Phase II Bioenergy Production from MSW by High Solids Anaerobic Digestion

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2017 Quarterly Report # 1

January 1, 2017-March 31, 2017

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LIST OF ACRONYMS AND ABBREVIATIONS

AD	Anaerobic Digestion
B	Biosolids
BMP	Biochemical Methane Potential
$CaCO_3$	Calcium Carbonate
CH_4	Methane
C&T	Collection and Transportation
CHP	Combined Heat and Power
d	day
FW	Food Waste
GHG	Greenhouse Gases
GW	Green Waste (also known as yard waste)
HS-AD	High Solids Anaerobic Digestion
I	Sensitivity Index
L	Limestone
L-AD	Liquid Anaerobic Digestion
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
MSW	Municipal Solid Waste
NH_4^+	Ammonium
O&M	Operations and Maintenance
OFMSW	Organic Fraction of Municipal Solid Waste
OS	Oyster Shells
PV	Present Value
S/I	Substrate to Inoculum Ratio
SS	Seed Sludge
SS-AD	Solid State Anaerobic Digestion
STP	Standard Temperature and Pressure
TS	Total Solids
UPV	Uniform Prevent Value Factor
UPV*	Non-Uniform Present Value Factor
VFA	Volatile Fatty Acids
VS	Volatile Solids
WAS	Waste Activated Sludge
WTE	Waste to Energy

QUARTERLY REPORT #1

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

PERFORMANCE PERIOD: January 1, 2017-March 31, 2017

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INTRODUCTION AND OBJECTIVES

Energy recovery from municipal solid waste (MSW) is commonly practiced in the US by collecting and utilizing landfill gas for heat, vehicle fuel or conversion to electricity using internal combustion engines or turbines. The most common strategy in the US for enhancing landfill gas production is through recirculation of leachate through the entire waste stream. Many landfills in Europe; however, separate the organic fraction of MSW (OFMSW) for energy recovery through anaerobic digestion (AD). This promotes faster OFMSW degradation, a higher biogas quality based on methane (CH_4) composition, lower fugitive greenhouse gas (GHG) emissions and production of a nutrient rich compost (also called digestate) that can be used as a fertilizer. Depending on the total solids (TS) concentration of the substrate, anaerobic digestion can be applied under wet (≤ 10% TS), semi-dry (11-19% TS) or high solids (≥20%TS) conditions. Advantages of High Solids AD (HS-AD; also known as solid-state AD [SS-AD] or dry fermentation) include lower parasitic energy losses, reduced water use and leachate production and recovery of nutrients as a compost product (Hinds et al., 2017).

The overall goal of this project is to improve the environmental and economic sustainability of HS-AD of OFMSW in Florida. Specific objectives for Phase II (Fig. 1) are to:

1. Investigate the performance of HS-AD of OFMSW with varying substrate ratios (green waste [GW], food waste [FW], biosolids) and temperatures (35, 55 °C).
2. Apply life cycle assessment (LCA) to guide the selection of waste sources and operating conditions for HS-AD and
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 substrate and temperatures

Experimental set up: Biochemical Methane Potential (BMP) Assays were set up as described in Hinds *et al.* (2016). As shown in Table 1, different mixtures were used to test the effects of biosolids (B) and alkalinity sources (crushed oyster shells and limestone) addition on the performance of HS-AD of FW and GW. For each experimental condition, seven replicate reactors were run in 250-ml serum bottles at a constant mesophilic temperature of 35°C. Blanks containing only seed sludge and controls containing the experimental mixtures FW+GW and FW+GW+B with seed sludge and without any alkalinity sources were run in 100-ml serum bottles in triplicate. Blank BMPs were used to track the CH_4 production from the inoculum (determine an inoculum baseline for the experiment), and the controls were digested to determine baseline for the experiment with no alkalinity.

The study inoculum consisted of dewatered anaerobically digested sludge from the Northeast Clearwater Treatment Facility in Clearwater, Florida. FW waste was prepared as described by Ariunbaatar *et al.* (2014) and consisted of: apples, banana peels, oranges, mixed greens, carrots, egg shells, hard boiled eggs, bread, potatoes, and cooked chicken. GW was based on the typical composition of GW in Florida and contained: oak tree leaves, pine needles, grass, and shrubbery cuttings. Biosolids consisted of dewatered (via screw press) waste activated sludge (WAS) from the Falkenburg Advanced Wastewater Treatment Plant in Tampa, FL. The equivalent amount of crushed oyster shells and limestone were added to the reactors provided an alkalinity of 3,000 mg/L (as Calcium Carbonate ($CaCO_3$)).

Table 1. Experimental set up based on volatile solids (VS).

Mixture	Alkalinity Source	FW (g VS)	GW (g VS)	Biosolids (g VS)	Inoculum (I) (g VS)	S/I Ratio
FW+GW	-	1.2	1.0	0.0	1.2	1.8
FW+GW+B	-	1.2	1.0	1.0	1.2	2.7
FW+GW	Oyster Shells	3.5	3.0	0.0	3.5	1.8
FW+GW+B	Oyster Shells	3.5	3.0	3.1	3.5	2.7
FW+GW	Limestone	3.5	3.0	0.0	3.5	1.8
FW+GW+B	Limestone	3.5	3.0	3.1	3.5	2.7
Seed Sludge (Blank)	-	0.0	0.0	0.0	1.6	N

Analytical Methods: Biogas was initially collected on a daily basis from the headspace of each digestion bottle, but was collected less frequently as biogas production rates decreased. Biogas volume was determined using a 50-ml frictionless syringe. The CH_4 content of the biogas was measured using the sodium hydroxide (NaOH) displacement method as described by the American Society for Testing and Materials, ASTM (2002). BMPs were sacrificed periodically and the following chemical parameters of the leachate were analyzed using *Standard Methods* (APHA 2012): pH, alkalinity, TS, and VS. Leachate ammonium (NH_4^+) was analyzed using a Timberline Model TL-2800 Ammonia Analyzer (Boulder, CO, USA). Volatile fatty acids (VFAs) were measured using Hach test kit 10240 (Loveland, CO, USA); VFA values are reported as the equivalent amount of acetic acid. The CH_4 yield was calculated by subtracting the CH_4 produced by the blank (or inoculum) from the total cumulative CH_4 production from the BMP and then dividing that number by the substrate grams g VS from the BMP (see Eq. 1 below). CH_4 yield values were adjusted to standard temperature and pressure (STP, 273.2 K and 101.3 kPa).

$$Methane\ Yield = \frac{BMP\ mL\ CH_4 - \left[Blank\ mL\ CH_4 \times \left(\frac{SS\ BMP\ g\ VS}{SS\ Blank\ g\ VS}\right)\right]}{Total\ BMP\ g\ VS - SS\ BMP\ g\ VS} \quad \text{(Eq. 1)}$$

In this equation, *BMP mL* CH_4 is the total volume of CH_4 produced by the BMP, *Blank mL* CH_4 is the total volume of CH_4 produced by the blank, *SS BMP g VS* is the volatile solids mass of the BMP's seed sludge, *SS Blank g VS* is the volatile solids mass of the Blank's seed sludge, and *Total BMP g VS* is the volatile solids mass of the entire BMP reactor.

BMP Assay Results: A comparison of CH_4 yields for FW+GW with and without biosolids is shown in Figure 1. CH_4 yields were lower when biosolids were added to FW and GW. This may have been due to the recalcitrance of the WAS under mesophilic digestion conditions or differences in substrate to inoculum ratios (S/I) and TS concentrations used in BMPs with and without biosolids (Tables 1 & 2). The organic carbon in biosolids consists of two parts that differ in their degree of biodegradability: a labile fraction (53-71%) that can be quickly mineralized and a recalcitrant fraction (29-45%) that is not available or resistant to microorganisms (Torri *et al.*, 2014; Walton *et al.*, 2001). In addition, S/I and TS greatly affect BMP performance. BMPs with higher S/I ratios or TS require longer retention times to produce as much CH_4 as reactors with lower S/I ratios or TS (González-Fernández and García-Encina, 2009). Additional experiments with greater control over S/I ratio and initial TS concentrations are currently underway to eliminate these confounding factors. CH_4 yield results observed in this study (Table 3) are comparable to those achieved in prior studies for HS-AD of FW+GW (Chen *et al.*, 2014) and OFMSW and biosolids (Zhang *et al.*, 2008).

As expected, NH_4^+ concentrations increased and VS concentrations decreased over time as organic matter degraded (Table 2). NH_4^+ concentrations were not found to be in the toxic range (1,500-1,700 mg/L) for AD in any of the digestion sets (Gerardi, 2003). NH_4^+ release was higher in digestion sets with biosolids addition due to the higher nitrogen content of the WAS compared with FW+GW. This results in a compost product in the solid phase with higher total nitrogen content, potentially making it more valuable as a fertilizer. In addition, if the biosolids were treated in a liquid anaerobic (L-AD) system the resulting sidestream would need to be treated in a sidestream process or recycled back to the headworks resulting in high energy and chemical costs and potentially disrupting the mainstream treatment process. VS concentrations were reduced by an average of 3.6%, with the greatest VS reduction in FW+GW+B with OS (4.7%).

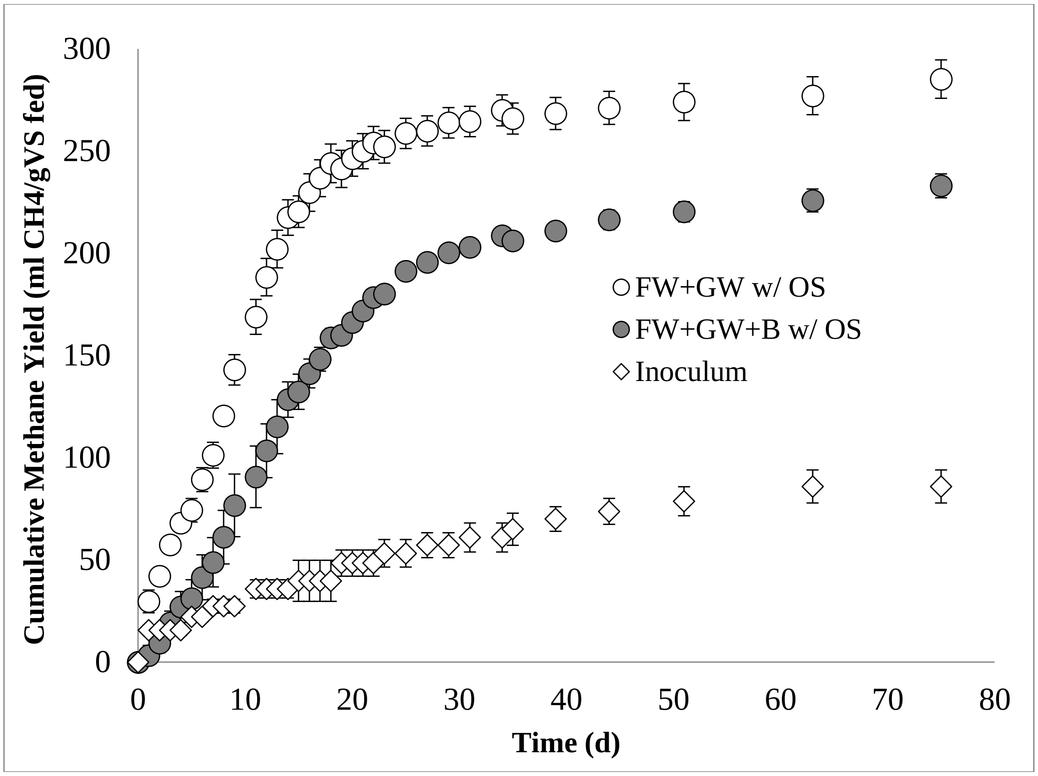

Figure 1. Cumulative CH_4 yields for FW and GW with OS and with and without biosolids.

Table 2. TS, VS, and NH_4^+-N of BMP assays.

Mixture	**TS (%)**		**VS (%)**		**NH_4^+-N (mg/L)**	
	D_0	**D_{43}**	**D_0**	**D_{43}**	**D_0**	**D_{43}**
FW+GW	12.5 (±0.0088)	NS	10.3 (±0.011)	NS	110	NS
FW+GW+B	13.2 (±0.0076)	NS	11.0 (±0.0080)	NS	120	NS
OS FW+GW	12.3 (±0.0051)	10.8 (±0.014)	10.1 (±0.0066)	7.71 (±0.0067)	110	490 (±0.12)
OS FW+GW+B	13.5 (±0.0037)	9.40 (±0.0068)	11.2 (±0.0035)	6.47 (±0.0021)	130	570 (±18)
L FW+GW	13.0 (±0.016)	9.17 (±0.00024)	10.5 (±0.018)	6.60 (±0.00015)	110	440 (±3.5)
L FW+GW+B	13.3 (±0.0057)	10.3 (±0.0018)	10.8 (±0.0037)	7.62 (±0.00042)	120	540 (±1.5)

VFA concentrations were found to be similar between digestion sets (Table 3). It was found that all sets maintained VFA concentrations much below levels considered inhibitory to methanogenesis (>10,000 mg/L) (Khanal, 2011). pH and alkalinity in all HS-AD digestion sets were also maintained at levels appropriate for methanogenesis (pH>6.5 and alkalinity>1,000 mg/L as $CaCO_3$) (Metcalf and Eddy, 2013). Alkalinity was found to be higher for the sets with biosolids addition (Table 3). CH_4 yields were significantly higher when an alkalinity source was added, with no significant differences between lime and crushed oyster shells (Figure 2). This may have been because of VFA production and localized alkalinity imbalances within microniches in the reactor due to incomplete mixing (Veeken and Hamelers, 2000), but requires more research to determine. The main advantages of adding biosolids in HS-AD are increased overall bioenergy production, recovery of nutrients and diversion of biosolids from land application or landfilling, which are discussed further in the life cycle cost assessment (LCCA) results.

Table 3. VFA, pH, alkalinity and CH_4 yields of BMP assays.

Mixture	**VFA (mg/L)**		**pH**		**Alkalinity (mg/L)**		**CH_4 (ml CH_4/g VS)**
	D_0	**D_{44}**	**D_0**	**D_{43}**	**D_0**	**D_{43}**	**D_{44}**
FW+GW	160 (±2.8)	NS	7.4 (±0.099)	NS	510 (±49)	NS	266 (±15)
FW+GW+B	110 (±2.8)	NS	7.3 (±0.064)	NS	660 (±85)	NS	184(±6.0)
OS FW+GW	180 (±11)	100 (±4.2)	7.4 (±0.15)	8.3 (±0.0)	770 (±350)	2,100 (±16)	271 (±8.0)
OS FW+GW+B	180 (±1.4)	110 (±4.9)	7.2 (±0.028)	8.4 (±0.014)	870 (±330)	2,400 (±18)	216 (±4.8)
L FW+GW	140 (±2.8)	90 (±0.14)	7.4 (±0.17)	8.3 (±0.0)	700 (±190)	1,900 (±7.1)	241 (±15)
L FW+GW+B	160 (±71)	110 (±1.4)	7.4 (±.14)	8.4 (±0.0)	580 (±88)	2,200 (±0.0)	225 (±4.5)

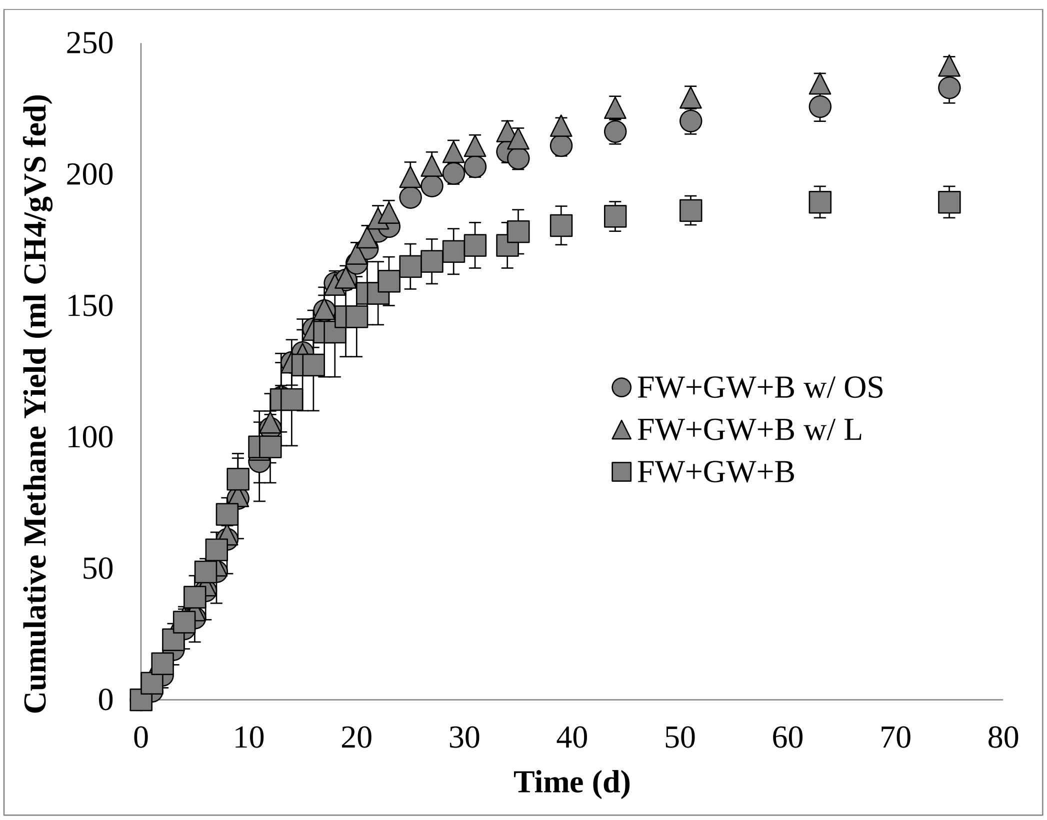

Figure 2. Cumulative CH_4 Yield for FW+GW+B w/ OS and Limestone as Alkalinity Sources**.**

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

Economic analysis: LCCA were conducted for full-scale HS-AD scenarios with varying biosolids addition and alkalinity sources using the present value (PV) method. The scenarios for this study were as follows: 1) FW and GW with oyster shells (FW+GW w/OS), 2) FW, GW, and biosolids with no additional alkalinity source (FW+GW+B), 3) FW, GW, and biosolids with oyster shells (FW+GW+B w/OS), and 4) FW, GW, and biosolids with limestone (FW+GW+B w/L). The LCCA included infrastructure, operation and maintenance (O&M), collection and transportation (C&T) costs, and revenues from beneficial products including electricity, heat, and digestate. The life cycle cost (LCC) was computed as follows:

$$LCC = C_I + C_{O\&M} \times UPV^* + C_{C\&T} \times UPV - (C_{R,t\&d\&h} \times UPV + C_{R,e} \times UPV^*) \text{ (Eq. 2)}$$

where C_I is the initial cost, $C_{O\&M}$ is the O&M cost, $C_{C\&T}$ is the C&T cost, $C_{R,t\&d\&h}$ are the revenues from tipping fee saving and digestate and heat sales, $C_{R,e}$ is the revenue from electricity sale, UPV is a uniform present value factor, and UPV* is a non-uniform present value factor. The discount or interest rate and the escalation rate used to calculate UPV and UPV* were assumed to be 1.9% (the average rate for 10 years) and 0.65%, respectively (EERC, 2017; USIR, 2017).

In this analysis, the available amount of the wastes were estimated based on the waste production from Hillsborough County in Florida. Figure 3 shows a production and management flow diagram for FW, GW, and biosolids in 2015 for Hillsborough County. In 2015, 100% of the FW and 39% of the GW was used in the county's resource recovery facility (incineration Waste to Energy) to generate electricity, while 56%, 1.4%, and 3.3% of the GW were used in mulch/organic soil production, composting, and landfill cover, respectively. Wastewater treatment facilities in the county produced 128,000 tons of biosolids and 81% were disposed in landfills in 2015. To estimate the total amount of organic wastes available for HS-AD, it was assumed that 40% of the produced commercial FW (37,700 tons/yr) was diverted from the current waste flow to the HS-AD resulting in a mixture ratio of FW, GW, and biosolids of 1.0:1.0:1.2 by TS. The residential FW was not considered in this analysis since there is no separate collection system for residential FW in Hillsborough County. The total amount of organic wastes for this analysis was approximately 113,000 tons/yr. For HS-AD using FW and GW, the same amount of organic wastes (a mixture ratio of FW and GW as 1:1 by TS) was used, which accounted for 60% of the produced commercial FW (56,600 tons/yr).

The HS-AD system was assumed to have the same configuration as a BIOFerm Dry Fermentation system, which is a mesophilic, batch, and single-stage technology (BIOFerm, n.d.). The system is comprised of garage style fermenters, a percolation tank, biogas storage tank, biofilter, and combined heat and power (CHP) unit. It was assumed that the operating conditions for the HS-AD system were the same as the experimental conditions with a 28-day retention time. The initial cost was estimated based on the data obtained from current installations of BIOFerm and existing literature (BIOFerm, n.d.; ILSR, 2010; Strimbu, 2016; Vavrin *et al.*, 2014). Figure 4 shows the capital costs as a function of the operating capacity for existing BIOFerm systems in the US. The HS-AD capital cost was estimated based on a regression model shown in Figure 4. The O&M cost covers the costs for all O&M activities, including processing feedstock, labor, and chemical use. Table 4 shows the existing data for O&M costs in U.S. ranging from $34 to $72 per ton. To be conservative, an O&M cost of $72/ton (Vavrin *et al.* 2014) was used in this study. The C&T cost for the wastes was $0.10/mile/ton, which was based on Faucette *et al.* (2002). Transportation vehicles were assumed to have a haul loading of 30-tons, with an average travel distance of 50-miles round trip (Faucette *et al.* 2002). The cost of the oyster shells was assumed to be zero because they were considered as wastes from local processing industries, while the cost of limestone was $0.2/kg. Since, small amounts of oyster shells and limestone were used in the HS-AD, transportation costs of these materials were not considered in this analysis.

A sensitivity analysis was conducted to determine how changes in input parameters impact the LCC results. For this study, the following input parameters were modified by ±10% and the LCC values were recalculated: amount of organic wastes, travel distance, tipping fee, and electricity, heat, and digestate sale prices. The sensitivity index (*I*) was calculated as follows:

$$I = \frac{(LCC_{i+1} - LCC_{i-1})/LCC_i}{(F_{i+1} - F_{i-1})/F_i} \qquad \text{(Eq. 3)}$$

where LCC_{i+1}, LCC_i, and LCC_{i-1} are the LCC associated with ±10% input parameter changes, and F_{i+1}, F_i, and F_{i-1} are input parameters for i+1 (10% increasing parameters), i (base parameters), and i-1 (10% decreasing parameters). The parameters used for the LCCA are shown in Table 5.

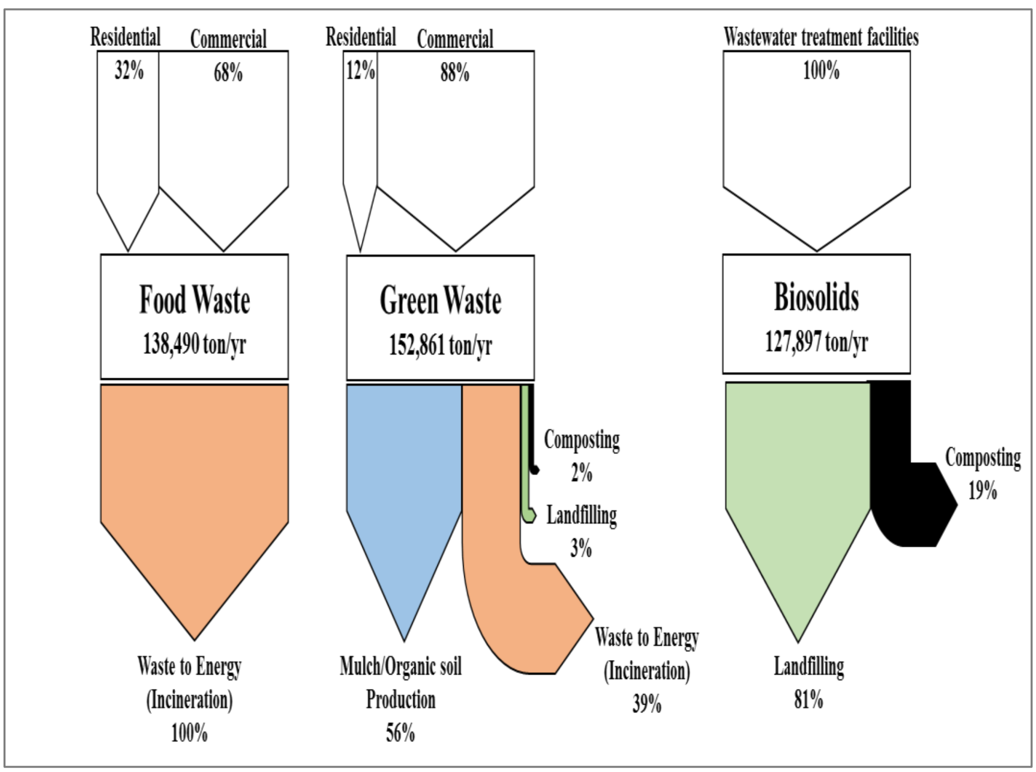

Figure 3. Production and management flow diagram of FW, GW, and biosolids.

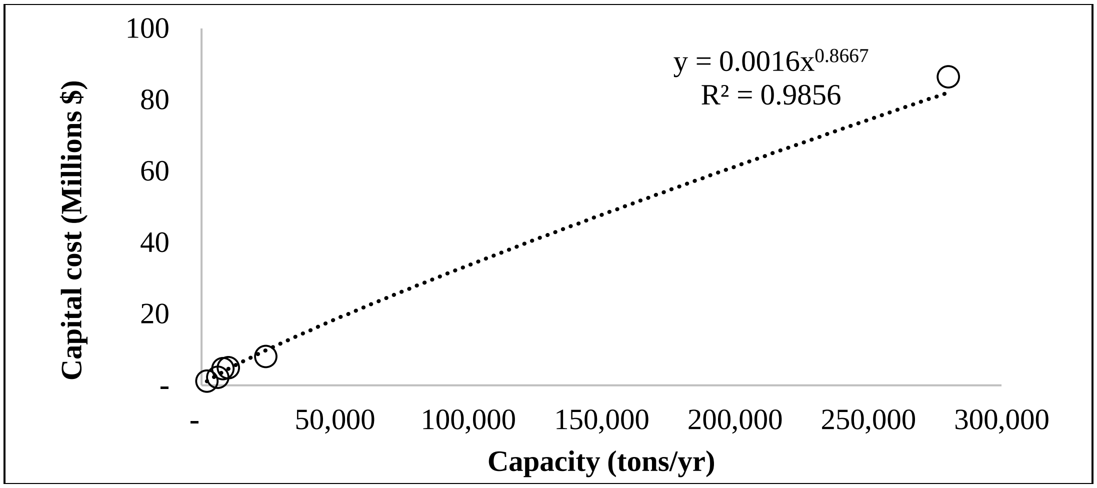

Figure 4. Capital Costs for the BIOFerm Systems in the US (Circle: Capital Costs Obtained from Literature; Dashed Line: A Regression Model Curve)

Table 4. Annual O&M costs for HS-AD in the US.

O&M cost ($/ton of Feedstock)	References
37.00	HWMA, 2010
40-55	ILSR, 2010
34.00	ILSR, 2010
72.00	Vavrin *et al.*, 2014

Table 5. Input parameters for LCCA.

Input	Value	References
Discount or Interest Rate (%)	1.9	USIR, 2017
Escalation Rate (%)	0.65	EERC, 2017
Average Hauling Distance (miles)	50	Assumed
C & T Rate ($/mile/ton)	0.1	Faucette et al., 2002
Tipping Fee ($/ton)	31	Hillsborough County, 2015
Limestone ($/kg)	0.2	USGS, 2014
Limestone Consumption (kg/ton organic wastes)	109	Obtained from our experiments
Oyster Shells ($/kg)	0	Assumed
Oyster Shells Consumption (kg/ton organic wastes)	82	Obtained from our experiments
Heating Value (kWh/m3)	9.94	Passos and Ferrer, 2015
Combined Heat and Power Efficiency: Heat (%) Electricity (%)	49.5 37.3	BIOFerm, n.d.
Electricity Rate ($/kWh)	0.08	EIA, 2016
Heat Rate ($/kWh)	0.01	Moriarty, 2013
Digestate Price ($/ton)	11.2	Schwarzenegger, 2010
Life cycle Cost Analysis Period (yr)	25	Assumed

Result of Economic Analysis: LCCA results for four different digestion options over 25 years are shown in Table 6. The largest revenue was generated from sale of electricity for all the digestion options, followed by heat and digestate sale. All options would save tipping costs for landfilling of GW and biosolids. The tipping fee for 3% of the GW (5,000 tons/yr) could be saved for HS-AD using FW+GW w/OS, while the other digestion options were able to save the tipping fee associated with 3% of the GW (5,000 tons/yr) as well as 35% of the biosolids (45,300 tons/yr). The C&T costs were not significant in the LCC results (< 5%), while the O&M costs were the largest contributor to the LCCs for all digestion options. For HS-AD using FW+GW+B w/L, the O&M cost was the highest among others due to the use of limestone (109 kg/ton organic wastes). Considering HS-AD using FW+GW w/OS and FW+GW+B w/OS, addition of biosolids was able to achieve higher revenues due to the increased CH_4 production and digestate quantities, as well as the avoided tipping cost for biosolids landfilling. For the three options, including FW+GW+B, FW+GW+B w/OS, and FW+GW+B w/L, the annual revenues greatly exceeded the sum of the initial and O&M costs, making the systems economically feasible. The most economical option was HS-AD using FW+GW+B w/OS due to its high CH_4 production.

Overall, annual O&M costs were significant when determining economic feasibility of the systems (shown in Figure 5). For instance, all digestion options were economically feasible when an annual O&M cost with $35/ton was applied. Considering the annual O&M cost of $72/ton, however, only the FW+GW w/OS option was not economically feasible. Thus, the LCC results can be sensitive to the annual O&M cost. The result of the sensitivity analysis is shown in Table 7. The results show that HS-AD using FW+GW+B is more sensitive to changes in all tested input parameters among the others. The travel distance had a minimal impact on the LCCs. The LCCs are more sensitive to electricity cost and amount of organic waste; the electricity cost is directly related to revenue for electricity sale, while the amount of organic wastes is closely related to the initial and O&M costs as well as revenues for electricity and heat sales.

Table 6. LCC for HS-AD options.

Item	**Option 1($)**	**Option 2 ($)**	**Option 3 ($)**	**Option 4 ($)**
Composition	FW+GW w/ OS	FW+GW+B	FW+GW+B w/ OS	FW+GW+B w/ L
Initial cost	38,410,000	38,410,000	38,410,000	38,410,000
O&M cost	174,526,000	174,526,000	174,526,000	204,273,000
C&T cost	373,000	373,000	373,000	373,000
Tipping fee saving	3,066,000	30,839,000	30,839,000	30,839,000
Electricity sale	145,430,000	142,118,000	157,261,000	173,139,000
Heat sale	19,638,000	19,190,000	21,235,000	23,379,000
Digestate sale	21,925,000	21,925,000	22,376,000	22,226,000
LCC	23,251,000	-763,000	-18,403,000	-6,526,000
LCC/1,000 tons organic wastes	205,000	-7,000	-163,000	-58,000

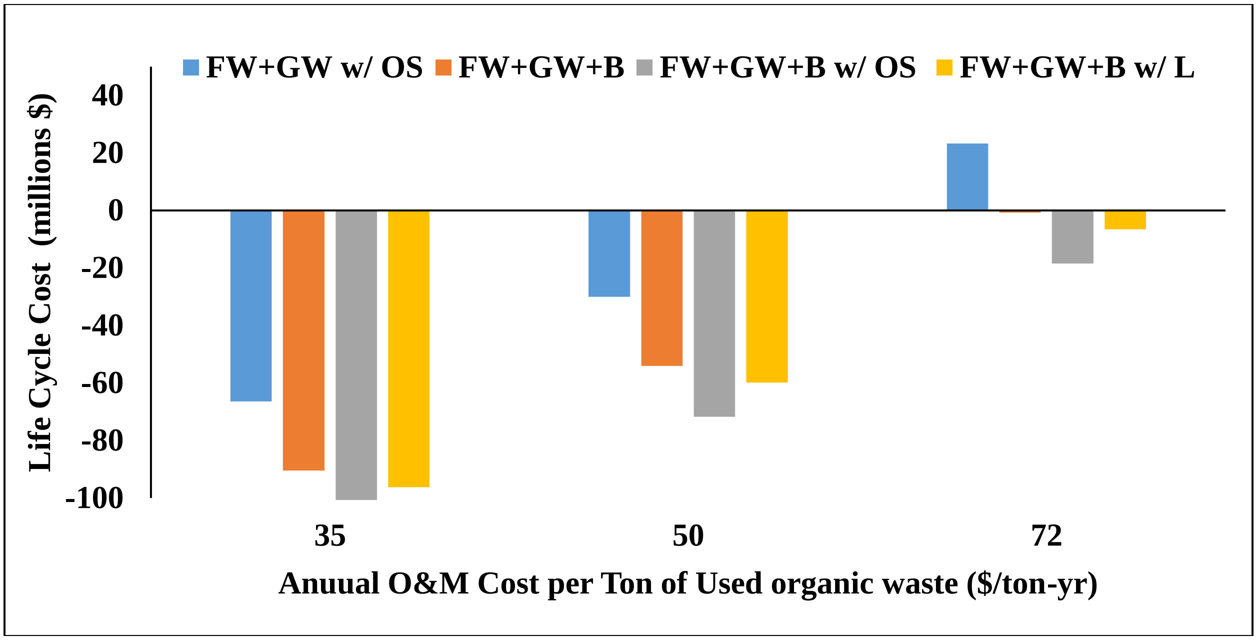

Figure 5. LCC as a Function of Annual O&M Cost per Ton of Organic Waste Used in the HS-AD with the Four Considered Digestion Options.

Table 7. Results of sensitivity analysis for different HS-AD options.

Item	**Option 1($)**	**Option 2 ($)**	**Option 3 ($)**	**Option 4 ($)**
Composition	FW+GW w/ OS	FW+GW+B	FW+GW+B w/ OS	FW+GW+B w/ L
Amount of organic waste	8.01	-244.13	-10.10	-33.06
Travel Distance	0.02	-0.48	-0.02	-0.057
Electricity sale cost	-6.25	186.26	8.55	26.53
Heat sale cost	-0.84	25.07	1.15	3.57
Digestate sale cost	0.94	-28.74	-1.22	-3.41
Tipping cost	-0.13	40.42	1.68	4.73

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

No progress was made on objective 3 during the first quarter.

DISSEMINATION ACTIVITIES

1. Oral presentation at WEF Residuals and Biosolids conference in Seattle, WA. April 11th, 2017.
2. Oral presentation at 1st International ABWET Conference Waste-to-Bioenergy 2017 in Paris, France. January 9th, 2017.
3. Poster presentation at Florida Water Resources Conference 2017 (FWRC) in West Palm Beach, FL. April 24th, 2017.
4. Poster Presentation at the USF Undergraduate Research and Arts Colloquium. April 6, 2017.
5. Outreach activity on HS-AD of food waste during USF's Engineering Expo, February 17th and 18th 2017.

METRICS

1. List graduate student or 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	PhD Student	Civil/ Environmental Engineering	Zhang	USF
Wang, Meng	Postdoctoral Researcher	Civil/ Environmental Engineering	Ergas	USF

2. List 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

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

- No peer reviewed publications have resulted from this project thus far from this project.

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

	Authors/Title	Conference/Date
1	P. Dixon, P. Bittencourt, E. Lee, M. Wang, E. Jimenez, Q. Zhang, S.J. Ergas. Effects of Biosolids Addition and Alkalinity Sources on High-Solids Anaerobic co-Digestion (HS-AcD) of Food Waste and Green Waste	WEF Residuals and Biosolids Conference, Seattle WA April 11, 2017
2	P. Dixon, P. Bittencourt, N. Anferova, P. Jenicek, J. Bartacek, M. Wang, S.J. Ergas. Effects of Biosolids Addition, Microaeration, and Alkalinity Sources on High-Solids Anaerobic Co-digestion (HS-AcD) of Food Waste and Green Waste	1st International ABWET Conference Waste-to-Bioenergy 2017, Paris, France, January 9th, 2017
3	Phillip Dixon, Paula Bittencourt, Eduardo Jimenez, Dr. Meng Wang, Eunyoung Lee, Dr. Qiong Zhang, and Dr. Sarina Ergas. Alkalinity and Temperature Effects on Methane (CH_4) Yield in High-Solids Anaerobic co-Digestion (HS-AcD)	Florida Water Resources Conference (FWRC), West Palm Beach FL, April 24th, 2017
4	*P. Bittencourt, E. Jimenez, P. Dixon, M. Wang, and S. J. Ergas. Effects of Alkalinity and Temperature on High-Solids Anaerobic co-Digestion	University of South Florida Undergraduate Research Colloquium, April 6, 2017

*Paula Bittencourt and Eduardo Jimenez won the Undergraduate Excellence in Research Awards at the 2017 USF Undergraduate Research and Arts Colloquium.

5. List 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 Environmental Research and Education Foundation (EREF) on the topic of "Enhanced Bioenergy Production from Lignocellulosic Wastes." Drs. Ergas, Zhang and Scott are co-PIs and the proposal is currently under review.

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

- Melissa Madden of FDEP joined our TAG (see below).

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 been in discussion with Beth Schinella and other stakeholders in Hillsborough County about the potential for piloting this technology for bioenergy recovery and treatment of MSW and biosolids from their South Central service area.

TAG MEMBERS

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TAG MEETING

The first TAG meeting was held on March 28, 2017. After the discussion, TAG members that attended in person were given a tour of the lab facilities where the laboratory-scale experiments were set up.

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