Bioenergy Production from MSW by Solids State Anaerobic Digestion
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Report # 3

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Abbreviations, Acronyms, and Units of Measurement

MSW - Municipal Solid Waste
OFMSW - Organic Fraction of Municipal Solid Waste
SS-AD - Solids State Anaerobic Digestion
P&P - Pulp and Paper Mill Anaerobic Digester
AD – Wastewater Treatment Plant Anaerobic Digester
BMP – Biochemical Methane Potential
TS - Total Solids
VS – Volatile Solids
SGEF - Student Green Energy Fund

Quarterly Progress Report

February 18, 2015 - May 17, 2015

PROJECT TITLE: Bioenergy Production from MSW by Solid-State Anaerobic Digestion

PRINCIPAL INVESTIGATOR(S): Dr. Sarina Ergas and Dr. Daniel Yeh

AFFILIATION: University of South Florida

COMPLETION DATE: August 17, 2015 **PHONE NUMBER:** 813-974-1119

PROJECT WEB SITE: http://mbr.eng.usf.edu/yardwaste/

Work accomplished during this reporting period:

During the third quarter of this Hinkley Center Project, progress on the following tasks was accomplished: 1) literature review, 2) industry survey, 3) bench-scale studies 4) pilot-scale studies and 4) results dissemination. Progress has been made in all subsections of the project, additional partnerships have been developed and two different works for publication are being prepared. Two graduate students, two undergraduates and one postdoctoral researcher have worked on the project.

Literature Review: The literature review has been extended based on the following objectives:

- Understanding the economic and environmental implications of SS-AD relative to other management strategies for the Organic Fraction of Municipal Solid Waste (OFMSW).
- Research questions and methodology have been refined for the second and third bench-scale studies and the first pilot-scale study.

Industry Survey: The industry survey has been extended based on the following objectives:

- Determining of potential OFMSW sources for use as SS-AD feedstock.
- Identifying existing infrastructure in Florida for processing OFMSW.
- Determination of potential sites, partners, and funding sources for a demonstration of SS-AD in Florida.
- Identifying the most appropriate SS-AD technology for a demonstration in Florida.
- Estimating energy production potential from OFMSW through SS-AD in Florida.
- Visits to four SS-AD facilities in California.

Facility Visits: Four SS-AD facilities were visited in California by graduate research assistant, Greg Hinds, during early May, three full-scale facilities and one pilot-scale facility. Two of the full-scale facilities (Monterey and San Jose) were designed by Zero Waste Energy and were functioning as designed with high efficiency and only minor challenges. The systems utilize SmartFerm technology, a technology originally developed in Germany. The third full-scale facility (UC Davis) was designed by CleanWorld, a Sacramento based

company that developed and patented the unique three-phase AD technology. The technology being used at the UC Davis facility has had some unforeseen challenges. Personnel from both companies mentioned the economic challenges associated with SS-AD of OFMSW, stating that legislative incentives and government grants have been necessary for project success. The fourth visit was to a pilot project at the Yolo County Central Landfill. The project, being led by Ramin Yazdani, is investigating the possibility of batch SS-AD within lined 'cells' on top of or alongside landfills. OFMSW can be separated and processed in these cells without significant additional investments or changes in waste haulers regimes. The cell-type digesters incorporate leachate recirculation, have long retention times (minimal space limitations and existing biogas infrastructure allow for long digestion cycles and full biodegradation), employ leachate pumps to force air through the cells after digestion (minimize post processing requirements), and include a biofilter as the top layer of the cell to remove odors during the final aerobic phase. The concept is promising for many applications. Results of the study are expected to be published within the year.

Bench Scale Experiments: Two rounds of bench scale experiments have been carried out and plans are under development for a third round of experiments.

Bench Experiment 1: The results of the first bench-scale experiment were described in the second quarterly. Briefly, the goal of this study was to quantify the effects of bioaugmentation with pulp and paper mill sludge (P&P sludge) on the Biochemical Methane Potential (BMP) of yard waste. Some challenges were encountered during this study and the results were inconclusive. Experience was gained in conducting BMP assays.

Bench-Scale Experiment 2: In the second study, digester compositions (Figure 1) were modified, digesters with autoclaved inocula were added as controls (to isolate the effects of the nutrients and the microbes present in the two different inoculums), the method used to measure methane production was changed to minimize error, additional replicate digesters were set up (for intermediate sacrifice), and a smaller particle size (2 sq. mm.) was used to improve the homogeneity of the yard waste to further minimize error. The substrate (yard waste) used in the second experiment and the sieving processes for standardizing the particle size are shown in Figure 2.

As shown in Figure 3, after subtracting methane production from the blanks, methane production from digesters inoculated with P&P sludge was significantly higher than that of the digesters inoculated with AD sludge (45% enhancement). This enhancement is comparable to the enhancement reported in prior SS-AD pretreatment studies, using physical, chemical, thermal, microbial pretreatment methods. A long lag period was observed in the control digesters followed by a high gas production rate. This may have been due to inadequate sterilization of controls. The methane production from both inoculated digesters (D1 and D2) is much greater than that of the un-inoculated digesters (C*), as expected. Preliminary chemical analysis also indicates that the hydrolysis rate in digesters inoculated with P&P sludge is greater than in the other digesters.

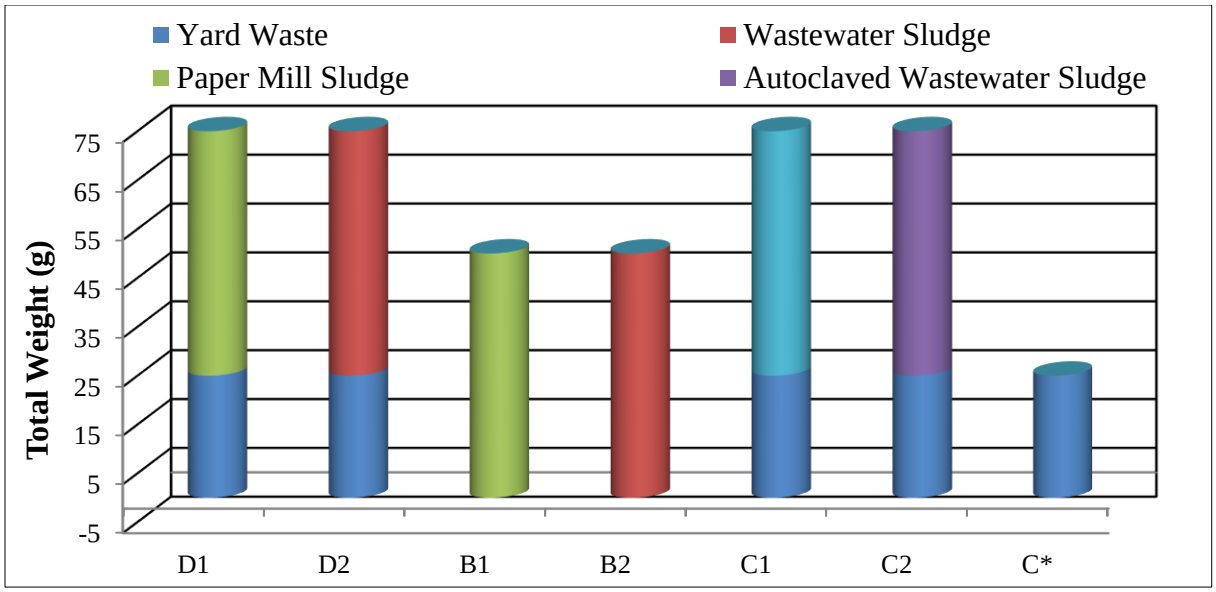


Figure 1: Bench-scale study 2 digester compositions.


Figure 2: Yard waste source at USF Botanical Gardens, pre-sieve, sieving and, and post sieved.

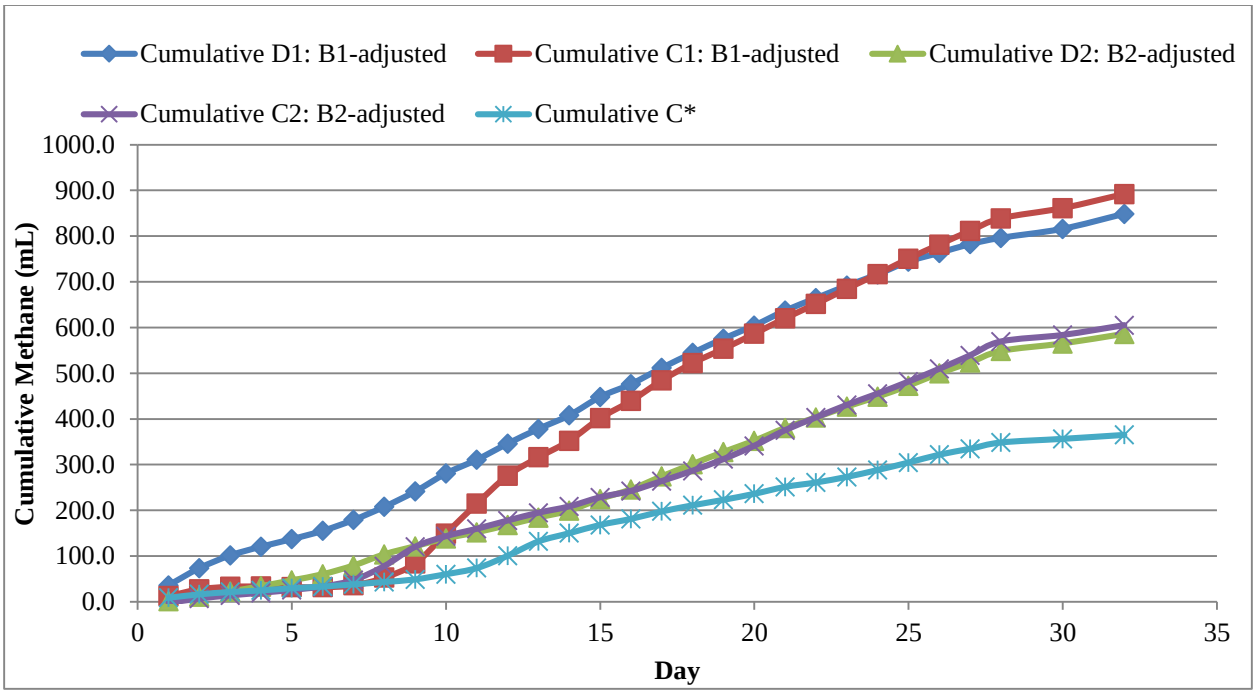
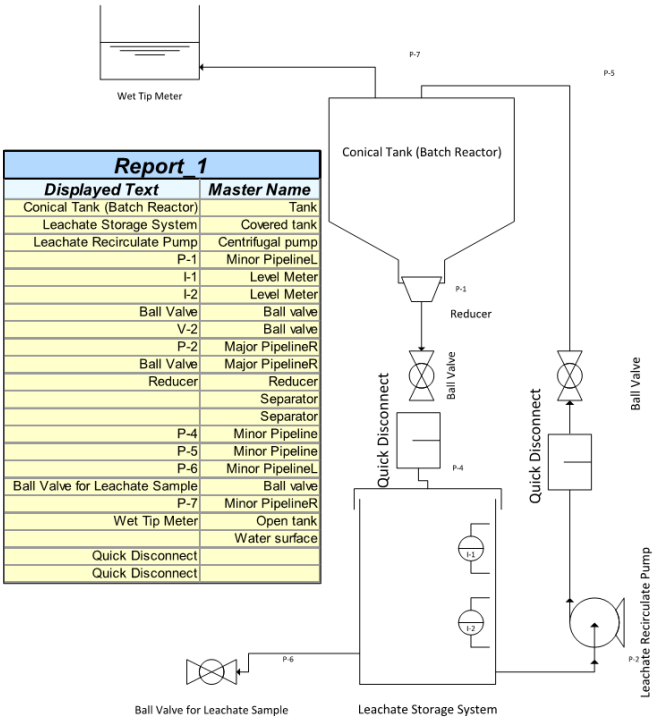


Figure 3: Cumulative methane production from bench scale study 2 digesters.

Pilot-scale Experiments: A pilot scale reactor was constructed and experiments are currently being carried out in this reactor.

Pilot Reactor: During the third quarterly period, the construction of the pilot reactor system was completed and first pilot-scale experiment was initiated. The experiment is a scaled-up version of the D2 digesters of the second bench-scale study (yard waste with AD sludge). The pilot system was designed to recirculate leachate produced from the breakdown of the waste. A process flow diagram (Figure 4) and photograph of the pilot reactor (Figure 5) is shown below. The pilot study is being performed in a constant temperature room (35 ^{o}C), though the system is equipped with necessary devices for operation in other locations during demonstrations.



Report_1	
Displayed Text	**Master Name**
Conical Tank (Batch Reactor)	Tank
Leachate Storage System	Covered tank
Leachate Recirculate Pump	Centrifugal pump
P-1	Minor PipelineL
I-1	Level Meter
I-2	Level Meter
Ball Valve	Ball valve
V-2	Ball valve
P-2	Major PipelineR
Ball Valve	Major PipelineR
Reducer	Reducer
	Separator
	Separator
P-4	Minor Pipeline
P-5	Minor Pipeline
P-6	Minor PipelineL
Ball Valve for Leachate Sample	Ball valve
P-7	Minor PipelineR
Wet Tip Meter	Open tank
	Water surface
Quick Disconnect	
Quick Disconnect	

Figure 4: Process flow diagram for the pilot system.

Figure 5: Pilot system

Information Dissemination Activities:

- Poster Presentation at AEESP Distinguished Lecture Series in Orlando. February 27th, 2015.
- Publication of Article describing SS-AD and the ongoing research at USF in *Talking Trash*, Florida Section of SWANA, Spring Newsletter. March 27, 2015.
- Poster Presentation at the USF Graduate Research Symposium. March 10, 2015.
- Poster Presentation at the USF Undergraduate Research and Arts Colloquium. April 9, 2015.
- Meeting and discussion of research project and preliminary results with industry professionals. May 4-8, 2015.

Metrics:

1. List graduate student or postdoctoral researchers **funded** by **THIS** Hinkley Center project

Last name, first name	Rank	Department	Professor	Institution
Hinds, Gregory	Masters Student	Civil/ Environmental Engineering	Dr. Sarina Ergas	University of South Florida
Dick, George	Masters Student	Civil/ Environmental Engineering	Dr. Daniel Yeh	University of South Florida
Meng Wang	Postdoctoral Researcher	Civil/ Environmental Engineering	Dr. Sarina Ergas	University of South Florida

2. List undergraduate researchers working on this Hinkley Center project

Ariane Rosario
Department: Civil & Environmental Engineering University of South Florida
Professor: Dr, Sarina Ergas
Institution: University of South Florida

Lensey Casimer
Department: Civil & Environmental Engineering University of South Florida
Professor: Dr. Sarina Ergas
Institution: University of South Florida

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

No peer reviewed publications have resulted from this project thus far. However, one publication in a newsletter has resulted, which can be seen here (http://www.swanafl.org/page-1130432?) and a minimum of two publication are expected during the fourth quarter, one on results of the second bench-scale experiment and the other on economic and environmental implications of

SS-AD in the waste management industry in the US, with a focus on select Florida countries as a case study.

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

Hinds, Gregory. "Bioenergy Production from Municipal Solid Waste through Solid-State Anaerobic Digestion." University of South Florida, College of Engineering Research Day. Tampa, Florida. 19 Nov. 2014.

Hinds, Gregory. "Bioenergy Production from Municipal Solid Waste through Solid-State Anaerobic Digestion." University of Central Florida, AEESP Lecture. Orlando, Florida. 27 Feb. 2015.

Hinds, Gregory. "Enhanced Methane Production from Lignocellulosic Waste in Solid-State Anaerobic Digestion through Bioaugmentation" University of South Florida, Graduate Student Research Symposium. Tampa, Florida. 10 Mar. 2015.

Rosario, Ariane. "Enhanced Methane Production from Lignocellulosic Waste in Solid-State Anaerobic Digestion through Bioaugmentation" University of South Florida, Undergraduate Research and Arts Colloquium. Tampa, Florida. 9 Apr. 2015.

NOTE: Ariane Rosario won the award for Best Poster Presentation at the 2015 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?

- Greg Hinds was partially supported by an NSF funded S-STEM Scholarship during the 2014-2015 academic year.
- Greg Hinds will be partially supported by a USF Foundation Stessel Fellowship in fall 2015. The fellowship gives priority to graduate students in Environmental Engineering with GPA > 3.5 working in the MSW management field.
- Ariane Rosario was partially supported (40%) by funds from the College of Engineering Research Experience for Undergraduates (REU) program.
- Lensey Casimir will be fully supported (100%) by funds from the NSF Tampa Interdisciplinary Environmental Research (TIER) REU program.
- A science teacher from Plant City High School, Matthew Dawley, will work as an intern on this project during the summer of 2015. The teacher will be funded through an NSF Research Experience for Teachers (RET) program.
- An interdisciplinary team of students prepared and submitted a proposal to the USF Student Green Energy Fund (SGEF) to conduct a feasibility study on implementing SS-AD on the USF campus to improve the sustainability of organic waste management at the

university. This proposal was not selected for funding; however, a new interdisciplinary team of eight graduate and undergraduate students is working on a proposal for the next solicitation.

- A proposal was submitted to the Environmental Research and Education Foundation (EREF) on the topic of "Sustainable Bioenergy Production from MSW by Solid State Anaerobic Digestion."
- A team of student conducted a design feasibility study for a SS-AD facility on the USF campus as part of a class in Green Engineering.

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

In the third quarter of this project relationships have been developed with industry professionals from companies and entities including CleanWorld, Zero Waste Energy, Yolo County Central Landfill, Hillsborough County, and the University of Florida. Ramin Yazdani of Yolo County California and Coby Skye of LA County California 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).

At this time, the research has not been used by FDEP and other stakeholders.

TAG members:

Table 1: TAG Members

TAG Member	**Affiliation**	**Title**
Steven G. Morgan	Florida Department of Environmental Protection	Waste Permitting, Environmental Services Section, SW District
Wendy Mussoline	UF, Dept. of Soil & Water Science	Postdoc, Environmental Biotechnology Lab
Juan R. Oquendo	Gresham, Smith, & Partners	Sr. Environmental Engineer & Waste to Energy Leader
Debra R. Reinhart	UCF, Dept. Civil, Environmental & Construction Eng.	Professor & Assistant Vice President
Larry Ruiz	Hillsborough County	Landfill Operations Section Manager
Adrie Veeken	Attero, the Netherlands	Bio-based Products Business Developer
Shawn Veltman	CHA Consultants	Director of Technical Services, Water & Wastewater
Bruce Clark	SCS Engineers	Senior Engineer
Chris Bolyard	Waste Management, Inc	Manager
Ramin Yazdani	Yolo County California	Senior Civil Engineer
Coby Skye	Las Angeles County California	Environmental Programs

TAG meetings:

The first TAG meeting was held on November 6, 2014. After the discussion, TAG members that attended in person were given a tour of the lab facilities in which the initial bench-scale experiments were set up. The second TAG meeting was held on March 11, 2015. TAG members also were able to view lab studies in progress and give feedback on the pilot system before final construction was complete. Larry Ruiz and Bruce Clark came to view the experiments at a later date and give feedback at a later date.