AD, and processing of HS-AD) on the impact categories considered. Overall, processing/operation energy is the only process that resulted in negative contributions to the impact categories, that is, it resulted in a reduction of the environmental setbacks associated with each impact category. Of the other three processes, collection and transportation (over a 20-year span) are the major contributors in all four categories, and they are particularly significant in the global warming and acidification categories, in which the contribution from construction is almost negligible.

Figure 8 shows the percent contribution of each unit (CHP operation, pumping, blowers, digesters operation, etc.) for each of the four impact categories considered for the HS-AD operation. CHP operation and digester operation are the two main units for the HS-AD process, followed by percolate tank operation. All other units have very small impacts in the four categories considered. As expected, the CHP operation unit has a negative contribution in all categories, meaning it reduces the environmental impacts of these categories. Coupling a CHP unit to the HS-AD process is beneficial, and was expected to reduce environmental impacts, since it utilizes the CH_4 produced by the HS-AD process to produce energy, as both heat and electricity.

Similarly, Figure 9 presents the percent contribution of each unit for the construction process. CHP construction and digester construction accounts for more than 90% of the impact for all categories. These two units are the ones that require the largest amount of materials, and so it was expected that they would be the units with most impact. Of the other units, construction of the biofilter represents about 5% of the impacts in the acidification category; construction of the percolate tank accounts for modest, positive impacts in the global warming and acidification categories, and negative impact in the eutrophication category.

The next steps on LCA will be to vary digesters' operating temperature and waste composition, and assess how these changes affect the LCA of the HS-AD process.

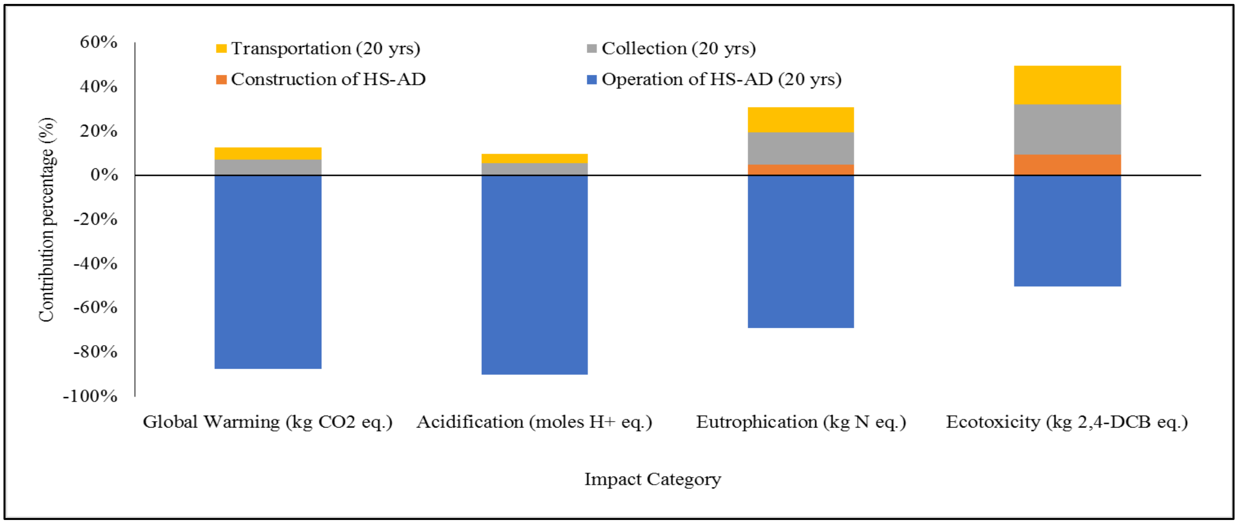

Figure 7. Contribution of each process for the impact categories of global warming, acidification, eutrophication, and ecotoxicity.

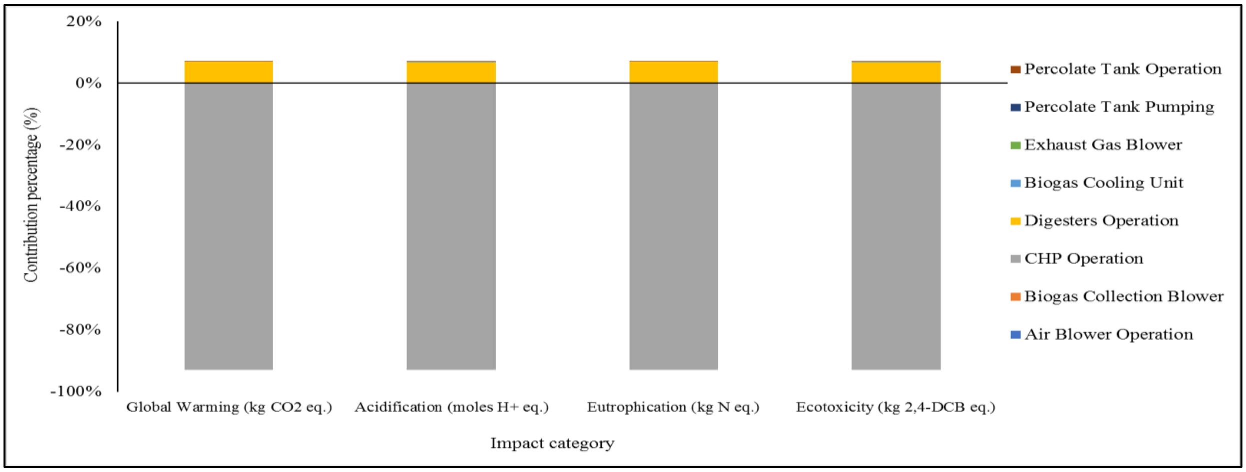

Figure 8. Unit contribution for each impact category for the operation of HS-AD.

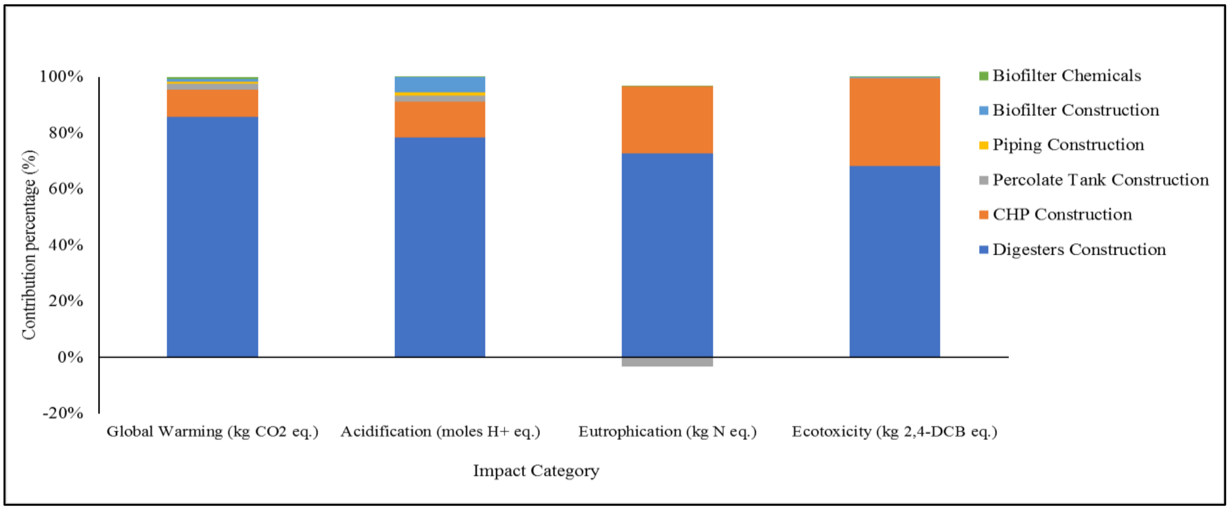

Figure 9. Unit contribution for each impact category for the construction process.

Objective 3: Compare HS-AD with other waste management options (e.g., landfilling, waste to energy (WTE), composting) to ensure economic and environmental sustainability

The collection and transportation costs and the land acquisition costs have been updated in this quarterly report. Initial costs for collection and transportation trucks were excluded in this analysis because the trucks exist in current waste management systems. Collection costs for the operation phase focused on FW and YW. These costs were recalculated based on the following assumptions: a diesel refuse truck is 10 tons haul load, the collection is performed for 260 days per year (5 days per week, 8 hours per day), the average traveled distance is 100 miles per haul, the diesel price is $2.4 per gallon of diesel (EIA, 2017), and the fuel economy is 3 miles per gallon of diesel (Laughlin & Burnham, 2014).

Transportation costs are related with the distance from the transfer station to final processing facilities such as landfill, composting system, WTE, and HS-AD (the case of FW and YW) and from the Wastewater Treatment Facility to the facilities (the case of B). Transportation distance and a load of the trailer were assumed to be 35 miles (a round trip) and 20 tons, respectively. The calculation for the collection and transportation costs are as follows;

$$C_C = \frac{(M_{FW} + M_{YW}) \times D_C \times P}{L_C \times F}$$

$$C_T = \frac{(M_{FW} + M_{YW} + M_B) \times D_T \times P}{L_T \times F}$$

C_C and C_T are collection and transportation costs ($/year), respectively. M_{FW}, M_{YW}, M_B are total mass of produced FW, YW, and B per year (ton/year), respectively. L_C and L_T are truck haul loads for collection (10 tons/ haul) and transportation (20 tons/ haul), respectively. D_C and D_T is an average travel distance per haul for collection (100 miles per haul) and transportation (35 miles per haul). F and P are the fuel economy of a truck (3 miles/gal) and diesel price ($/gal). The collection and transportation costs are shown in Table 3.

Table 3. Collection and transportation costs

Items	Cost	
	$/year	$/25 years
Collection cost	217,000	4,291,200
Transportation cost	84,800	1,677,500

The land requirements for the selected waste management options (e.g., landfilling, WTE, composting, and HS-AD) were estimated based on literature and information from existing facilities. The costs for land in Hillsborough County were estimated from real estate website (LandWatch, n.d.). The average land cost was $1,327 per m^2 (±$1,205 per m^2). This cost was applied to calculate the land acquisition for the selected waste management options. Table 4 shows the results for land acquisition costs of each waste management option (about 60,583 tons of waste processed). The highest land acquisition cost was the composting system due to the longer retention time of the composting system (106 days). Also, this system used the windrow technology, which requires larger land areas than in-vessel technology. As expected, the second highest land acquisition cost was the landfill facility, followed by HS-AD. The lowest land acquisition cost was the WTE facility.

Table 4. Land acquisition cost for the selected waste managment options

Waste management options	Area requirement (m^2)	Average land acquisition cost ($)
HS-AD facility	4,900	6,498,000 ± 5,902,000
Composting facility	78,200	103,708,000 ± 94,193,000
Waste to Energy facility	4,100	5,437,000 ± 4,939,000
Landfill facility	72,800	96,547,000 ± 87,689,000

Since standard deviation of the land cost per square meter was high, the next steps in the LCCA will be to assess uncertainty analysis using Monte Carlo simulation. Final LCCA results will be updated in the final report.

DISSEMINATION ACTIVITIES

Phase II research has been disseminated through reports to the Hinkley Center (4 quarterly), 1 PhD proposal presentation (Dixon, 2017), 2 poster presentations, and one conference presentation (Energy Water Food Nexus International Summit 2017). Two additional abstracts were accepted for presentations at conferences in February (Global Waste Management Symposium 2018) and March (International Conference on Solid Waste Technology and Management) 2018. Outreach activities have included displays and presentations at USF's Engineering Expo (anaerobic digesters were created out of soda bottles) and the Van Buren Middle School Great American Teach-In (an anaerobic digestion presentation was given to the school located in Tampa with a class room project). These presentations were aimed at teaching anaerobic digestion, which has been deemed one of the most complicated biological processes, in a simple manner to young people. In addition, a presentation was given to the University of South Florida's (USF's) Florida Water Environment Association (FWEA) student chapter. A presentation was given for the USF National Science Foundation (NSF) Partnerships for International Research and Education (PIRE) annual meeting. A class presentation was given by a student in Dr. Ergas' Biological Principles in Environmental Engineering class. Some of the USF Hinkley Center bioenergy production from MSW researchers have been involved in starting a new USF group called the Food Waste Initiative. The group aims to use food waste that that is created at USF and in the Tampa community. The strategies that have been looked at are food waste distribution for consumption through shelters and anaerobic digestion. As part of the anaerobic digestion strategy an anaerobic digester was installed at the USF botanical gardens in January 2018. The digester will be used to recover energy and nutrients from food waste and invasive plants.

METRICS

1. List of graduate student and postdoctoral researchers funded by this Hinkley Center project:

Last name, first name	Rank	Department	Professor	Institution
Dixon, Phillip	PhD Student	Civil/ Environmental Engineering	Ergas	USF
Lee, Eunyoung	Postdoctoral Researcher	Civil/ Environmental Engineering	Zhang	USF
Wang, Meng	Postdoctoral Researcher	Civil/ Environmental Engineering	Ergas	USF

2. List of undergraduate researchers working on this Hinkley Center project:

Last name, first name	Rank	Department	Professor	Institution
Bittencourt, Paula	BS student	Mechanical Engineering	Ergas	USF
Jimenez, Eduardo	BS Student	Civil & Environmental Engineering	Ergas/Zhang	USF
Casimir, Lensey	BS Student	Civil & Environmental Engineering	Ergas	USF
Stolte Bezerra Lisboa Oliveira, Deborah	BS Student	Chemical & Biomedical Engineering	Zhang	USF
Stolte Bezerra Lisboa Oliveira, Luiza	BS Student	Chemical & Biomedical Engineering	Zhang	USF

3. List of research publications resulting from this Hinkley Center project.

The following publications were based on Phase I of this project:

Hinds, G.R., Mussoline, W., Casimir, L., Dick, G., Yeh, D.H., Ergas, S.J. (2016) Enhanced methane production from yard waste in high-solids anaerobic digestion through inoculation with pulp and paper mill anaerobic sludge, *Environmental Engineering Science*, 33(11): 907-917.

Hinds, G.R., Lens, P., Zhang, Q., Ergas, S.J. (2017) Microbial biomethane production from municipal solid waste using high-solids anaerobic digestion, In *Microbial Fuels: Technologies and Applications,* Serge Hiligsmann (Ed), Taylor & Francis, Oxford, UK.

4. List of research presentations resulting from this Hinkley Center project.

	Title/Authors	Conference/Date
1	Effects of Biosolids Addition and Alkalinity Sources on High-Solids Anaerobic Co-digestion of Food Waste and Green Waste. Phillip Dixon, Eunyoung Lee, Paula Bittencourt, Eduardo Jimenez, Meng Wang, Qiong Zhang, and Sarina Ergas	2017 SWANA summer conference and Hinkley Center Colloquium, Fort Myers, FL, July 24-25, 2017
2	Effects of Biosolids Addition and Alkalinity Sources on High-Solids Anaerobic Co-digestion of Food Waste and Green Waste.	Renewable Energy Systems and Sustainability Conference in Lakeland, FL, July 31-Auguest 1, 2017

	Phillip Dixon, Eunyoung Lee, Paula Bittencourt, Eduardo Jimenez, Meng Wang, Qiong Zhang, and Sarina Ergas	
3	High-Solids Anaerobic Co-digestion of Food Waste and Yard Waste with Biosolids for Sustainable Bioenergy Production Eunyoung Lee, Paula Bittencourt, Eduardo Jimenez, Lensey Casimir, Meng Wang, Phillip Dixon, Qiong Zhang, and Sarina Ergas	Energy Water Food Nexus International Summit 2017, Orlando, FL, October 19-20, 2017
4	High-Solids Anaerobic Co-digestion of Food Waste and Yard Wastes with Biosolids for Bioenergy Production Eunyoung Lee, Paula Bittencourt, Eduardo Jimenez, Lensey Casimir, Meng Wang, Qiong Zhang, and Sarina Ergas	Global Waste Management Symposium 2018, Indian Wells, CA, February 11-14, 2018
5	Life Cycle Assessment for High Solids Anaerobic Digestion of Food Waste, Yard Waste, and Biosolids Luiza Stolte Bezerra Lisboa Oliveira, Deborah Stolte Bezerra Lisboa Oliveira, Eunyoung Lee, Eduardo Jimenez, Sarina Ergas, and Qiong Zhang	The Thirty-Third International Conference on Solid Waste Technology and Management, Annapolis, MD March 11-14, 2018

5. List of who has referenced or cited your publications from this project?

At this time, the results from this research study have not been referenced by others.

6. How have the research results from this Hinkley Center project been leveraged to secure additional research funding?

- Phillip Dixon was partially supported by an NSF funded Partnership in International Research and Education (PIRE) grant during the 2017 academic year.
- Paula Bittencourt and Eduardo Jimenez were partially supported (40%) by funds from the USF College of Engineering Research Experience for Undergraduates (REU) program.
- A proposal was submitted to the US-Israel Binational Agricultural Research and Development (BARD) fund on the topic of, "Production of High Value Products from Agricultural Residues via High Solids Anaerobic Digestion, Pyrolysis and Thermo-Catalytic Conversion."

7. What new collaborations were initiated based on this Hinkley Center project?

We have initiated collaborations with the following researchers:
- John Kuhn, Department of Chemical & Biomedical Engineering, USF
- Babu Joseph, Department of Chemical & Biomedical Engineering, USF
- Oz M. Gazit, Faculty of Chemical Engineering, Technion Israel Institute of Technology
- Ellen R. Graber, Faculty of Soil, Water & Environmental Sciences, ARO-Volcani Center, Israel

8. How have the results from this Hinkley Center funded project been used (not will be used) by FDEP or other stakeholders? (1 paragraph maximum).

We have presented this work to Beth Schinella and Luke Mulford and other stakeholders in the Department of Public Utilities in Hillsborough County. They have indicated that they would like to participate in future pilot-scale studies of HS-AD of food waste, yard waste and biosolids.

TAG MEMBERS

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