**SUMMARY:**
**BENEFICIAL REUSE SOLUTIONS FOR LANDFILL OPERATIONS AND MANAGEMENT**

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In 2016, the Bill Hinkley Center for Solid and Hazardous Waste Management funded FAU Lab.EES to investigate organic waste diversion from landfills to anaerobic digestion to capitalize on existing anaerobic digester capacity in the wastewater sector. The project will explore the impact of organic waste diversion on landfill gas recovery and landfill economics.

Biogas is produced by wet organic waste decomposing under anaerobic conditions. First the microorganisms break open the cellular substrate in a process known as hydrolysis. Then microorganisms turn those molecules into organic acids, which become the food for the methanogens that produce methane, the energy component of biogas. In a landfill, this biogas builds up and is slowly released into the atmosphere if the site has not been engineered to capture the gas or flared to carbon dioxide from a series of landfill gas (LFG) collection wells. Landfill gas released in an uncontrolled way can be hazardous since it can become explosive when it escapes from the landfill and mixes with oxygen from the air.

In Florida, organic wastes make up 6-20% of the municipal solid waste (MSW) stream, but only 2-5% is diverted from landfills meaning that about 2 million tons per year end up in the landfill. This material has a high moisture content (>70%) and a low heating value (<2500 BTU/lb) compared to MSW without organic waste (~5000 BTU/lb). Therefore, organics are not as desirable for waste-to-energy operations either, but they are ideal for anaerobic digestion. In 2015, there were 1497 anaerobic digesters in the US, of which 83% were being used strictly for wastewater applications.

Recent innovations in co-digestion have unlocked the potential for cleaner biogas (65-75% methane) with only 10% of the digester feed being diverted food waste, tripling the digester biogas output in some cases. Using the total amount of food waste reported for the State of Florida and estimates from Dung et al. (2014), this represents a potential to generate 1829 – 4043 GWh per year, which is equivalent to the energy required to power 321,000 – 710,000 homes (USEPA 2013) or 8% of all of the energy requirements for the State.

However, since food waste is rich in carbon, if a fraction of this material is diverted from the landfill or waste-to-energy stream, it may ultimately impact LFG production and methane content at the solid waste facility. Therefore, we propose to quantify these effects by calibrating the USEPA LFG Emissions Model (LandGEM, Alexander et al. 2005) based on experimental measurements of methane production potential and first order decay rate at different food waste diversion ratios. Using the new data, this study will investigate if we can take advantage of unused anaerobic digester capacity in the wastewater sector to generate more clean biogas from diverted food waste and determine the life cycle cost impact of organic waste diversion programs from the perspective of the solid waste industry and also holistically from the entire waste sector if implemented.

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**PROGRESS REPORT**
(August 2017)

**Project Title: BENEFICIAL REUSE SOLUTIONS FOR LANDFILL OPERATIONS AND MANAGEMENT**

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**Students**: Rohan Sethi, Ghulam Quddus, Joao De Almeida, Bertrand King

## Methodology/Scientific Approach

**TASK 1. Compilation of information and updated literature review**. Rohan Sethi is continuing to update a comprehensive preliminary literature review for the characteristics, potential uses and process design and operation for organic waste diversion. To date, the following topics have been reviewed:

1) Identification of suitable organic waste feedstocks and typical characteristics used to describe them.
2) Modifications to conventional anaerobic digestion to be able to process organic waste for energy production and identify the undergoing process of volume reduction and volatile solids reduction.
3) Identification of potential legal, policy, or social barriers to implementation and associated costs.
4) Identification of key parameters (pH, temperature, detention time, VFAs, biogas production, biogas composition, and TDS) and understand the correlation with each other.

**TASK 2. Assemble stakeholder task force.** The proposed task force will be comprised of key stakeholders such as solid waste facility managers, waste facility managers, waste/septage haulers, wastewater utilities, and Florida department of environmental protection (FDEP), CNG/LFG users. Rohan Sethi attended the Environmental Research Summit on Food Organics held on July 24-26, 2017 in Ontario, California to collect more information on the technology and challenges being faced in food waste industry. FAU will be meeting with Steve Roberge (WWTP Superintendent at Boca Raton Utility services department) on August 15, 2017 for collecting more information on anaerobic digester operations and ideal feedstock composition. FAU will also be meeting David Dalton (South Central Regional WWTP Director) and Darren Hollifield (East Central Regional WWTP Manager) as well the Broward County WWTP director for gaining more knowledge about the different perspectives of the current and proposed anaerobic digestion facilities in the FAU service area as well as operational and design input. Several key stakeholders were identified for invitation to the next TAG meeting scheduled in August.

**TASK 3. Collect representative food waste samples.** Publix Greenwise Store #1159 Recycling and Solid Waste Manager Kim Brunson has been contacted to obtain samples of organic waste for preliminary testing. Quality control manager in Boca Raton utility services department, Donald M. Kree has provided seed for the digester. He has also agreed to provide lessons learned on digester daily operations. A followup meeting to obtain data regarding the different types of

food organics which will produce a significant amount of landfill gases and help us study the different characteristics has been arranged with Donald M. Kree. FAU collected organic waste samples (Figure 1) for preliminary testing of the anaerobic digester for experiments conducted on May 12, 2017 (Figure 2). The parameters that were monitored included pH, temperature, slurry ratio, C/N ratio, inhibitory substances like ammonia and sulfide, VFAs and biogas quantity and quality. The amount of biogas generated and its composition for different mixtures was measured and compared to determine the methane production. The gases obtained were measured and assessed by using GEM5000 which is specifically designed for use on landfills to monitor landfill gas (LFG) collection and control systems. Operational data such as pH vs. time profiles for different feedstock ratios selected in TASK 2 will be collected. Preliminary analysis of the digester performance data from the first experiment indicates that codigestion of sludge with current selection of feedstock (vegetables and fruits) did generate biogas but should be replaced with with a feedstock with a higher content of FOG (Fats, Oils and Grease) and less moisture content. Bertrand King, Joao de Almeida, and Ghulam Quddus received an FAU Undergraduate Research Grant for $1200 to purchase a column and supplies for the HPLC detection of organic acids. They are currently working on method development and training.

**Figure 1. Joao de Almeida mixing food waste with the seed obtanied from the City of Boca Raton.**

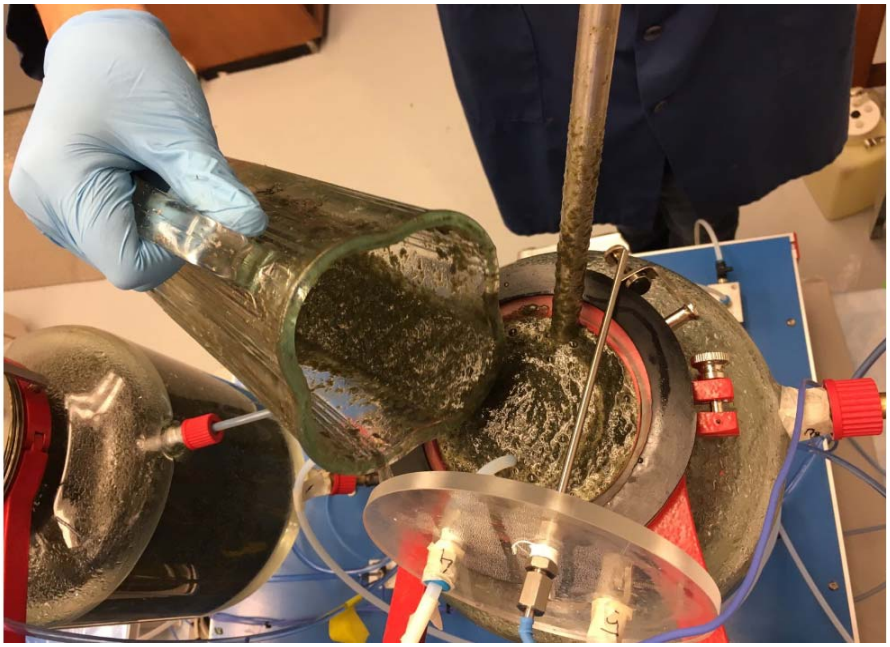

**Figure 2. Rohan Sethi loading the reactors with the mixed food waste.**

**TASK 4. Food waste separation impacts to LFG recovery.** Landfill gas is the product of a series of complex reactions involved in the decomposition of organic matter that produce gases and compounds like methane or natural gas. Some of the technical issues regarding the fuel use of landfill gas include gas composition, the effects of corrosives and particulates on equipment, potential energy losses, and gas extraction and cleanup. Energy users are concerned with the problems and solutions associated with the use of LFG as a fuel source. FAU conducted a preliminary experiment on May 12, 2017 to obtain data to understand the energy consequences of food diversion using results obtained from preliminary testing in TASK 3. The intent is to model and quantify the changes to landfill gas composition and flowrate with reduced organic content in the mix.

**TASK 5. Assess life cycle cost.** Using the data developed in TASKS 2-4, an assessment has been conducted to evaluate the associated costs and environmental consequences. Ghulam Quddus conducted quantification and carbon footprint evaluation using the Co-digestion economic analysis tool (CO-EAT) as part of a directed independent study for his Innovation Leadership Honors Program curriculum. He used a simulation of nine scenarios in the CO-EAT model, and each scenario contains different operating capacity ranging from 20% to 60% in 5% increments. FAU will further analyze the types of food waste available (like soybeans, peanut butter and high protein dog food) from available markets or restaurants and compare the basis of the costs associated with the food diversion scenarios.

**TASK 6. Develop final recommendation and prepare publication materials.** The final report is being developed. A meeting to refine the content was conducted in July. A strategy will be established for looking into the work and experiments being conducted based on the comments from reviews. A TAG meeting was conducted in December 2, 2016 and a presentation was made to the Air and Waste Management Association Southeast Florida Chapter meeting in January 2017. A second TAG meeting is scheduled for August 28, 2017.

**EREF – Conference Held on 24-26 July 2017 in Ontario, California**

The Environmental Research and Education Foundation (EREF) held the Regional Summit on Organics Management in collaboration with the California Refuse Recycling Council.

- Trish Roath and Bryan Staly (president and CEO) gave the welcome presentation on the ongoing and upcoming projects for research grants in 2016-2017.
- Debra Kantner gave a presentation on municipal solid waste organics by describing the main sources of MSW and then explaining organics management strategies with data based on their research and EPA estimates. She explained that about 19 of 50 states have banned yard waste and only 5 have proper food waste disposal bans. They compared the regions on the basis of tonnage per month of waste.
- Louie Pellegrini from Livermore Sanitation gave a presentation on the local perspectives of organics management and collection by reviewing technologies and challenges in the regulation of organics processing.
- Tej Gidda and Kyle Muffles from Canada provided an overview of Canadian perspectives on organics management and presented information about a facility in British Colombia and its operation.
- Kathy Lynch and Veronica Pardo from CRRC regulatory affairs gave a presentation on the update regarding policies impacting and involved in organics diversion and processing. They reviewed the current challenges with the existing regulatory framework along with potential opportunities.
- Brandon Moffatt from Canada from Stormfisher Environmental gave a presentation comparing organics recovery in Ontario (Canada) and California. He gave an overview on the 2.8 MW biogas plant in London, Toronto and showed data on organics breakdown by comparing it with California data. He discussed the assessment of existing infrastructure in California and Ontario.
- Shakira R. Hobbs from Clemson University and EREF scholar gave her presentation on food waste and bioplastics management and how to increase sustainability. She presented on her current PhD program in which she went to Belize with her team to research on how to make use of bioplastics and food waste by converting it to biogas for cooking or electricity purposes.
- Tracie Onstad discussed about sorting/policy decision making for organics management.
- Ken Beaver from Marathon gave his ideas on the diversion of organics, also discussing different ways of collection and sorting. He discussed about the TORXX kinetic pulverizer for efficient size reduction.
- Los Angeles based multi-family food scrap recovery, Athens Services gave their views on the future of organics by comparing two locations they surveyed: (a) Griffin (Montectica Heights, Northeast LA) with 16 units, 2 floors and (b) old bank (Downtown Los Angeles) with 70 units, 8 floors, which showed what difficulties they had and how they made it possible to convince people to participate in the recovery program.
- Victoria Ngo from Cal Recycle gave a presentation on the air and water considerations for composting. She talked about the kinds of permits required and who regulates air pollution in California.

**Future Work**

- Complete the update of the literature review focusing on a) design considerations and operational performance data for anaerobic digesters used for generating biogas from food waste, and b) volume reduction, volatile solids reduction, and methane production.
- Run the laboratory scale digester with different slurry ratios to obtain data for the modeling scenarios.
- Contact the key stakeholder group to get a clear perspective on objectives of food diversion processing by anaerobic digestion.
- Identify the major food waste components that produce more biogas and higher methane content
- Conduct a preliminary assessment of associated costs and environmental effects.

**Project Metrics**

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

| Last name, first name | Rank | Department | Professor | Institution |
|---|---|---|---|---|
| Sethi, Rohan | MSCE candidate | CEGE | Meeroff | FAU |
| | | | | |

2. List undergraduate student/researchers working on this Hinkley Center project

| Last name, first name | Department | Professor | Institution |
|---|---|---|---|
| Quddus, Ghulam | CEGE | Meeroff | FAU |
| Almeida, Joao | CEGE | Meeroff | FAU |
| King, Bertrand | CEGE | Meeroff | FAU |
| | | | |

3. List research publications resulting from this Hinkley Center project (use format for publications as indicated in the Hinkley Center Investigators Guide).
   None yet

4. List research presentations resulting from this Hinkley Center project (use format for listing presentations as indicated in the Hinkley Center Investigators Guide).
   Technical Advisory Group Meeting held on December 2, 2016

5. List research papers that have cited any publications (or the final report) resulting from this Hinkley Center project (use format for publications as indicated in the Hinkley Center Investigators Guide).
   None yet

6. List additional research funding that has been secured due to leveraging the research results from this Hinkley Center project (give project title, funding agency, amount of funding, award date, and award period)
   $1200 Undergraduate Research Grant

7. List submitted proposals which leverage the research results from this Hinkley Center project (give the proposal title, funding agency, requested funding, date submitted)
   None yet

8. List new collaborations initiated based on this Hinkley Center project

Rhonda Moll (Test America), Marc A. Lefebvre (Mas Environmental, LLC)

9. How have the results from this Hinkley Center funded project been used (***not will be used***) by the FDEP or other stakeholders in the solid waste field? Please note that the term "other stakeholders" is meant to broadly include any party or practitioner in the solid waste field. This includes county solid waste directors and their staff, municipal solid waste directors and their staff, solid waste facility design engineers, local/county/city solid waste management regulatory staff, federal solid waste regulatory staff, landfill owners and operators, waste haulers, waste to energy plant owners and operators, recyclers, composting plant owners and operators, yard waste operators, construction and demolition debris companies and organizations, county recycling coordinators, citizens and members of the academic community, etc. (1 paragraph maximum)
   None yet to our knowledge

**TAG Members:**
Mark Eyeington, Mark Maclean, Mark Bruner, Owrang Kashef, D.V. Reddy, Craig Ash, Ravi Kadambala, Ron Schultz, Jeff Roccapriore, André McBarnette, Dan Schauer, Damaris Lugo, Amanda Krupa, Richard Meyers, Amede Dimonnay, Art Torvela, Ted Batkin, Roshan Jachuk, Fred Bloetscher