Data Integration and Deep Learning for Continuous Gas Fermentation Process, 2.5.3.704

PI: Wayne Mitchell, LanzaTech

Project Type

- *Project Type:* DFO
- *Goals of the relevant DFO:* Engage with industry to access and utilize the developing capabilities of the Agile BioFoundry

Timeline

- *Project Start Date: May 1, 2018*
- *Project End Date: April 30, 2019*
- *Percent Completed: 35%*

	Total Funding Pre-FY17*	FY 17 Funding	FY 18 Funding	Total Planned Funding (FY 19-Project End Date)
DOE Funded	$0	$0	$104K	$500K
Project Cost Share	$0	$0	$45K	$216K

Partners: Argonne National Laboratory (ANL), National Renewable Energy Laboratory (NREL), Agile Biofoundry (ABF)

Management Approach

This project links LanzaTech's (LT) unique expertise and accumulated fermentation data with ANL's capacity in computational and AI analyses.

- *Wayne Mitchell* (LT): Project PI and director
- *James Daniell* (LT): Metabolic modeling
- *Asela Dassanayake* (LT): Computational biologist
- *Philip D. Laible* (ANL): Coordinating Laboratory PI
- *Peter E. Larsen* (ANL): Machine learning/Artificial Intelligence
- *Gregg Beckham* (NREL): NREL PI, Scaling / Integration

Technical Approach

Develop an 'inline' AI-guided process that will monitor and adjust industrial, waste gas-fed fermentation conditions in real time to optimize output of biofuels

- Integrate extensive LT database of fermentation data across multiple scales (bench to industrial)
- Leverage detailed metabolic model of fermentation organism
- Construct AI module as an Artificial Neural Network (ANN) that provides operational feedback to maximize fermentation output and minimize bioreactor crashes

ANNs are capable of learning to detect patterns in complex systems, without *a priori* knowledge of the underlying mechanisms of the system. This makes ANNs ideal for learning from dynamic, complex systems where it is not feasible to derive a mechanistic understanding.

This approach aims to be generalizable with the plan to design inline AI control modules that are applicable to a wide variety of industrial fermentation processes.

Technical Progress and Future Plans

Project goals and milestones remain on target.

- Expert-curated fermentation datasets transferred to ANL (from ~14K available fermentation runs) for use in training AI models.
- Down-selected 21 fermentor data streams (out of ~220) suitable for AI training
- Evaluated initial data that are suggestive of increased capacity to predict fermentation status from organism metabolism metrics
- Future milestones include:
  1. Completion of multilayered, AI system that integrates real-time fermentor output with metabolic models of fermentor organisms
  2. Construction of artificial neural networks that anticipate future fermentor states and suggest inline process modifications

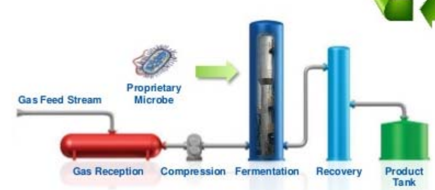
Relevance and Impact

Goal: Maximize production of biofuels from gas-fed fermentations through AI monitoring of fermentation:

- Maintain steady state in continuous culture
- Enhance strain stability
- Minimize fermentation crashes
- Predict scale-up from bench to industrial fermentations

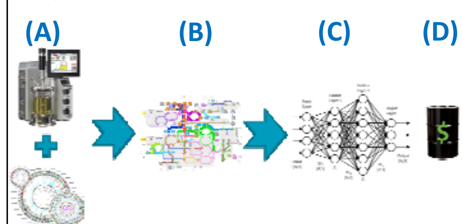
Insights gained from work with LanzaTech and its advanced and scaled bioconversion processes will allow companies at early stages of development to anticipate and proactively resolve potential scaling hurdles and stability issues during lab, bench, or pilot phases.

The LanzaTech Process



LanzaTech's process involves biological conversion of carbon to products through gas fermentation. Using microbes that grow on gases (rather than sugars, as in traditional fermentation), carbon-rich waste gases and residues are transformed into useful liquid commodities used in everyday applications, providing a novel approach to carbon capture and reuse.

AI-Guided Process Improvements



A multilayer AI model system is proposed. **(A)** Data are collected in real time from fermentor. **(B)** Collected data and microorganism genomic information are used to predict metabolic processes in fermentor organism. **(C)** Predicted metabolic data are used as input to ANN to anticipate possible changes in fermentor status (e.g., fermentor crash, loss of production, instability in steady state). **(D)** Information from ANN is used to make process changes to maintain fermentation productivity and stability, leading to maximized fermentation product yields.