

# QUARTERLY PROGRESS REPORT

September 2023 – November 2023

**PROJECT TITLE:** Evaluating and Optimizing the Value of Anaerobic Digestion of Food Waste using Sensitivity Analysis and Machine Learning

## **PRINCIPAL INVESTIGATOR(S):**

PI: Ana Martin-Ryals, Assistant Professor, [admartin@ufl.edu](mailto:admartin@ufl.edu), 352-294-6708

Co-PI: Nikolay Bliznyuk, Associate Professor of Statistics, [nbliznyuk@ufl.edu](mailto:nbliznyuk@ufl.edu), 352-294-6734

Affiliation: Agricultural & Biological Engineering (ABE), University of Florida, Gainesville, FL

**PROJECT WEBSITE:** [Hinkley Project - UF/IFAS Agricultural and Biological Engineering](#)

## **WORK ACCOMPLISHED DURING THIS REPORTING PERIOD:**

Work during this reporting period included establishing a project website, conducting our first TAG meeting, and beginning work on Objectives 1 and 2 as described below.

Objective 1 is to establish a dataset linking feedstock characteristics, anaerobic digestion (AD) operating parameters, and AD performance metrics. During this reporting period, the team carried out an initial review of published experimental studies investigating AD of post-consumer food waste, and extracted data on feedstock characteristics (e.g., macro- and micro-nutrients, total solids, volatile solids, total carbon, total nitrogen, etc.), operating parameters (e.g., organic loading rate, retention time, temperature, pH, etc.) and performance metrics (e.g., methane production, solids removal). The literature review was primarily carried out by two undergraduate student researchers and the graduate student hired for this project, Jithran Ekanayake, under the supervision of PI Martin-Ryals. The review yielded a dataset of 103 individual data points, or records, which has been compiled into a single Excel spreadsheet. We are still in the process of cleaning the data to obtain consistent parameter values and units across all records.

Table 1 provides a summary of the number of records obtained that contained data on relevant feedstock, operational, and performance parameters. The greatest challenge we faced during the literature review was identifying references that had detailed feedstock characterization data. Of the 103 records, only 22 contained data on feedstock macromolecule content (carbohydrate, protein, and lipids), and 23 contained elemental composition data (C, H, O, N, P, and/or S). Most operational parameters were clearly reported in all 103 records, and all records provided a metric for AD performance as either biogas or methane yield with limited reporting of solids removal or digestate quality.

Objective 2 is to develop a machine-learning (ML) framework to predict AD performance based on feedstock characteristics and operating parameters. This effort will be carried out by Jithran, with guidance by Co-PI Bliznyuk. During this reporting period, Jithran received foundational training in statistical ML techniques including principal component analysis (PCA) and random

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forest, which he is ready to apply to the initial dataset established from Objective 1. The random forest models will help guide future literature review efforts and improve the efficiency of later artificial neural network model-development using a larger set of observations by identifying the most relevant subset of predictor variables. This will also lay the foundation for hyperparameter tuning using genetic algorithms.

Over the next reporting period, we will carry out the initial PCA and random forest analysis using the dataset established during this reporting period. Upon identifying which predictor variables are the most relevant, we will continue reviewing the literature to expand our dataset for AD of post-consumer food waste and to include co-digestion of food waste and other relevant feed stocks (i.e., wastewater biosolids, and fats, oils, and grease), with focus on papers that include the most relevant predictor variables. We will also follow-up with TAG members to obtain full-scale AD performance data for further ML-model testing and validation. We will hold our second TAG meeting at the end of next quarter to review progress of the ML-model development, and to discuss the next phases of the project which will include economic and sensitivity analysis.

**Table 1.** Number of records obtained from the first quarter literature review that contained information on relevant feedstock, operational and performance parameters for anaerobic digestion of post-consumer food waste. Median and range values are given for parameters whose values have been adjusted as needed to obtain consistent units across all records. The other parameters are still being processed.

Feedstock Characteristics								
Carbs	Protein	Lipids	Carbon	Hydrogen	Oxygen	Nitrogen	Phosphorus	Sulfur
22	22	22	21	10	8	23	4	2
Operating Parameters							AD Performance	
Reactor Volume (L)	C/N	pH	Temp. (C)	Retention Time (days)	Food/ Microbe	Organic Loading Rate	Methane Yield	Biogas Yield
103	64	48	101	103	34	76	69	49
Median: 450 Range: 0.25 – 900,000	Median: 16.3 Range: 9 – 223	Median: 7.36 Range: 6.89-8.14	Median: 40 Range: 20-55	Median: 40 Range: 1 – 431	Median: 1.3 Range: 0.5 – 5			

## TAG MEETINGS:

Date: Sept. 20, 2023

Participants (name/title/email):

- Ana Martin-Ryals, Assistant Professor, admartin@ufl.edu
- Nikolay Bliznyuk, Associate Professor of Statistics, nbliznyuk@ufl.edu
- Jithran Ekanayake, Graduate Student, jithranekanayake@ufl.edu
- Tim Townsend, Executive Director, Hinkley Center, ttown@ufl.edu
- Steve Laux, P.E., Hinkley Center, steven.laux@essie.ufl.edu

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- Mike Heimbach, City of Gainesville Sustainability Manager, HeimbachMJ@GainesvilleFL.gov
- Eric Neihaus, GRU Planning Engineer, NeihausEW@gru.com
- Patrick Irby, Waste Collection & Alternatives Manager, Alachua County, pirby@AlachuaCounty.US
- Soren Jorgensen, Senior VP of Global Business Development, Bigadan A/S, sji@bigadan.dk
- Justin Stankiewicz, Director of RNG Development, Chesapeake Utilities Corporation, jstankiewicz@chpk.com
- Del Bottcher, President of Soil and Water Engineering Technology Inc., dbottcher@swet.com
- Amir Varshovi, Founder/CEO of Green Technologies LLC, avarshovi@green-edge.com

List of TAG members who were **unable** to attend this meeting:

- David Gregory, Manger Solid Waste Division, Orange County Utilities, david.gregory@ocfl.net

[Link to the video recording of the TAG meeting](#)

## METRICS REPORTING:

1. Summary of input provided by the TAG during this period.

Minutes from the first TAG meeting held on September 20, 2023, are available on the project website. This meeting served to reorient the TAG to the objectives of the project. Some TAG members expressed an interest in learning more about relevant economic incentives and carbon credits that could support the economics of a digester project. This will be addressed during the economic analysis phase of the project in third and fourth quarters. It was also asked if the literature data that will be used for the ML-model development will be representative of actual “real-world” operating conditions, or ideal lab conditions. PI Martin-Ryals confirmed that the data will represent realistic operating conditions to the best extent possible. However, she also asked the TAG members if they have access to any real-world digester datasets that could be used for the ML-model development. Soren Jorgensen from Bigadan mentioned he may be able to get access to actual full-scale digester data. The team will follow-up with him during the next reporting period, and apply this data to the ML-model testing and validation.

2. Publications resulting from **THIS** Hinkley Center project.

None

3. Research presentations resulting from (or about) **THIS** Hinkley Center project.

- Martin-Ryals, Ana. “Leveraging food waste for production of bioenergy and biomaterials via anaerobic digestion”. American Society of Agricultural and Biological Engineering Annual International Meeting. Omaha, Nebraska, Jul 9-12, 2023

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- Martin-Ryals, Ana. “Advancing carbon, water and nutrient recovery from anaerobic digestion of food waste”. Manure Lunch Seminar Series. Alachua, Florida, Dec 1, 2023

4. List who has referenced or cited your publications from this project.

None

5. How have the research results from **THIS** Hinkley Center project been leveraged to secure additional research funding? What additional sources of funding are you seeking or have you sought?

No additional funding has been secured at this time. However, the PIs did submit an internal ABE Pathfinder Graduate Student Fellowship proposal to support continuation of this project. The proposal is currently under review, and would provide 4 years of tuition and stipend to support a PhD student. PI Martin-Ryals will also re-submit an NSF CAREER proposal in July 2024 to support expansion of this project to include experimental testing and validation.

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

PI Martin-Ryals was contacted by representatives from the engineering consulting firm CDM Smith, who have been solicited by the City of Gainesville to carry-out a feasibility study on anaerobic digestion of food waste. If that study moves forward, PI Martin-Ryals and her students will assist CDM Smith with collecting local food waste generation and compositional data, which will benefit the economic and sensitivity analysis of this project and could lead to further experimental and/or modeling work.

7. How have the results from **THIS** Hinkley Center funded project been used (not will be used) by the FDEP or other stakeholders?

None

**PICTURES:** Graphical abstract for Hinkley Center website:

