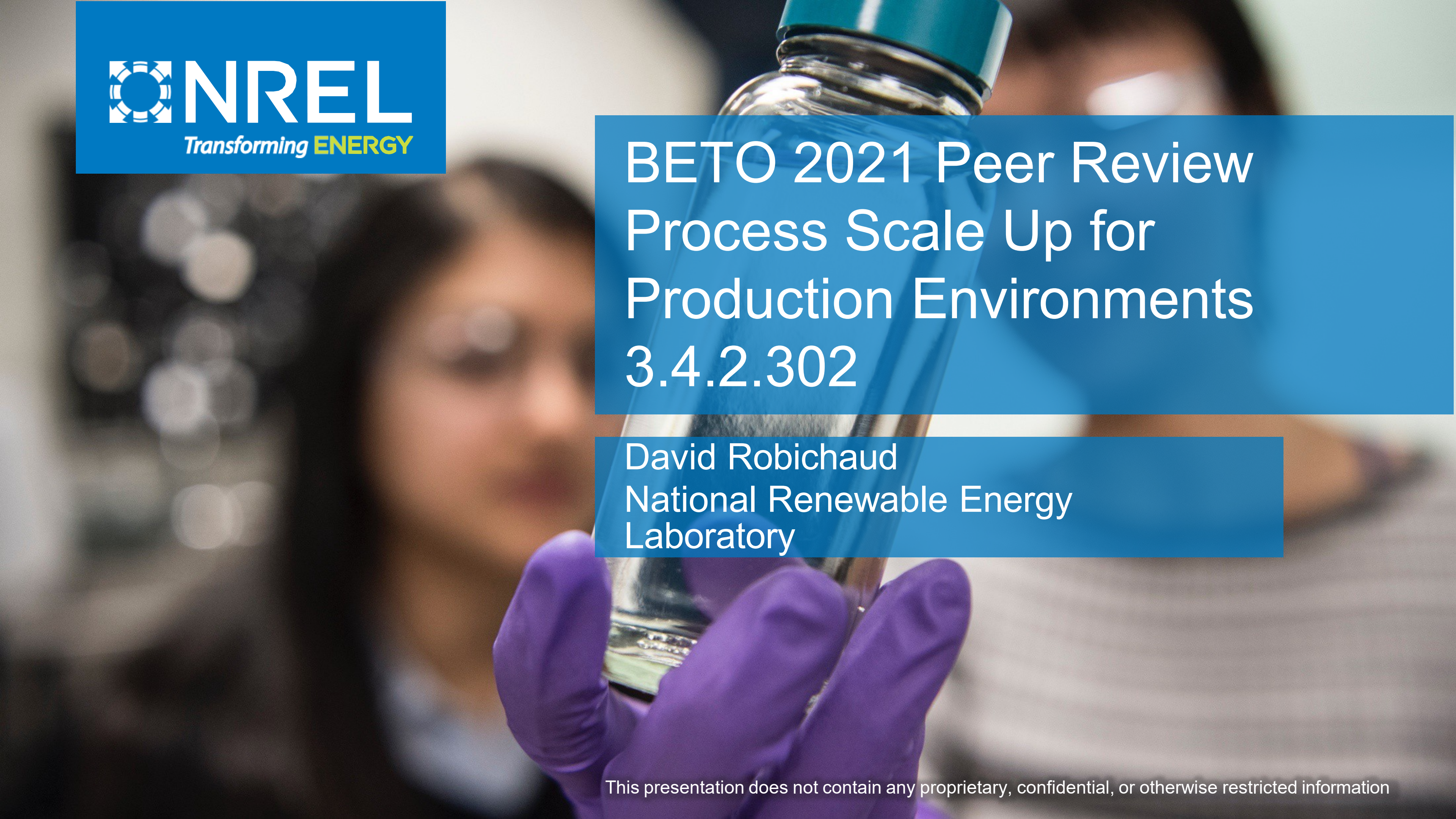


BETO 2021 Peer Review Process Scale Up for Production Environments 3.4.2.302

David Robichaud
National Renewable Energy Laboratory

Project Overview

BETO's success enables private industry to subsequently demonstrate and commercially deploy technologies in integrated biorefineries (IBRs)
– draft MYP 2020

80% of new technologies fail to meet performance expectations
– Jim Spaeth 2017 ADO workshop

Failure to Launch: Why Advanced Biorefineries Are So Slow to Ramp Up Production

https://theicct.org/blog/staff/failure-to-launch-biorefineries-slow-ramp-up

Posted Tuesday, 13 November 2018, 14:36
Nikita Pavlenko

KiOR: The inside true story of a company gone wrong

May 17, 2016 | Jim Lane

https://www.biofuelsdigest.com/bdigest/2016/05/17/kior-the-inside-true-story-of-a-company-gone-wrong/

Review Article

Current Challenges in Commercially Producing Biofuels from Lignocellulosic Biomass

Venkatesh Balan[1,2]

http://dx.doi.org/10.1155/2014/463074

New innovation → Promising lab-scale results → Pilot/Demo → Miss performance metrics → Fail

New path → Succeed

Need to disrupt this failure pipeline

Market Trends

Category	Trend
Product	Anticipated decrease in gasoline/ethanol demand; diesel demand steady
	Increasing demand for aviation and marine fuel
	Demand for higher-performance products
	Increasing demand for renewable/recyclable materials
Feedstock	Sustained low oil prices
	Decreasing cost of renewable electricity
	Sustainable waste management
	Expanding availability of green H_2
	Closing the carbon cycle
Capital	Risk of greenfield investments
	Challenges and costs of biorefinery start-up
	Availability of depreciated and underutilized capital equipment
Social Responsibility	Carbon intensity reduction
	Access to clean air and water
	Environmental equity

NREL's Bioenergy Program Is Enabling a Sustainable Energy Future by Responding to Key Market Needs

Value Proposition

- *Integrated Process* data to retire risks and support stronger design basis for commercial partners

Key Differentiators

- Other projects target innovation and discovery at a single unit operation under ideal conditions. This project looks at the integrated processes under conditions that represent commercial-reality.
- BETO-supported capabilities at NREL at multiple scales, coupled with strong computational modeling position us to uniquely address scale-up and integration risks

1. Management

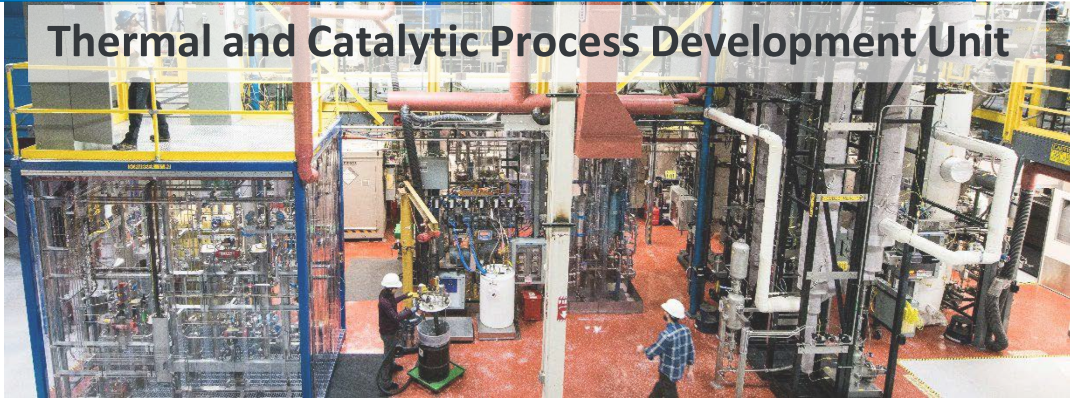
PI: David Robichaud – Externally-focused, research plan

PM: Kristin Smith – Internally-focused, managing financial/resources

Task Structure	Description	Value	Collaboration
Task 1: Develop new capabilities in TCPDU	*Commission and operate a new regenerating, recirculating, riser system in the TCPDU; support Task 3*	*New capability to investigate risks associated with recirculating catalyst technologies*	
Task 2: Scaling relationships and kinetic modeling	*Provide pilot-scale data to support new kinetic model development*	*Allows for in silico risk investigation; connects to scales beyond NREL*	CCPC, fcic, ChemCatBio
Task 3: Conduct CFP Verification experiments at pilot scale	*Conduct CFP verification campaign at pilot scale*	*Develop a strong design basis for hand-off to industry*	CCPC, fcic, ChemCatBio

1. Management

Risk Management



Safety

How do you operate H_2 above autoignition?

Approach:

1. Assigned a flammable gas code expert
2. Leverage BETO's PDU working group
   - Toured PNNL's hydrotreating facility
3. Engaged external experts
   - Hydrogen safety panel

Research

How do you make sure data is relevant to the next scale?

Approach:

1. Communication with lower TRL projects & TEA
2. Engagement with industry (e.g., I-corps interviews)
3. Stage gates and Go/no-go decision

2. Approach

Task 1: Develop new capabilities in TCPDU

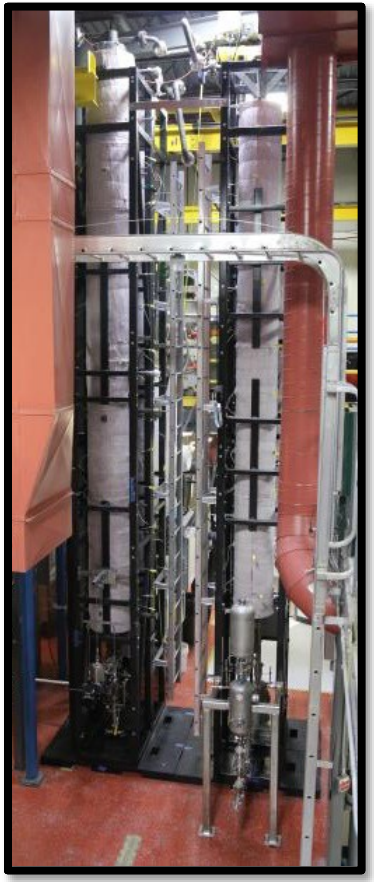
Role: Develop new capabilities that enable project to support new and diverse technologies

ID **needs** to support BETO technology objectives

Consider alternatives

Design with help (e.g. PSRI)

Build and Commission

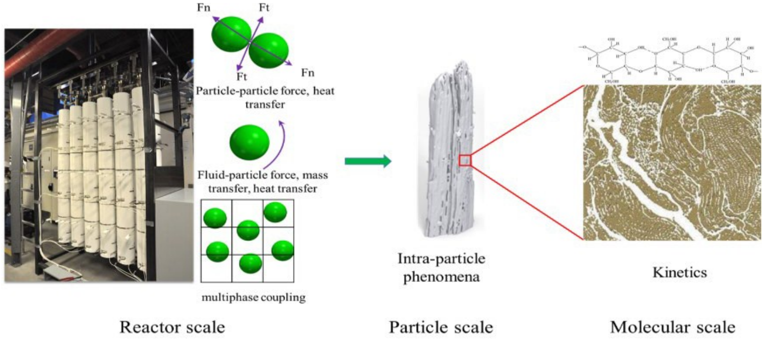


2. Approach

Task 2: Scaling relationships and kinetic modeling

Role: provide pilot-scale, integrated data to validate kinetic models

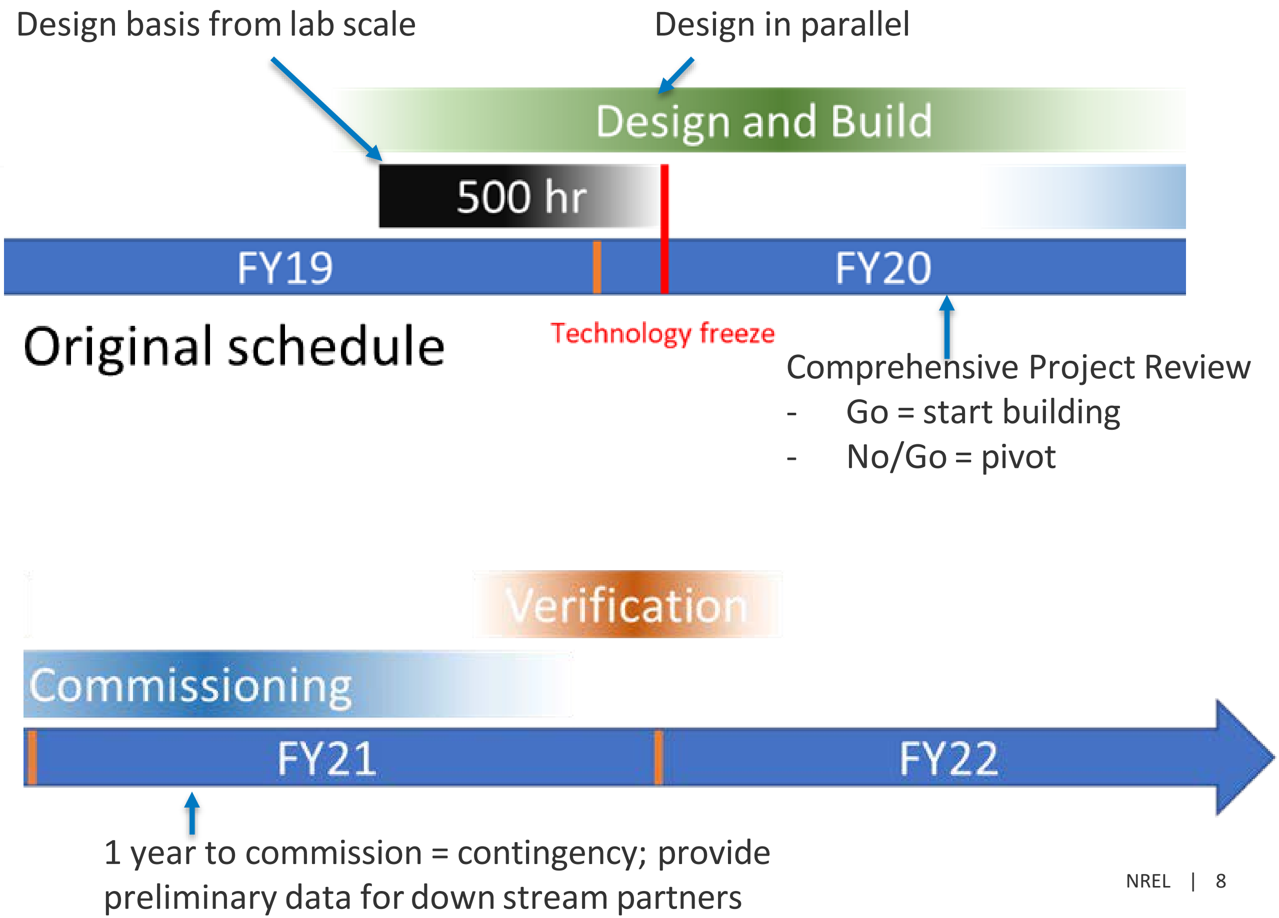
Risk	Approach
Models are only relevant on the system they are developed on	(1) Validate reactor-particle-kinetic models against selective piloting data across various scales and reactor configurations
Providing process data with modeling resolution	(1) Incorporate additional sample points and instrumentation *where they need it* (2) Modeler's visited site multiple times to understand the process, how and where data is collected, and the final quality of the data analysis



A new approach to kinetic model development: Multiscale modeling + validation across multiple reactors/scales

2. Approach

Task 3: Conduct CFP Verification experiments at pilot scale



3. Impact

Task 3: Conduct CFP Verification experiments at pilot scale

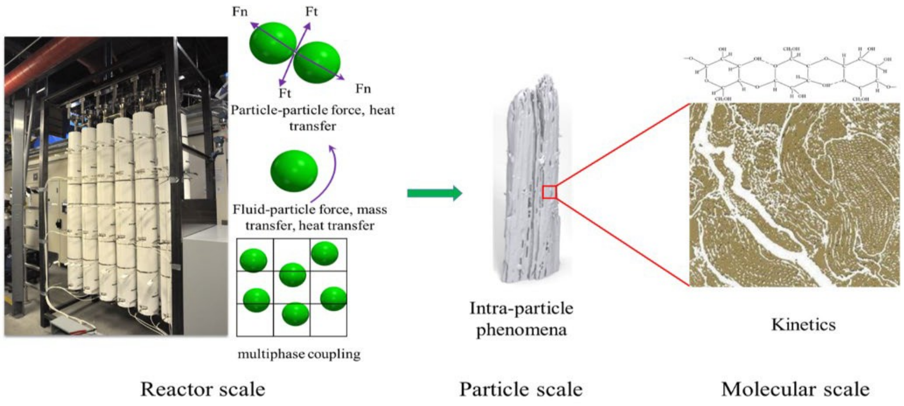
New innovation → Promising lab-scale results → ~~Pilot demo~~ → Miss performance metrics → Fail

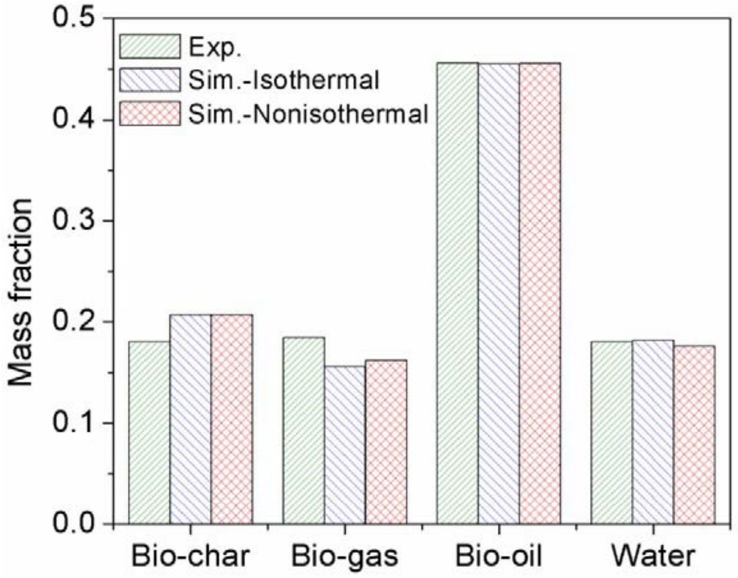
Promising lab-scale results ↓ Pivot

We disrupted the story. Failed early and pivoted to better success opportunities.

4. Progress and Outcomes

Task 2: Scaling relationships and kinetic modeling





Gao et al. Chemical Engineering Journal 2021

Multiscale modeling to investigate impact of across reactor scales

4. Progress and Outcomes

Task 1: Develop new capabilities in TCPDU	Task 2: Scaling relationships and kinetic modeling	Task 3: Conduct CFP Verification experiments at pilot scale

Goal: repurpose a packed bed reactor to support CFP verification

- Issues with regeneration at bench scale that were still being resolved;
- Experimental data was not available

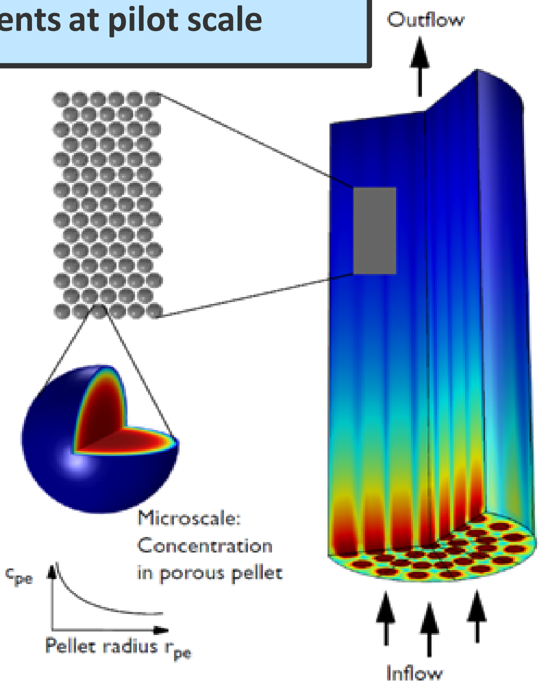


Image made using COMSOL Multiphysics® software and provided courtesy of COMSOL.[26]

Outcome: early identification of potential process disruption at the pilot scale due to thermal excursions during regeneration. Ongoing collaborative research targets alternative reactor designs to improve heat transfer capabilities at scale.

Pecha, B.; et al. *Reaction Chemistry and Engineering*, 2020

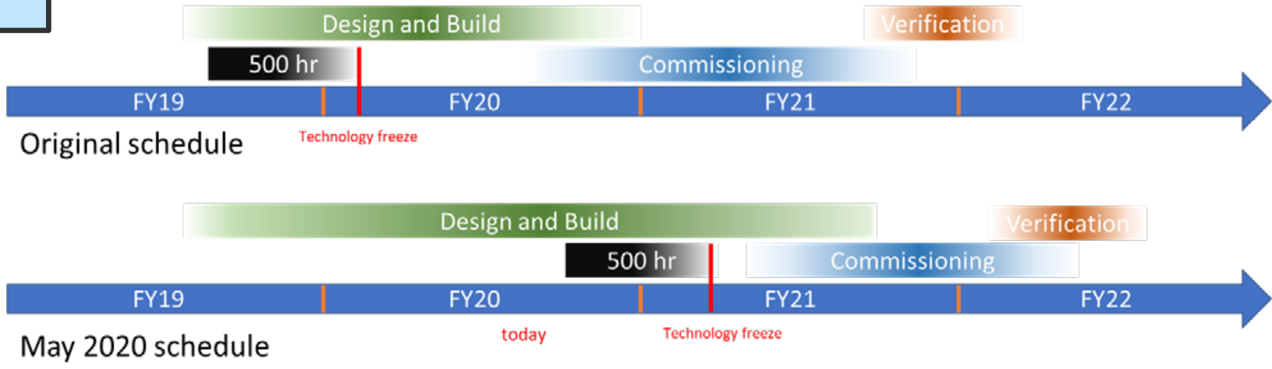
Adkins, B. D.; et.al, *Reaction Chemistry and Engineering, Submitted*

ChemCatBio Chemical Catalysis for Bioenergy · CCPC Consortium for Computational Physics and Chemistry

4. Progress and Outcomes

Task 3: Conduct CFP Verification experiments at pilot scale

- Comprehensive Project Review conducted in April 2020
- Go/no-go in June 2020



A detailed **block flow diagram** which clearly defines all inputs/outputs for pilot scale unit operations

A **process indicator matrix** that provides a row-by-row comparison across scales

An overarching **risk assessment** to identify research needs and inform forward looking decision making

Outcome: successful application of risk management strategy to inform a proactive verification pivot (**No Go**) and identify additional data needs to inform technology scale up

4. Progress and Outcomes

Path Forward: separate project from pilot plant

Project = Pilot plant

Project

- Use any system, not just PDU, to achieve project objectives
- Expand CPR and stage-gating process
- Collaborate with CFP projects (2.3.1.314) to retire risks with closeout technology

Pilot plant

- Currently in safe shutdown state
- Working with BETO to renovate facility to meet challenges in the next 5-10 years
- Energy I-corps interviews with Industry
- Risk, not scale

Summary

Product

- Anticipated decrease in gasoline/ethanol demand; diesel demand steady
- Increasing demand for aviation and marine fuel
- Demand for higher-performance products
- Increasing demand for renewable/recyclable materials

Feedstock

- Sustained low oil prices
- Decreasing cost of renewable electricity
- Sustainable waste management
- Expanding availability of green H_2
- Closing the carbon cycle

Capital

- Risk of greenfield investments
- Challenges and costs of biorefinery start-up
- Availability of depreciated and underutilized capital equipment

Social Responsibility

- Carbon intensity reduction
- Access to clean air and water
- Environmental equity

NREL's Bioenergy Program Is Enabling a Sustainable Energy Future by Responding to Key Market Needs

Value Proposition

- Generate data of the *process* to retire risks and support stronger design basis for commercial partners

Key Accomplishments

- Install a new riser capability to support recirculating catalyst technologies
- Provided integrated data to validate models
- Pivoted away from the verification campaign; now focusing on developing CPR process and supporting CFP technology close out.

Quad Chart Overview

Timeline
- October 1, 2019
- September 30, 2021

	FY20	Active Project
DOE Funding	(10/01/2018 – 9/30/2021)	(negotiated total federal share over active project)

Project Partners*
- ChemCatBio
- FCIC

Barriers addressed
ADO-A. Process Integration

ADO-D. Technology Uncertainty of Integration and Scaling

Project Goal
The objective of this effort is to support the BETO's mission of transitioning bioenergy technologies to market by derisking process integration and scale up.

End of Project Milestone
Close out CFP technology. Record risks, mitigation strategies.

Project team:
Kristin Smith
Katherine Gaston
Matt Oliver
Chris Golubieski
Ray Hansen
Danny Carpenter
Marc Pomeroy

Bioenergy Technologies Office

www.nrel.gov

NREL/PR-2800-79334

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency Bioenergy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

Transforming ENERGY