DOE Bioenergy Technologies Office (BETO) 2021 Project Peer Review

Develop an efficient and cost-effective novel anaerobic digestion system producing high purity of methane from diverse waste biomass

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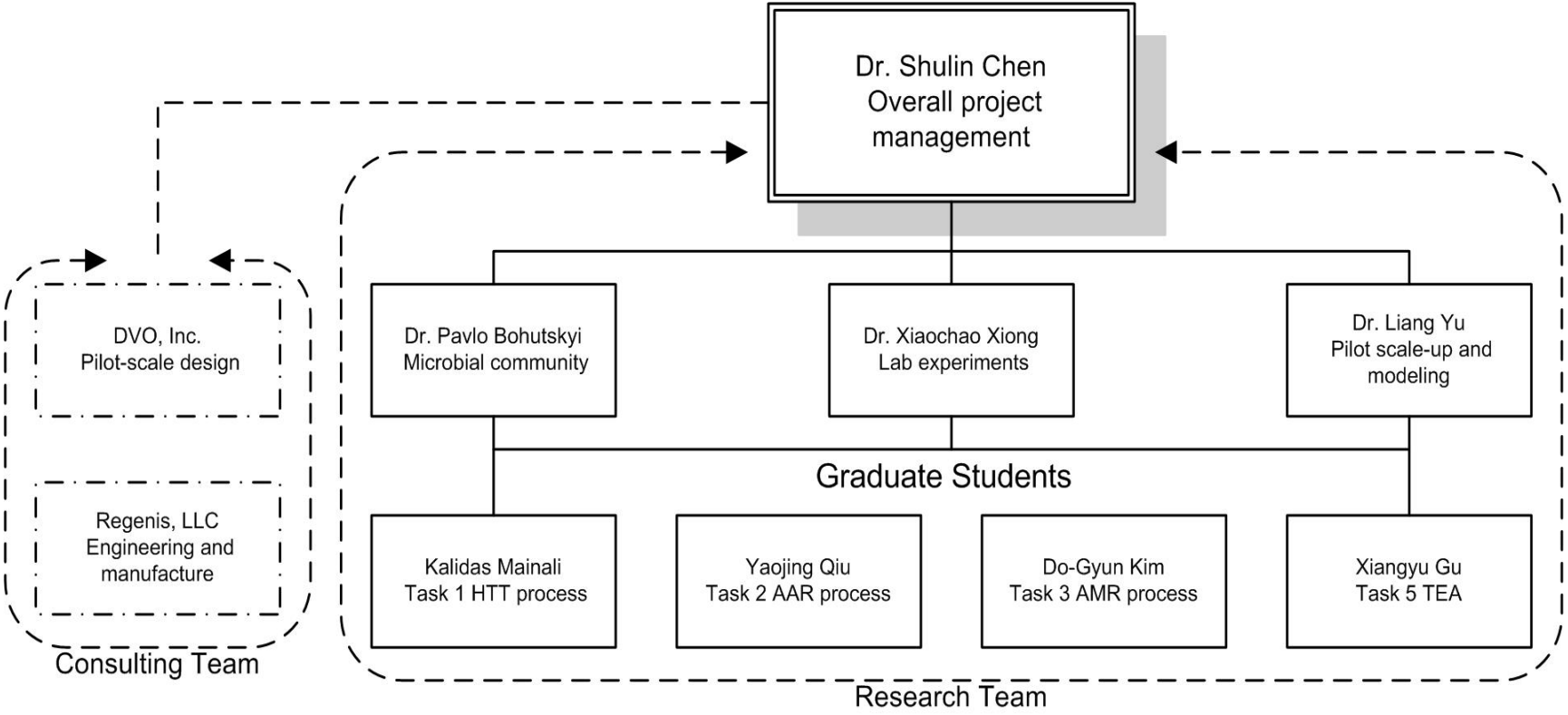
Project Overview

- Founded under Fiscal Year 2019 Commercial Trucks and Off-Road Application FOA (DE-FOA-0002044): Two project periods: P1: 10/1/2020-9/30/2022; P2: 10/1/2022-9/30/2023.
- Goal: To reduce production cost of pure biomethane derived from waste through anaerobic digestion (AD) by pretreating recalcitrant feedstock and intensifying core processes.
- **Project rationale**
  - Slow disintegration and hydrolysis of recalcitrant feedstocks into biodegradable molecules and low methane contents in the biogas are inherent barriers of AD processes that have challenged the engineering community to come up effective solutions.
  - New technologies that overcomes the above barriers are needed by the industry to convert the vast amount of organic waste to renewable energy.
  - Eliminating the limitation in feedstock supply to achieve economy of scale and process intensification are two potential strategies for cost reduction.

Management: Project Team Structure

An interdisciplinary team with strong industrial partners



Management: Project Execution, Communication and Risk Mitigation

- Emphasize planning and communication

  -Written plans for managing project, intellectual property, and data
  -Weekly meeting within the research team to discuss research activities
  -Monthly meeting of the project team involving industrial partners and DOE project manager to evaluate progress against milestones
  -Quarterly project meeting to evaluate progress against project management plan
  -Using Basecamp as project management platform to assure efficient execution

- *Strategies to mitigate technical risks*

  -Synergizing biological and hydrothermal process to reduce severity
  -Taking a wholistic approach to optimize the overall system
  -Capitalizing on the experience of industrial partner to lower engineering risks

Novel Approach for Overcoming Barriers

- Biomass heterogeneity and low methane yield: employing a hydrothermal Reactor (HTR) unit that treats the solid digestate produced from various types of waste biomass for improved digestibility.
- Hydrolysis as a limiting step and low reaction rate of anaerobic digestion process: Using hyperthermophilic anaerobic acidification reactor (AAR $\geq 60^{o}C$) for high-rate conversion of organic waste into volatile fatty acids (VFAs).
- Low productivity and low methane purity: using a pressurized thermophilic anaerobic methanogenesis reactor (AMR, $\geq 50^{o}C$) for accelerated transformation of the VFAs into high purity methane.
- Ammonia inhibition: Recovering ammonia nitrogen to reduce inhibition and producing fertilizer as a co-product.

Target Performance Metrics

Parameters	Type of baseline technology	Target improvement	Degree of improvement
LCOE (cent/kWh)	26.9	11.6	Improved by 57%
EROI	2.76	5.15	Improved by 87%
AD hydraulic retention time (days)	22	7	Reduced to third
Biogas Yield (m^3/ton VS) (Methane Yield 60%)	230 (138)	575 (345)	150%
*Baseline conditions: Current DVO mixed plug flow digester cost for 2000 cow dairy producing 21 dry ton manure waste per day.			

I. LCOE (levelized cost of Energy), EROI (Energy return on investment)
II. Theoretical methane yield of dairy manure (400– 450 m^3/ton VS)

Varol, A. and Ugurlu, A., 2017. Comparative evaluation of biogas production from dairy manure and co-digestion with maize silage by CSTR and new anaerobic hybrid reactor. *Engineering in Life Sciences*, *17*(4), pp.402-412.

Go/No-Go Decision Point

- ***Reaching the specified milestones***
  -Manure soluble COD reaches 80%
  -Food waste soluble COD reaches 90%
  -VFA productivity achieving 150% of baseline technology
  -Total ammonia nitrogen maintained below 1,700mg/l
  -Biogas productivity achieving 150% of baseline technology
  - Methane purity reaches 75%
- ***Achieving reducing the levelized cost of energy (LCOE) and Energy Return on Investment (EROI) by 25% of the baseline technology, which is the mandated goal by the FOA***

Impact: Advancing AD Technology

- Achieving the milestones and metrics demonstrates the success of a novel system that advances AD technology to a new performance level.
- Producing critical data for raising the technology from TRL3 to TRL5, decreasing the risk in implementing the technology.
- Publishing the new knowledge discovered in high impact journals and reporting project results in professional conferences to contribute to the scientific and engineering communities.
- Offering the novel AD system as a new platform for DOE's technology portfolio for the production of renewable natural gas from different types of municipal wastes.

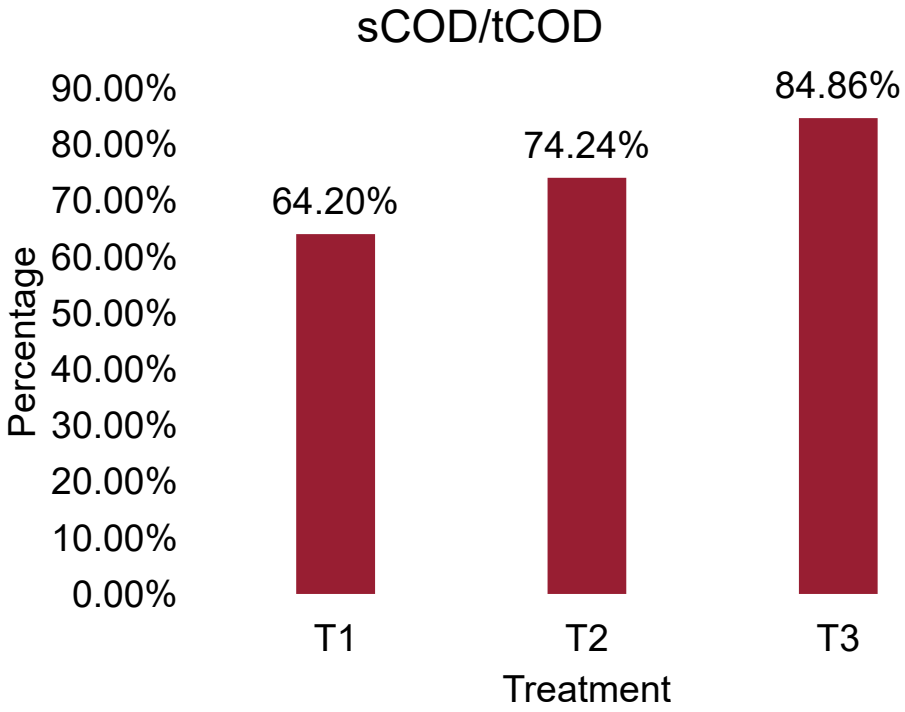
Impact: Advancing AD Industry

- Success in this project will remove several key technical barriers that have constrained the potential of AD as an industry.
- Our industry partners (DVO, Inc who has built most of the dairy anaerobic digesters in the US and Regenis as a major digester installer) by providing the baseline data and assisting engineering and scale up of the system, make the project highly relevant to the industry.
- The keen interests and active participation of DVO and Regenis will accelerate the commercialization and adoption of the technology, enabling the utilization of a broader range of the vast organic waste resources.

Progress and Outcomes: Overall Status

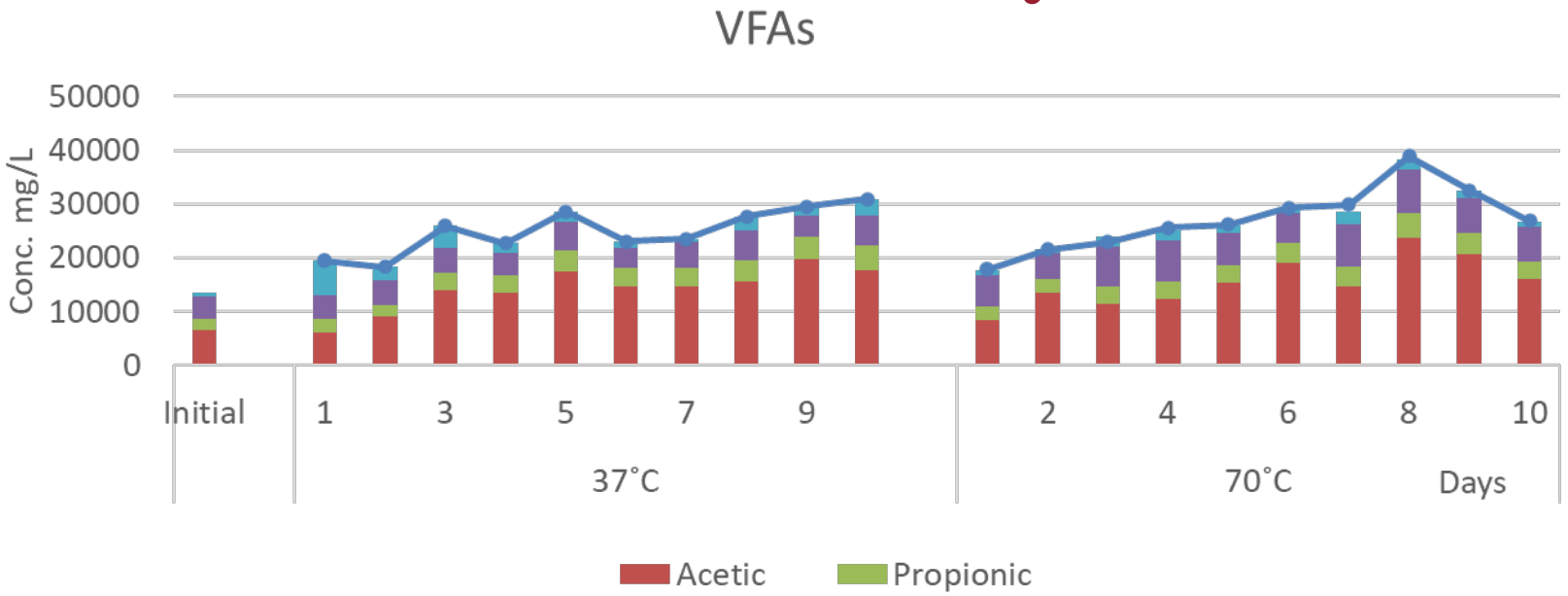
- The first quarter of the project is off to a good start. The project has been executed according to the plan, including both research activities and management meetings.
- Initial progress has been made towards achieving three of the six milestones as summarized in the following slides.
- The project is benefited from the active and enthusiastic participation of industrial partners from onset.
- The project has already start producing data and results. Four manuscripts are under preparation.
- The COVID-19 pandemic has created challenges in lab work and staffing buy did not cause major issues.

Progress : Achieved Milestone 1.1.1 Conditionally



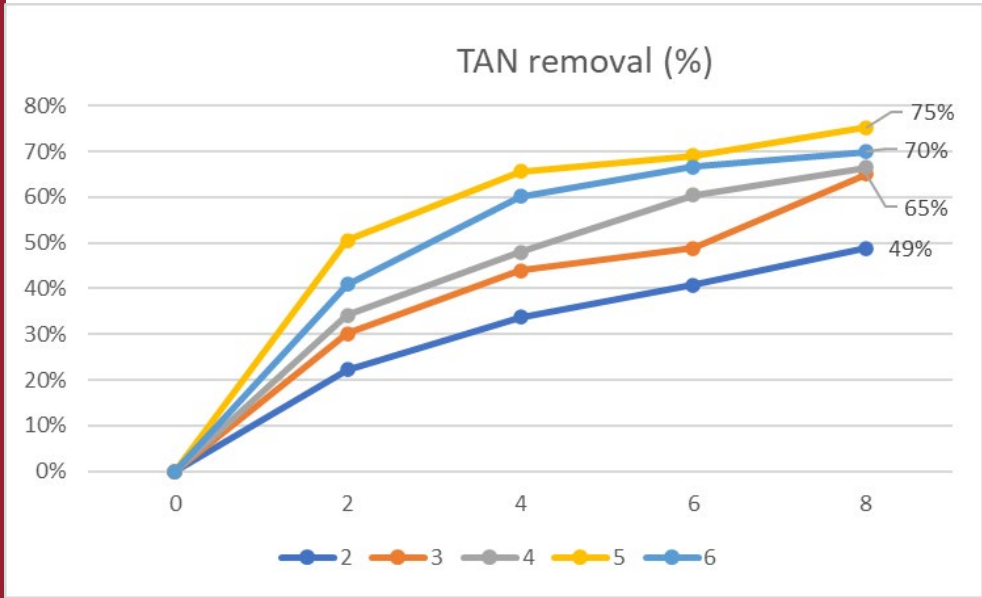
- Milestone 1.1.1: Treat the solid digestate produced from dairy manure to demonstrate 80% disintegration of dairy manure as measured by soluble COD. Deadline: February 28, 2021.
- The milestone was achieved under high-severity conditions, related work will continue to reduce the severity of the treatment.

Progress : Achieved Milestone 2.1.1 Conditionally



Milestone 2.1.1: Anaerobic acidification under hyperthermophilic temperature to demonstrate shortening hydraulic residence time to 6 days and achieving VFAs productivity 150% of that of the control. Deadline: September 30, 2021.

Progress : Achieved Milestone 3.1.1 conditionally



- Milestone 3.1.1: Ammonia inhibition test to demonstrate biogas production without ammonia inhibition by keeping total ammonia nitrogen (TAN) less than 1700 mg/L through ammonia stripping process. Deadline: September 30, 2022.
- Milestone was achieved using simulated biogas (mixture of CO2 and methane) at batch lab scale.

Quad Chart Overview

Timeline

- Project start date: October 1, 2020
- Project end date: September 30, 2023

	FY20 Costed	Total Award
DOE Funding	(10/01/2019 – 9/30/2020) *$120,000*	(negotiated total federal share) $2,234,051
Project Cost Share	$30,000	$558,842

Project Goal

To reduce cost of pure biomethane derived from waste through anaerobic digestion (AD) through using diverse feedstock and process intensification

End of Project Milestone

Milestone 5.3.1: TEA and performance simulation (month 36)- Project will demonstrate conclusion on whether the project meet the performance targets: (1) the increase of digestion of mixed biowastes to 90%, (2) the increase of methane purity to 75%, and (3) improvements of levelized cost of energy (LCOE) and EROI over the baseline, by 57% and 87% respectively.

Project Partners*

- Partner 1: PNNL, Richland Washington
- Partner 1: DVO Inc, Chilton, WI 53014
- Partner 2: Regenis, LLC, Ferndale, WA 98248

Funding Mechanism

Application FOA (DE-FOA-0002044).

Fiscal Year 2019 Commercial Trucks and Off-Road Application

Next Steps

- Refine the process to achieve the first three milestones at next larger scale and more cost effectively;
- Start the work of all tasks scheduled for Project Period 1 and achieve the remaining 3 corresponding milestones;
- Integrate the unit operations to demonstrate their performance with a bench-scale system;
- Prepare for applying IP protection of the technology;
- Publish the results and disseminate the new knowledge.

Summary

- This project aims at developing an AD system that integrates hydrotreating and in-situ methane purification so that diverse waste feedstocks can be accepted and needs for downstream processing can be reduced.
- Having aggressive performance metrics that exceed the target mandated by the program FOA, this is an important yet challenging project that if successful will produce significant broad impacts in advancing the industry as well as expanding DOE's technology portfolio.
- With strong and active industry participation and using actual existing technology as baseline, this project is highly relevant to the industry, and the technology will be readily transferred if successful.
- During the first four project months that this review covers, the project has made good progress towards achieving the scheduled milestones with a much challenging work remaining.

Thank you for your attention!