U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Biochemical Conversion / Lignin Utilization – Day 1

Beau Hoffman, Lisa Guay

Biochemical Conversion / Lignin Utilization Conversion Peer Review Panel

Name	Affiliation	Previous Peer Review Experience
Lisette Akers (Lead Reviewer)	LignoBio	
Xianglan Bai	Iowa State University, Dept of Mechanical Engineering	
Genevieve Croft	Schmidt Futures	
Jeffrey Dietrich	Rarebird	
Chris Rao	University of Illinois, Dept of Chemical and Biomolecular Eng.	’21, ‘19

Housekeeping

Format:

- Each presentation is 20 minutes
  + 5 minutes of panel Q&A
  + 5 minutes of audience Q&A

- Ryan Lawrence will be giving time checks
  (10 min, 5 min, 1 min remaining)

- Please do not take photos
  (ALL presentations will be posted publicly)

Peer Review Agenda – Day 1

DAY 4 – Thursday, April 6, 2023					
8:00 AM	*10:00 AM*	*120*	*Registration, Breakfast, Plenary*	*All*	
10:00 AM	10:15 AM	15	Technology Area Daily Intro	BETO	
10:15 AM	10:45 AM	30	Biochemical Platform Analysis	NREL	Ryan Davis
10:45 AM	11:15 AM	30	Biochemical Process Modeling and Simulation	NREL	Yannick Bomble
11:15 AM	11:45 AM	30	Analytical Development and Support	NREL	Justin Sluiter
11:45 AM	*1:00 PM*	*75*	*Lunch*	*All*	
1:00 PM	1:30 PM	30	Lignin First Biorefinery Development	NREL	Gregg Beckham
1:30 PM	2:00 PM	30	Lignin Conversion to Sustainable Aviation Fuel Blendstocks	NREL	Gregg Beckham
2:00 PM	2:30 PM	30	Lignin Utilization	NREL	Gregg Beckham
2:30 PM	*2:50 PM*	*20*	*Break*	*All*	
2:50 PM	3:20 PM	30	Biological Lignin Valorization	NREL	Davinia Salvachua
3:20 PM	3:50 PM	30	SPERLU Selective Process for Efficient Removal of Lignin and Upgrading	Spero Renewables, LLC	Ian Klein
3:50 PM	4:20 PM	30	Recyclable Thermoset Polymers from Lignin Derived Phenols	Spero Renewables, LLC	Ian Klein
4:20 PM	*5:00 PM*	*40*	*Closed Door Comment Review Session*	*Reviewers*	

Analysis/Crosscutting Activities

Lignin Valorization

BETO’s Strategy for Today’s Presentations

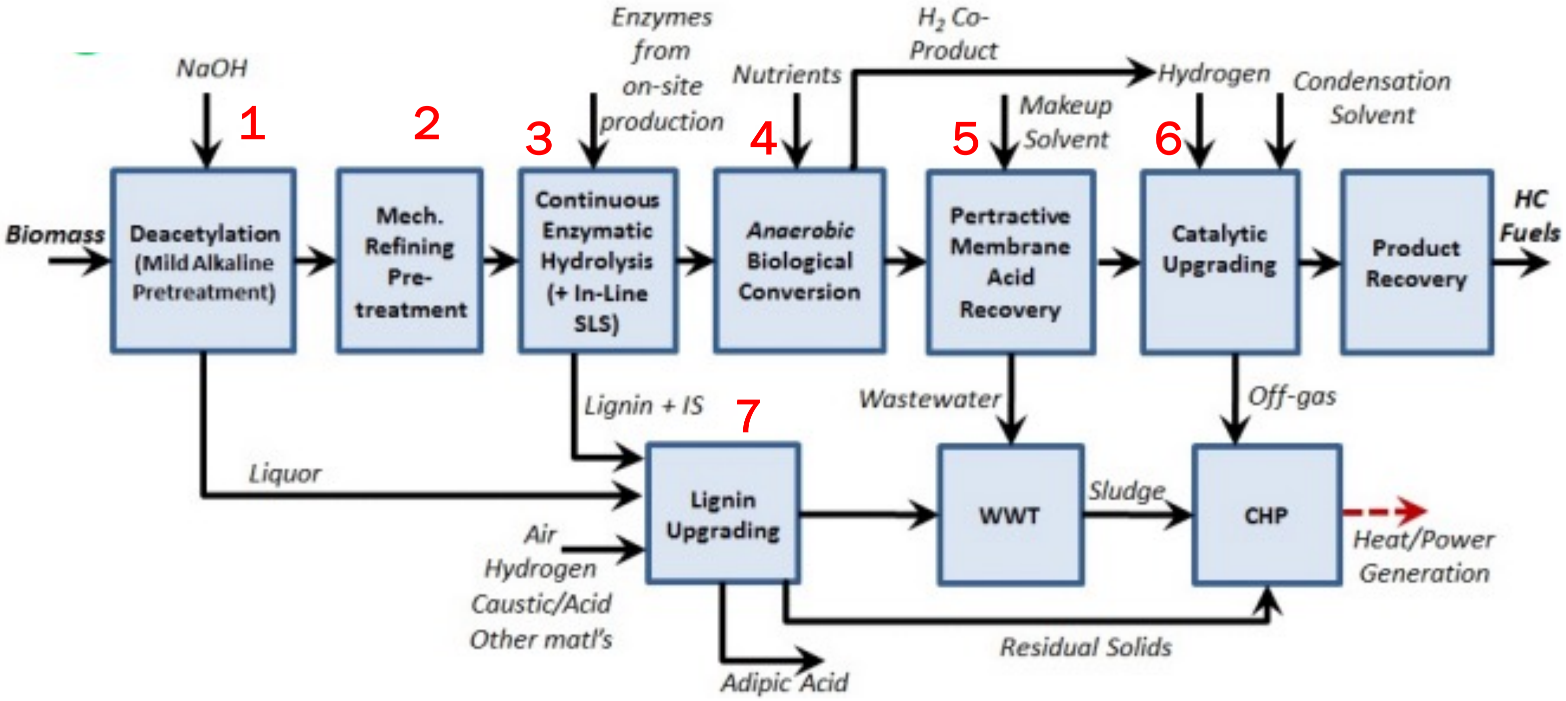
Lignin Deconstruction/Upgrading

Goal: >54% upgradable products from Lignin by 2030

- Deconstruction and depolymerization
  - Lignin First, Lignin Utilization, SPERLU
- Conversion of lignin oils to liquid fuels
  - Lignin to SAF
- Valorization of lignin-derived monomers to high value products
  - Biological Lignin Valorization, Spero Recyclable Thermoset

- Two approaches to lignin
  - Lignin to Products
  - Lignin to Fuels

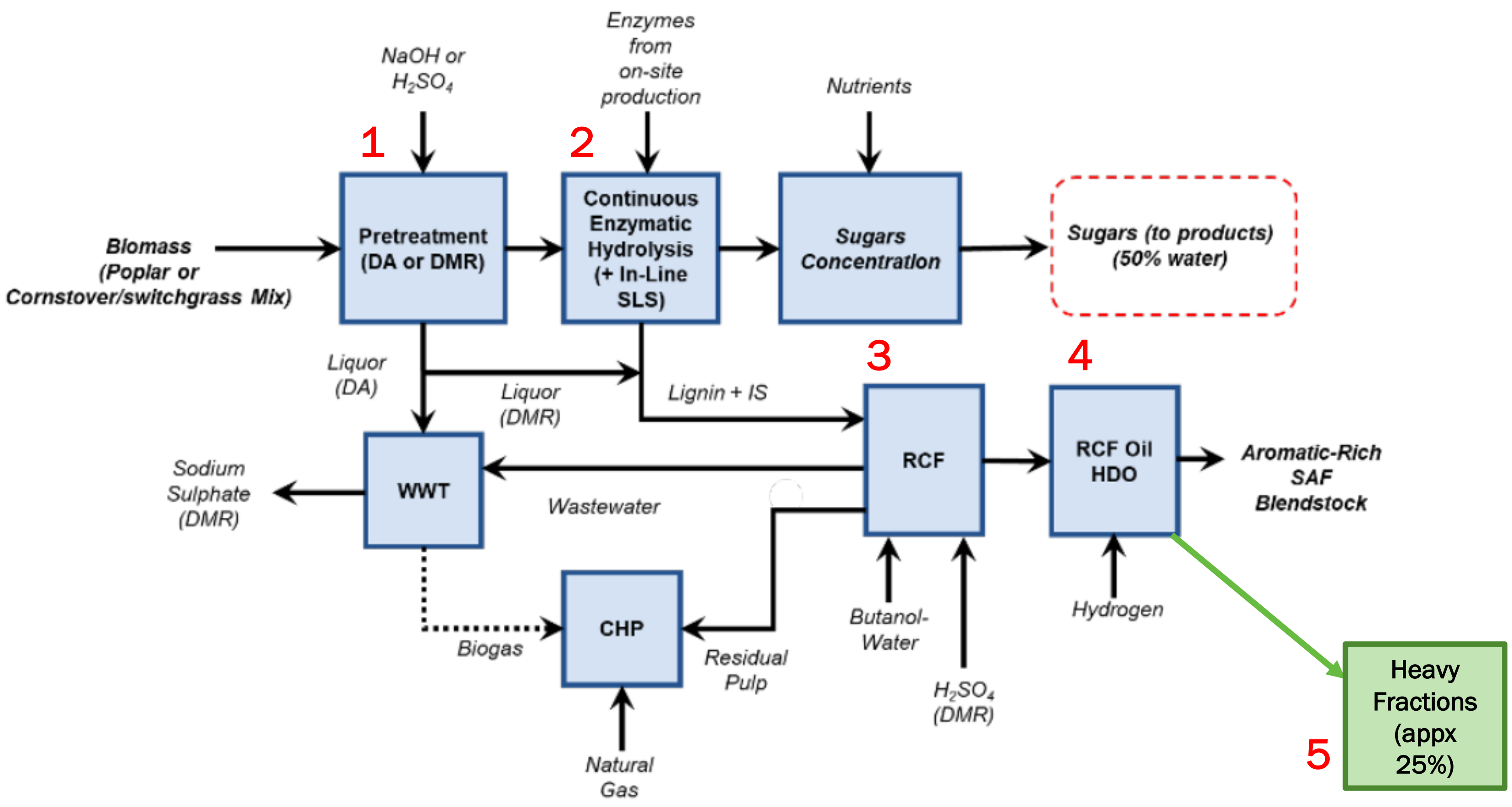
Sugars to Fuel Pathways (Lignin to Products)



Sunsetted
Active (this session)
Active (other session)

1 Low Temperature Advanced Deconstruction, NREL DMR-CRF, SAFFIRE Project
2 Low Temperature Advanced Deconstruction, NREL DMR-CRF, SAFFIRE Project
3 Cont. Enzy. Hydrolysis, EEO
4 Biological Upgrading of Sugars
5 Biological Upgrading of Sugars, Quasar FOA Project
6 CUBI, Alder FOA Project
7 Lignin Utilization, Sepcon CCC Task, Lignolix FOA Project, Biological Lignin Valorization, Sperlu Enzymatic lignin deconstruction, Electrocatalytic depolymerization

Sugars to Products (Lignin to Fuels)



Sunsetted
Active (this session)
Active (other session)

1 Low Temperature Advanced Deconstruction
2 Cont. Enzy. Hydrolysis, EEO
3 Lignin-First, Spero FOA Project
4 LigSAF
5 Lignin Utilization, Biological Lignin Valorization

Relevant FOAS / Funding Opportunities

Lignin FOAs

- Lignin Utilization (FY18)
- Designing Recyclable Plastics (FY19

Lab Call

- Internal Lignin upgrading/deconstruction

>50% utilization of lignin
>10% increase in recyclable content
>10% increase in bioproduct performance*

Spero Projects
Lignolix**
Separations Consortium**

NREL Lignin Projects

*Relative to an appropriate benchmark technology
**Not presenting today

A New Funding Opportunity Announcement is Live!

BETO's Conversion Team has announced their 2023 R&D FOA.

$14,000,000 Available to support projects from 2 topic areas:

Topic Area 1: Overcoming Barriers to Syngas Conversion

- ✓ Improve economics and operation of gasification-based SAF production
- ✓ Overcome barriers such as: feedstock preprocessing, optimizations that ameliorate downstream cleanup, process intensification, etc

Topic Area 2: Overcoming Barriers to Biochemical Products

- ✓ Produce renewable, low carbon chemicals that replace petrochemicals.
- ✓ Biological conversion of waste and renewable feedstocks to chemical products
- ✓ Achieve significant GHG reductions
- ✓ Specific emphasis on near term commercialization.

Teaming list is available to facilitate partnering for both topic areas! Visit EERE Exchange to Sign up

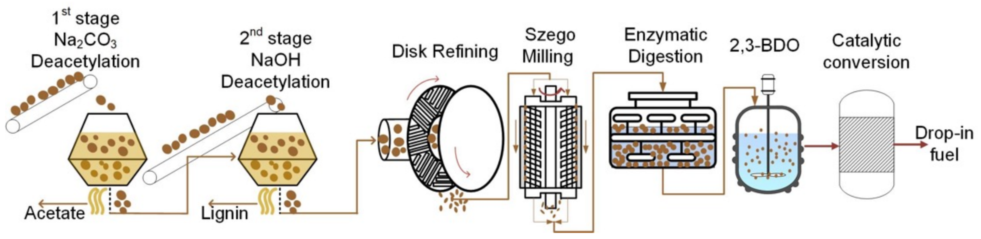
2021 Peer Review Feedback

Recommendations:

1) Increase use of LCA to guide research
2) Greater transparency in TEA methodology/assumptions
3) Clarify emphasis on DMR investments
4) Build a balance of early stage and deployment

Increase use of LCA to guide research

Examples of LCA analyses that are informing R&D priorities



	GHG* (CO_2e/kg)	Fossil Energy (MJ/kg)	Total Energy (MJ/kg)	Cost ($/lb)
NaOH (100%)	2.1	28.9	32.3	0.24
Na_2CO_3 (100%)	0.7	5.93	5.94	0.08

*The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model (GREET)


USDRIVE
DRIVING RESEARCH AND INNOVATION FOR VEHICLE EFFICIENCY AND ENERGY SUSTAINABILITY

U.S. DRIVE Net-Zero Carbon Fuels Technical Team Analysis Summary Report 2020

September 2021

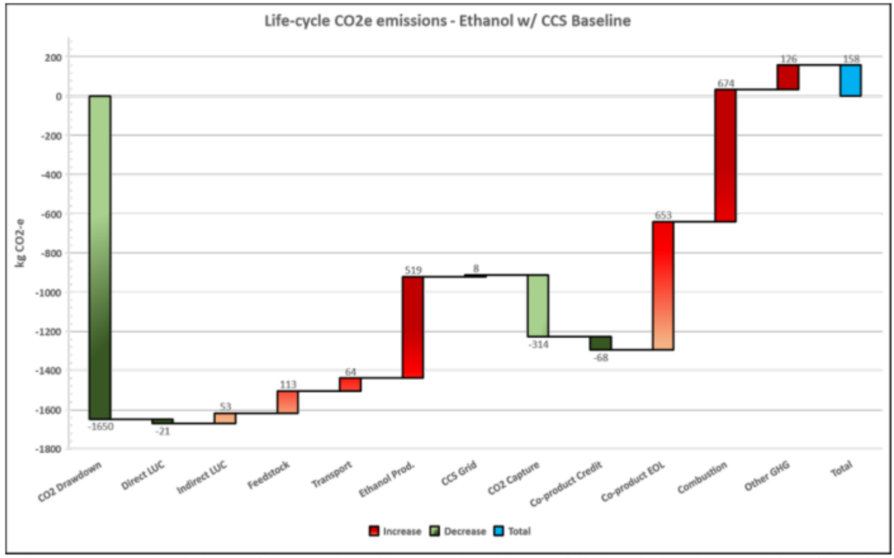


Figure 6. LCA carbon balance of fermentation with CCS only.

Topic Area 2: Affordable, Clean Cellulosic Sugars for High Yield Conversion Overview

Topic Area 2 Specific Requirements

- GHG emissions tracked in gCO2e/lb sugars;
- Water consumption tracked in gallons water/lb sugars; and
- Carbon intensity of the process

TEA Methodology

Examples of standardized assumptions and publicly available TEA tools

Biorefinery Analysis Process Models

NREL Transforming ENERGY

THIS PAGE IS TO DISTRIBUTE THIS INFORMATION TO THE PUBLIC
To save files to local computer, right click on link and choose "Save Target As...". For Aspen Plus BKP files, replace ".tiff" file name extension with ".bkp".

NOTICE: All information on this page is subject to a disclaimer.

Last Updated: November 2018

Algae Production via Open Pond Cultivation: NREL Algae Farm Model (Excel TEA Tool)

Contacts: Ryan Davis and Jennifer Clippinger

2016 Algae Farm Design Report of Davis et al. [PDF]

- Excel Spreadsheet

NREL 2017 Biochemical Sugar Model

Contacts: Ling Tao and Ryan Davis

- BKP File (Built in Aspen Plus V7.2)
- Excel Spreadsheet
- Readme Summary Sheet

Process Design for Biochemical Conversion of Biomass to Ethanol (2002 and 2011 Design Reports)

Contacts: Ling Tao and Ryan Davis

2011 Design Report of Humbird et al. [PDF]

DW1102A — Files supporting the 2011 Design Report

Tables in the spreadsheet may differ slightly from those in the report due to small errors corrected after publication.

- BKP File (Requires Aspen Plus V7.2; does not require NREL databanks or Fortran compiler)
- Excel Spreadsheet with Macros (Requires Excel 2007 or later)

DW1107A – Direct Port of DW1102A to Aspen Plus V7.3

- BKP File (Requires Aspen Plus V7.3)
- Excel Spreadsheet with Macros (Requires Excel 2007 or later)

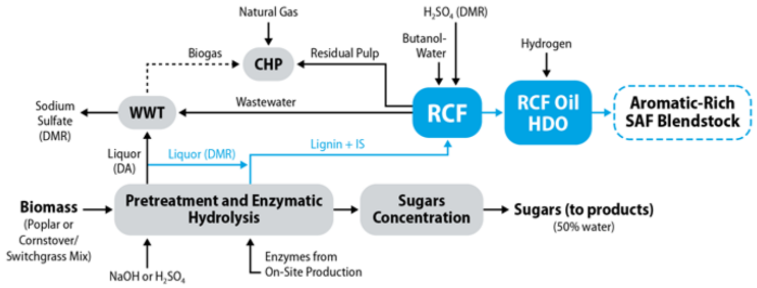
Biorefinery Analysis Process Models | NREL

Topic Area 2: Affordable, Clean Cellulosic Sugars for High Yield Conversion Overview

Topic Area 2 Specific Requirements

- Provide a techno-economic analysis to calculate the minimum sugar selling price including:
  - Cost of enzyme production and/or purchase
  - Capital and operating costs to produce monomeric sugars
  - Assuming a delivered feedstock cost of $86/ton

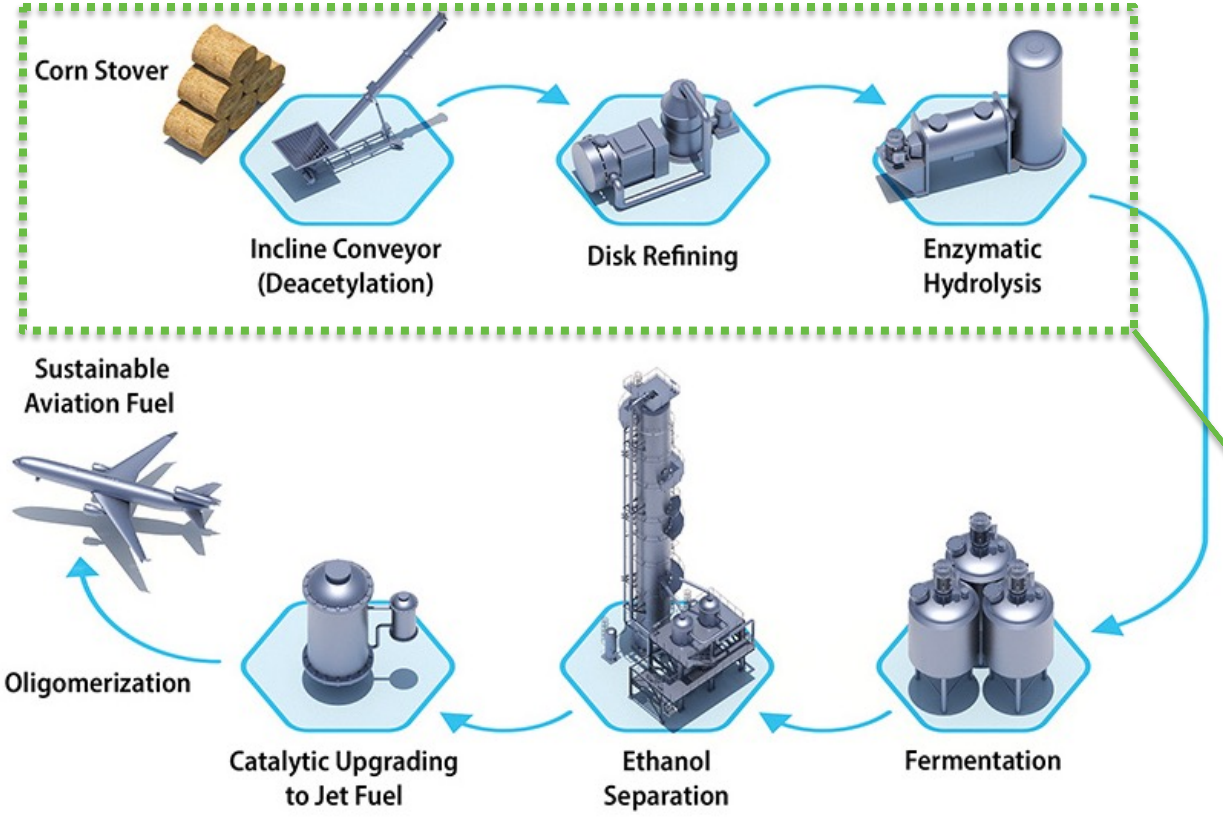
Increased emphasis on "smaller system boundary" TEA



Case	Feedstock	Pretreatment and enzymatic hydrolysis	Minimum sugars selling price ($/kg)	GHG emissions[1] (gCO_2e/MJ SAF)	GHG emission reduction
1	Poplar	DAP-EH	0.33	19	77%
2	Corn stover	DAP-EH	0.37	16	81%
3	Poplar	DMR-EH	0.53	35	59%
4	Corn stover	DMR-EH	0.60	39	54%

Why the Emphasis on DMR?

Deacetylation and Mechanical Refining (DMR)



electrek

Southwest Airlines is investing in a sustainable aviation fuel pilot program

Michelle Lewis | Jun 3 2022 - 3:02 pm PT | 0 Comments

DALLAS INNOVATES

Southwest Airlines Invests in Startup That's Turning Corn Waste into Jet Fuel

As part of a Department of Energy-backed effort, Dallas-based Southwest Airlines is investing in SAFFiRE Renewables, a new startup that aims to turn corn waste into sustainable aviation fuel.

BIOMASS MAGAZINE

Biden administration takes action to expand SAF production, use

By Erin Voegele | September 09, 2021

BETO investments in the Pretreatment and Process Hydrolysis and Low-Temperature Advanced Deconstruction Projects 2014-2022

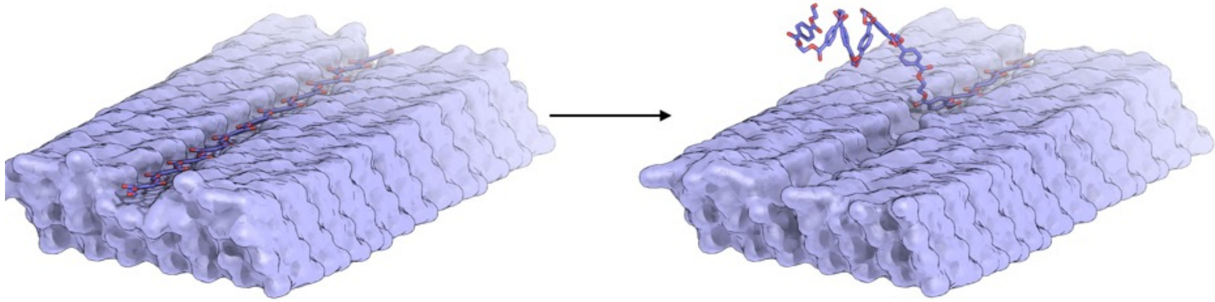
D3MAX advancebio SYSTEMS LLC LanzaJet NREL NATIONAL RENEWABLE ENERGY LABORATORY

Ensure a Balance of Early and Applied TRL Work

"Therefore, this should not become an either/or for fundamental research versus applied science and large-scale demonstrations. The most powerful combination of activities for BETO would be the retention of the strong scientific program that BETO has built while advocating for new projects to support what appears to be a strong administration interest in large-scale demonstration."
-2021 Biochemical Conversion and Lignin Utilization Panel

Examples of fundamental R&D that are critical for applied R&D projects:

Analysis/Crosscutting Activities

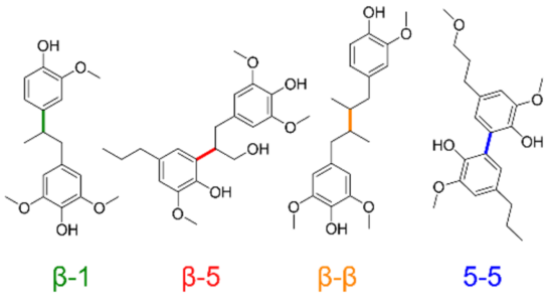


Polymer chain in crystal surface — Polymer chain extracted from surface

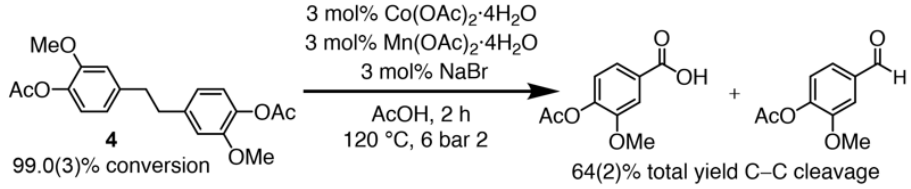
Molecular dynamics based procedure to compute the free energy to decrystallize a single chain.
Decrystallization is the first step in many depolymerization processes, including biological routes (e.g. PETase).

Lignin Utilization

Exemplary C-C bonds in lignin that catalytic approaches must cleave



Exemplary C–C bonds in lignin that catalytic approaches must cleave



Gu, Palumbo, Bleem *et al. in review*

Questions

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