Biochemical Conversion and Lignin Utilization Portfolio Review

BETO Peer Review

8 March 2021

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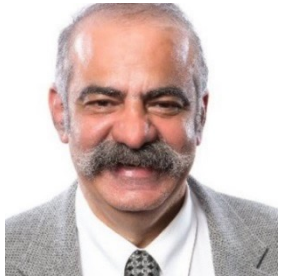
Bioenergy Technologies Office

U.S. Department of Energy

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Biochemical Conversion Review Panel

Name	Affiliation	Previous Peer Review Experience
Chris Rao (Lead Reviewer)	University of Illinois at Urbana-Champaign	2019 Panel
Charles Abbas	iBiocat	2019 Panel
Daniel Noguera	University of Wisconsin-Madison	New this year
Joseph Bozell	University of Tennessee, Knoxville	2019 Panel
Chris Gerken	ICM	New this year



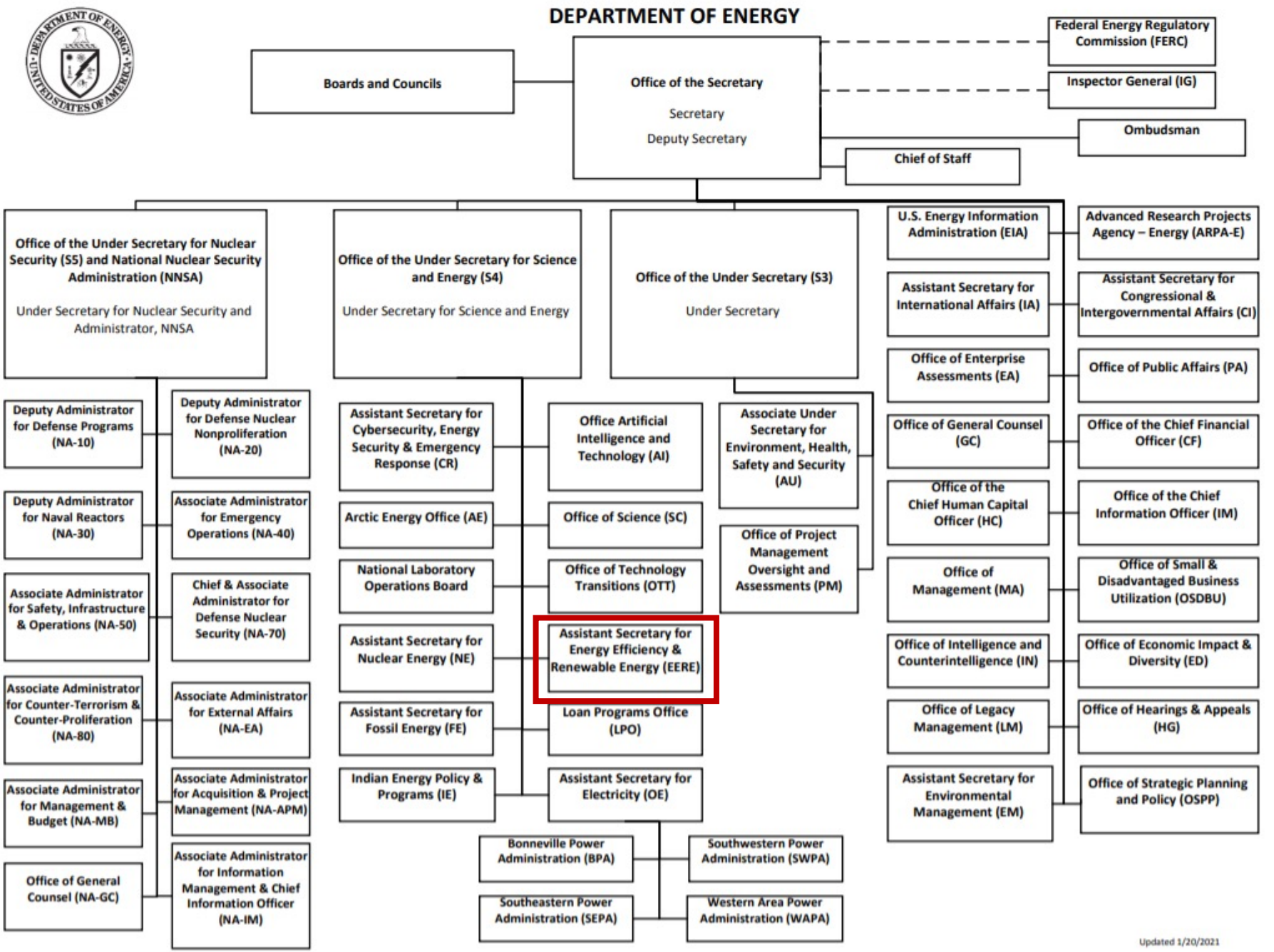
Charles

Chris G.

Daniel

Chris R.

Joseph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Secretary
Deputy Secretary
Federal Energy Regulatory Commission (FERC)
Inspector General (IG)
Ombudsman
Chief of Staff
Office of the Under Secretary for Nuclear Security (S5) and National Nuclear Security Administration (NNSA)
Under Secretary for Nuclear Security and Administrator, NNSA
Office of the Under Secretary for Science and Energy (S4)
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Southeastern Power Administration (SEPA)
Western Area Power Administration (WAPA)
Associate Under Secretary for Environment, Health, Safety and Security (AU)
Office of Project Management Oversight and Assessments (PM)
Updated 1/20/2021

BETO at a Glance

FY21 Budget Breakdown

US Department of Energy: $35B

Office of Energy Efficiency and Renewable Energy: $2.86B

Bioenergy Technologies Office: $255M

BETO at a Glance

Production & Harvesting

Feedstock Supply & Logistics
Works to reduce the cost, improve the quality, and increase the volume of sustainable feedstocks available for delivery to a conversion process.

Advanced Algal Systems
Focuses on improving the productivity of algal biomass and enhancing the efficiency of cultivation and harvesting.

Conversion & Refining

Conversion
Develops technologies to convert non-food feedstocks into biofuels, bioproducts, and biopower.

Conducts feedstock blend testing, separations, materials compatibility evaluations, and techno-economic analyses to focus research on highest impacts.

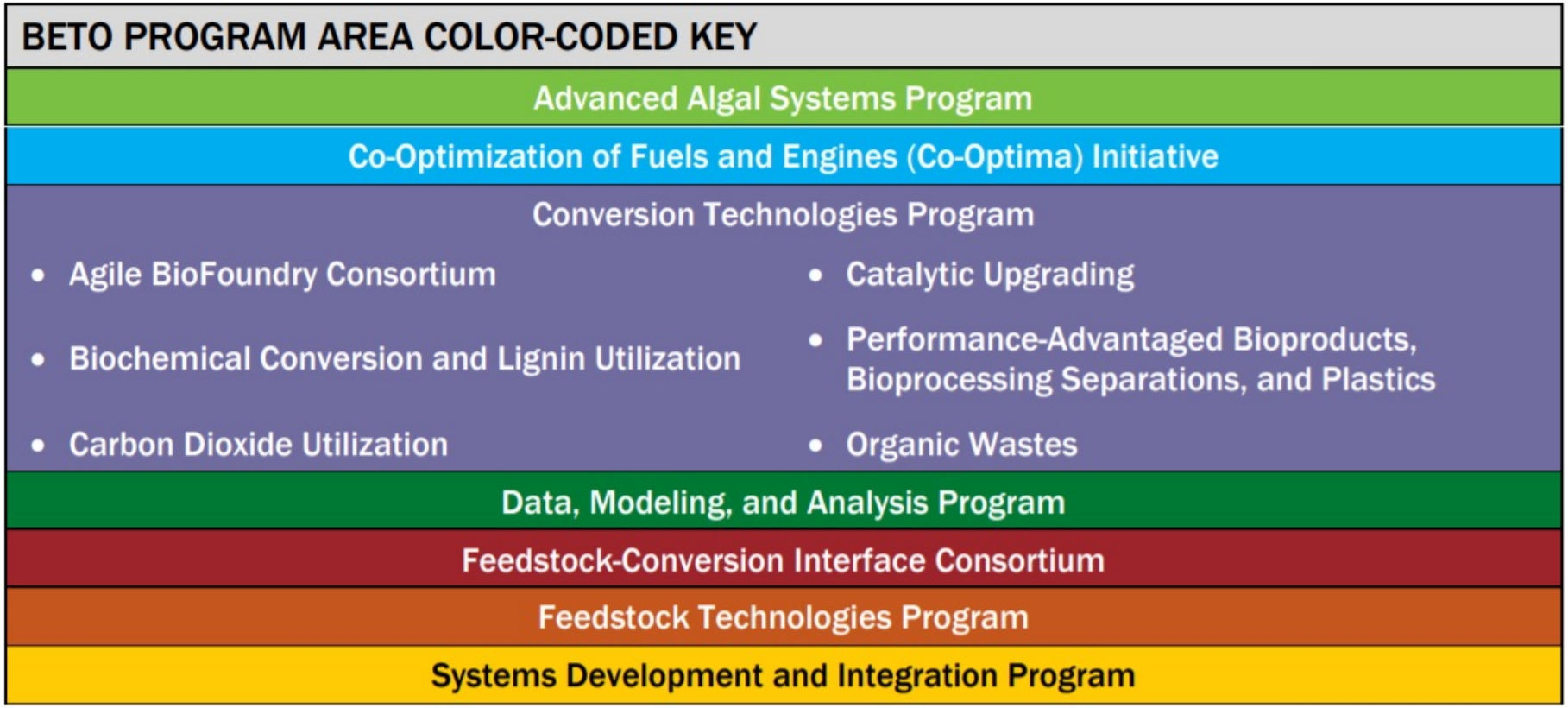
Distribution & End Use

Advanced Development and Optimization
Aims to reduce technology uncertainty in bioenergy by integrating individual technologies into a system/process and provides vital knowledge fed back to research programs.

Crosscutting

Sustainability and Strategic Analysis
Supports program decision-making and develops science-based strategies to understand and enhance the economic and environmental benefits of advanced bioenergy.

BETO at a Glance



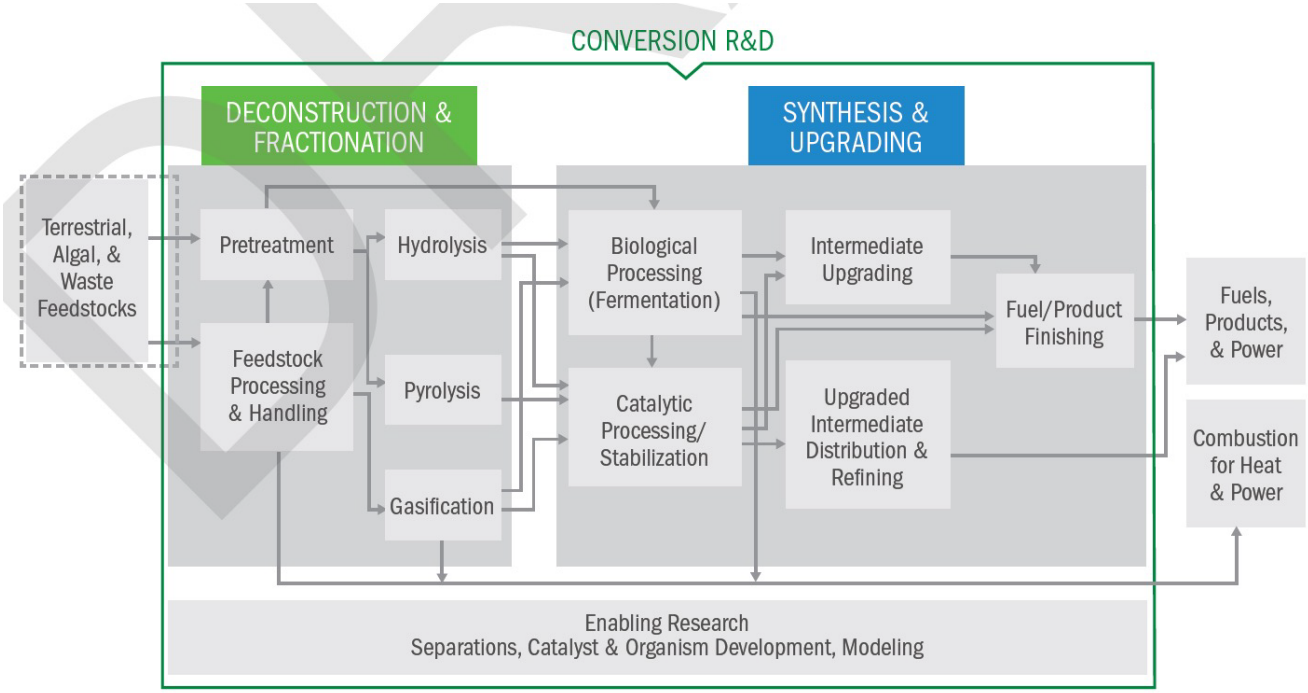
Conversion FY21 Budget: ~$110M

Biochemical Conversion and Lignin Review

Conversion R&D Strategy:

- *develop efficient and economical biological and chemical technologies to convert biomass feedstocks into energy-dense liquid transportation fuels, such as renewable gasoline, diesel, and jet fuel, as well as bioproducts, chemical intermediates, and biopower*.

- We approach the bioeconomy as a bunch of possible pathways combining process steps or unit operations that can be linked together to create a product. BETO cannot pursue all possible process permutations, and in any case, industry will pick what they need.



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Conversion Goals and Milestones

Conversion Goals:

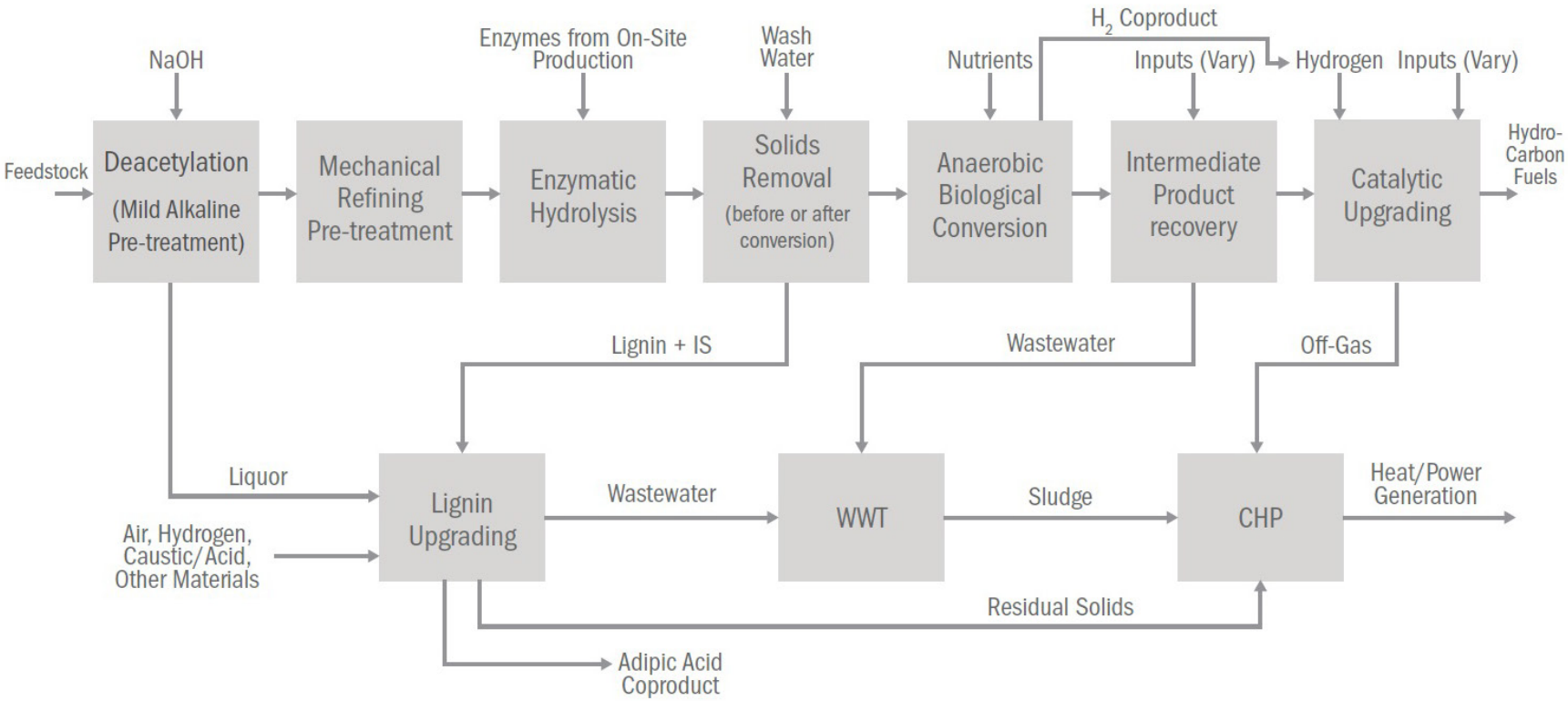
- **By 2021**, complete the research necessary to **verify in 2022 a mature modeled MFSP of $3/GGE** or less for a complete technology pathway to hydrocarbon biofuel and, where appropriate, a coproduct, with a minimum 50% reduction in emissions relative to petroleum-derived fuel.
- **By 2029**, complete the research necessary to verify integrated systems research at engineering scale for hydrocarbon biofuel technologies at **mature modeled MFSP of $2.5/GGE using economically advantaged feedstocks** to produce renewable fuels and coproducts.

Milestones toward those goals:

- **By 2020**, provide enabling capabilities in synthetic biology for industrially relevant, optimized chassis microorganisms and design-build-test-learn (DBTL) cycles for fuel and chemical production that reduce time to scale-up by at least 50% compared to the current average of ~10 years.
- **By 2024**, complete the R&D necessary to define a route to a 2030 verification of a mature modeled MFSP of $2.5/GGE or less for biomass through a conversion pathway to hydrocarbon biofuel and coproducts with a GHG emissions reduction of 50% or more compared to petroleum-derived fuel.
- **By 2025**, produce bioproducts at needed scales (20–100 kg) for product testing to support off-take agreements and end-user/market acceptance.

Biochemical Conversion Pathways

General pathway for dry feedstock conversion via Low Temperature deconstruction and biological upgrading



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Biochemical Conversion and Lignin Utilization Portfolio

In general, the projects within the portfolio can be thought of as either:

- Pathway Specific: aimed priority unit operations or key processing components (identified by BETO) that form the technology building blocks that may contribute the most significant improvements to our modeled design cases.

- Enabling Research: projects that more generally reduce the time and cost required to develop new and improved catalysts and organisms while driving conversion efficiency and develops more efficient and less expensive separations.

Also, the portfolio is generally split between two categories of projects:

- Annual Operating Plans (AOPs): agreements between DOE and the national labs, generally three years in length

- External projects via Funding Opportunity Announcements (FOAs): projects which are competitively awarded via publically announcements. Generally 2-3 years in length

Biochemical Conversion and Lignin Utilization Portfolio

16 AOP Projects, $12.4M in FY21

Project Title	Performer
Biochemical Platform Analysis Project	NREL
Low Temperature Advanced Deconstruction	NREL
Enzyme Engineering and Optimization	NREL
Continuous Enzymatic Hydrolysis Development	NREL
Biological Upgrading of Sugars	NREL
Biological Upgrading of Thermochemical Aqueous Streams	NREL
Targeted Microbial Development	NREL
Bench Scale Integration	NREL
Biochemical Process Modeling and Simulation	NREL
Analytical Methods Development and Support	NREL
Cell-Free & Immobilization Technologies	NREL
Gas phase selective partial oxidation of lignin	NREL
Synthetic metabolic pathways for bioconversion of lignin derivatives	NREL
Lignin First Biorefinery Development	NREL
Lignin Utilization	NREL
Biological Lignin Valorization	NREL

- 11 BC lab projects: $9.2M
- 5 Lignin lab projects: $3.2M

10 FOA Projects, $15.8M total

Project Title	Performer
Improving Tolerance of Yeast to Lignocellulose-derived…	MIT
Engineered reversal of the β-oxidation cycle in clostridia for the synthesis of fuels and chemicals	Northwestern University
Alkaline-Oxidative Pretreatment of Woody Biomass for Optimal Co-Product	Michigan State university
Process Intensification for the Reduced Commercial CAPEX of Biofuels Production Using Dynamic Metabolic Control	Duke
Biodiesel and higher value products from stillage fiber	Xylome
A Two-Chamber Growth and Production System for Robust Continuous Bioprocessing	Pow Genetic Solutions, Inc.
Towards Economical Cell-free Isobutanol Production	Invizyne
SPERLU Selective Process for Efficient Removal of Lignin and Upgrading	Spero Energy, Inc.
Lignin Fractionation and Valorization: Focusing on both Value and Quality	Clemson University
Upgrading Lignin-containing Biorefinery Residues for Bioplastics	Texas A & M

- 7 BC FOA projects: $11.4M
- 3 Lignin lab projects: $3.2M

Monday

Day 1 – MONDAY, MARCH 8, 2021

Start Time EST	End Time EST	BIOCHEMICAL CONVERSION & LIGNIN UTILIZATION		
		Presentation	**Organization**	**Presenter**
2:20 PM	2:30 PM	Intro to Biochemical Conversion Portfolio	*BETO*	*Ian Rowe*
2:30 PM	3:00 PM	Biochemical Platform Analysis	*NREL*	*Ryan Davis*
3:00 PM	3:30 PM	Low Temperature Advanced Deconstruction	*NREL*	*Xiaowen Chen*
3:30 PM	4:00 PM	Enzyme Engineering and Optimization	*NREL*	*Mike Himmel*
4:00 PM	4:10 PM	BREAK		
4:10 PM	4:40 PM	Continuous Enzymatic Hydrolysis Development	*NREL*	*Jim McMillan*
4:40 PM	5:10 PM	Biological Upgrading of Sugars	*NREL*	*Jeff Linger*
5:10 PM	5:40 PM	Biological Conversion of Thermochemical Aqueous Streams	*NREL*	*Gregg Beckham*
5:40 PM	6:10 PM	**Reviewer Wrap Up and Debrief**	***Reviewers***	

Wednesday

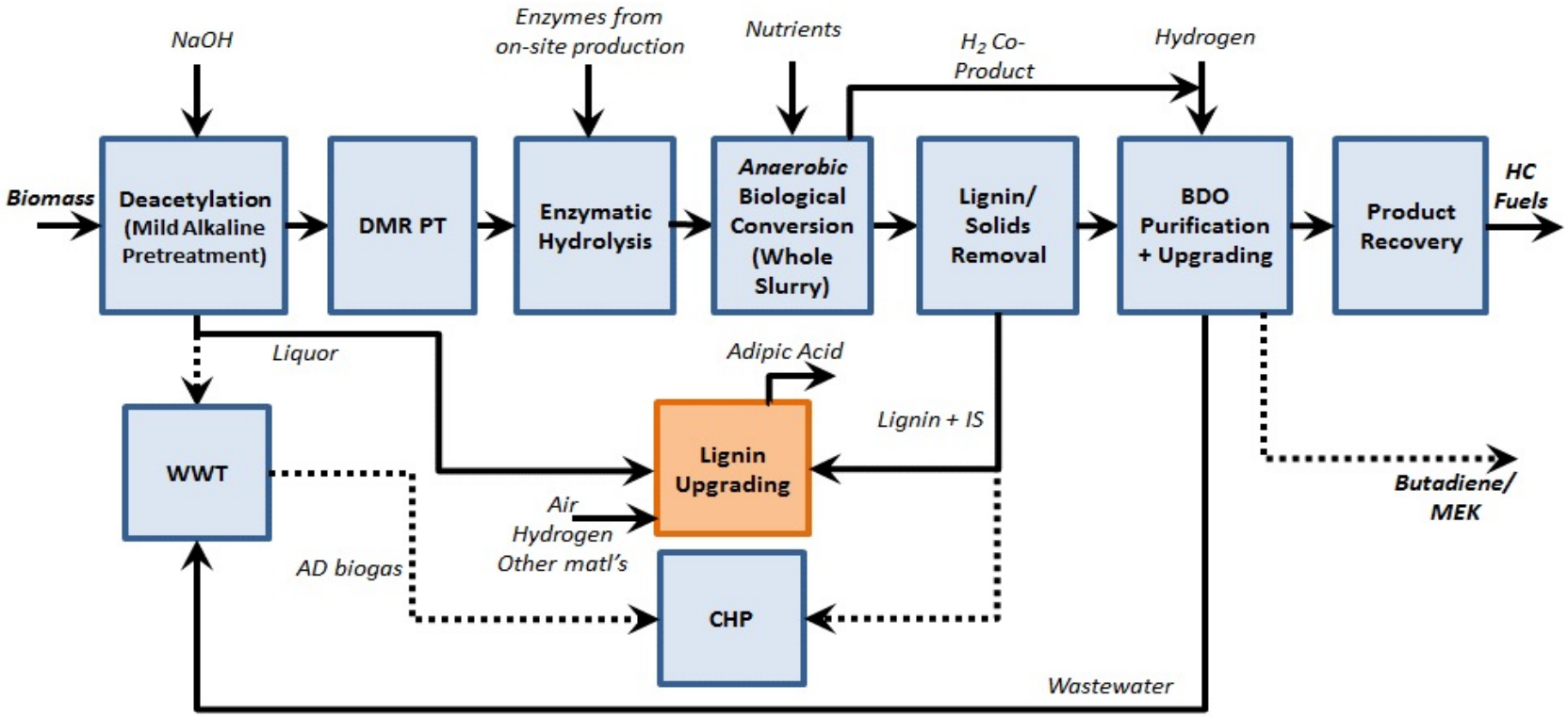
Day 3 – WEDNESDAY, MARCH 10, 2021

Start Time EST	End Time EST	BIOCHEMICAL CONVERSION & LIGNIN UTILIZATION		
		Presentation	**Organization**	**Presenter**
10:00 AM	10:30 AM	GATHER, TECH CHECK, NETWORKING QUESTIONS		
10:30 AM	4:50 PM	**Biochemical Conversion & Lignin Utilization**	***Conversion Program***	***Ian Rowe***
10:30 AM	10:40 AM	Intro to competitive projects	*BETO*	*Technology Area POC*
10:40 AM	11:10 AM	Improving tolerance of yeast to lignocellulose-derived feedstocks and products	*Massachusetts Institute of Technology*	*Dr. Greg Stephanopoulos*
11:10 AM	11:20 AM	Engineered reversal of the β-oxidation cycle in clostridia for the synthesis of fuels and chemicals	*Northwestern University*	*Micheal Jewett*
11:20 AM	11:35 AM	BREAK		
11:35 AM	12:05 PM	Alkaline-Oxidative Pretreatment of Woody Biomass for Optimal Co-Product	*Michigan State University*	*Eric Hegg*
12:05 PM	12:35 PM	Process Intensification for the Reduced Commercial CAPEX of Biofuels Production (PRICE CAP) Using Dynamic Metabolic Control	*Duke University*	*Michael Lynch*
12:35 PM	1:35 PM	LUNCH		
1:35 PM	2:05 PM	Biodiesel and higher value products from stillage fiber	*Xylome Corporation*	*Thomas Jeffries*
2:05 PM	2:35 PM	A Two-Chamber Growth and Production System for Robust Continuous Bioprocessing	*Pow Genetic Solutions, Inc.*	*Ouwei Wang*
2:35 PM	3:05 PM	Towards Economical Cell-free Isobutanol Production	*Invizyne Technologies, Inc*	*Tyler Korman*
3:05 PM	3:20 PM	BREAK		
3:20 PM	3:50 PM	SPERLU Selective Process for Efficient Removal of Lignin and Upgrading	*Spero Energy, Inc.*	*Ian Klein*
3:50 PM	4:20 PM	Lignin Fractionation and Valorization: Focusing on both Value and Quality	*Clemson University*	*Mark Thies*
4:20 PM	4:50 PM	Upgrading Lignin-containing Biorefinery Residues for Bioplastics	*Texas A&M*	*Joshua Yuan*
4:50 PM	5:20 PM	**Reviewer Wrap Up and Debrief**	***Reviewers***	

Tuesday

Day 2 – TUESDAY, MARCH 9, 2021				
10:00 AM	10:30 AM	GATHER, TECH CHECK, NETWORKING QUESTIONS		
10:30 AM	5:10 PM	**Biochemical Conversion & Lignin Utilization**	***Conversion Program***	***Ian Rowe***
10:30 AM	11:00 AM	Targeted Microbial Development	*NREL*	*Min Zhang*
11:00 AM	11:30 AM	Bench Scale Integration	*NREL*	*Nancy Dowe*
11:30 AM	12:00 PM	Biochemical Process Modeling and Simulation	*NREL*	*Yannick Bomble*
12:00 PM	12:15 PM	BREAK		
12:15 PM	12:45 PM	Analytical Development and Support	*NREL*	*Justin Sluiter*
12:45 PM	1:15 PM	Cell Free & Immobilization Technologies (CFIT)	*NREL*	*Yannick Bomble*
1:15 PM	1:45 PM	Gas phase selective partial oxidation of lignin for co-products	*NREL*	*Matthew Yung*
1:45 PM	2:45 PM	LUNCH (REVIEWER LUNCH TOGETHER, PUBLIC ON THEIR OWN)		
2:45 PM	2:55 PM	Introduction to Lignin portfolio	*BETO*	*Ian Rowe*
2:55 PM	3:25 PM	Synthetic Metabolic Pathways for Bio-conversion of Lignin Derivatives to Biofuels	*ORNL*	*Adam Guss*
3:25 PM	3:55 PM	Lignin Utilization	*NREL*	*Gregg Beckham*
3:55 PM	4:10 PM	BREAK		
4:10 PM	4:40 PM	Lignin First Biorefinery Development	*NREL*	*Gregg Beckham*
4:40 PM	5:10 PM	Biological Lignin Valorization	*NREL*	*Davinia Salvachua*
5:10 PM	5:40 PM	**Reviewer Wrap Up and Debrief**	***Reviewers***	

Lignin Valorization Key to Biochemical Conversion Design Cases



Lignin Valorization Key to Biochemical Conversion Design Cases