Harnessing the Bioeconomy for Carbon Drawdown: Potential and Innovation Needs

This presentation does not contain any proprietary, confidential, or otherwise restricted information

March 5, 2019
Analysis and Sustainability

A.J. Simon
Lawrence Livermore National Laboratory

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

Lawrence Livermore National Laboratory

Project Goal

- The goal of this project is to compare the technical and economic potential of bioeconomy pathways to draw down carbon dioxide (CO_2) from the atmosphere. Potential pathways include:
  - Bio-power with CO_2 capture and sequestration (CCS)
  - Biofuels with process CCS
  - Bioplastics and other chemical products
  - Biochar and agricultural practices

- This is a preliminary (one year) analysis project with the following objectives:
  - Qualitative meta-analysis of the fast-evolving field of proposed bioeconomy-enabled carbon drawdown pathways on the basis of supply, demand and technical readiness
  - Quantitative analysis of 4 - 5 selected pathways on the basis of CO_2 drawdown potential, including cost and environmental impacts on a per-unit carbon basis

In a carbon-constrained economy, fossil carbon starts out at a disadvantage, whereas bio-carbon based technologies start negative. Evaluating bioeconomy pathways through the lens of carbon management can inform R&D, investment and policy.

Project Status

Timeline

- Project Start: October, 2018
- Project end: October, 2019
- Percent complete: 33%

	Total Costs Pre FY17 **	FY 17 Costs	FY 18 Costs	Total Planned Funding (FY 19-Project End Date)
DOE Funded	N/A	N/A	N/A	$160k
Project Cost Share*	N/A	N/A	N/A	N/A

Barriers addressed

At-A. Comparable, Transparent, and Reproducible Analyses: Analysis results are strongly influenced by the datasets employed, as well as by the assumptions and guidelines established to frame the analysis. Standardized datasets, assumptions, and guidelines are needed to compare and integrate analysis results.

Objective

Compare the technical and economic potential of bioeconomy pathways to draw down carbon dioxide from the atmosphere

End of Project Goals

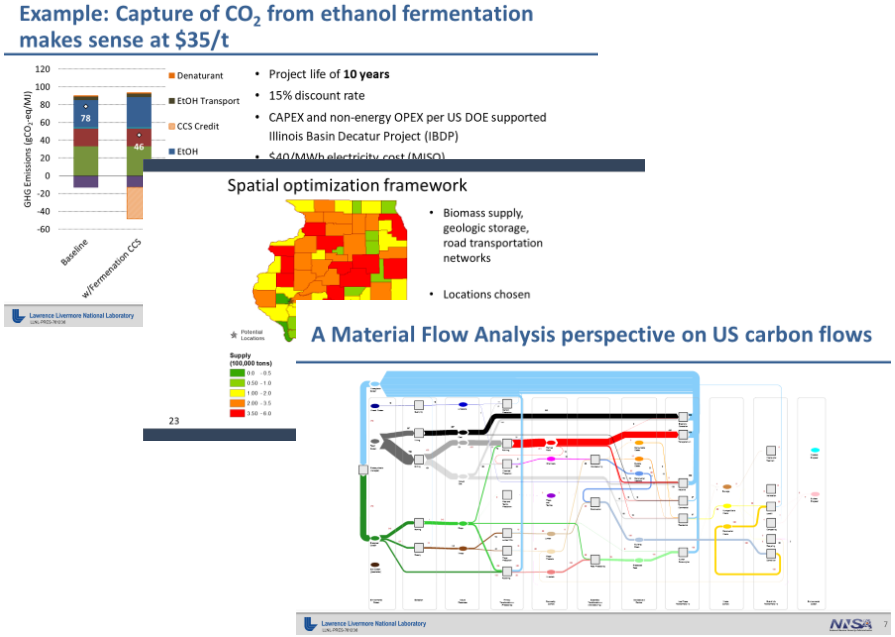
Qualitative meta-analysis of the fast-evolving field of proposed bioeconomy-enabled carbon drawdown pathways on a supply, demand and technical readiness basis.

Quantitative analysis of 4 - 5 selected pathways on the basis of carbon dioxide drawdown potential, including cost and environmental impacts on a per-unit carbon basis

Project Overview

- The field of carbon drawdown is evolving quickly and consistent assessment of diverse approaches is lacking.

- LLNL and UC Berkeley are uniquely poised to integrate deep subject matter expertise with broad systems analysis capability to advance the field



Approach (Management)

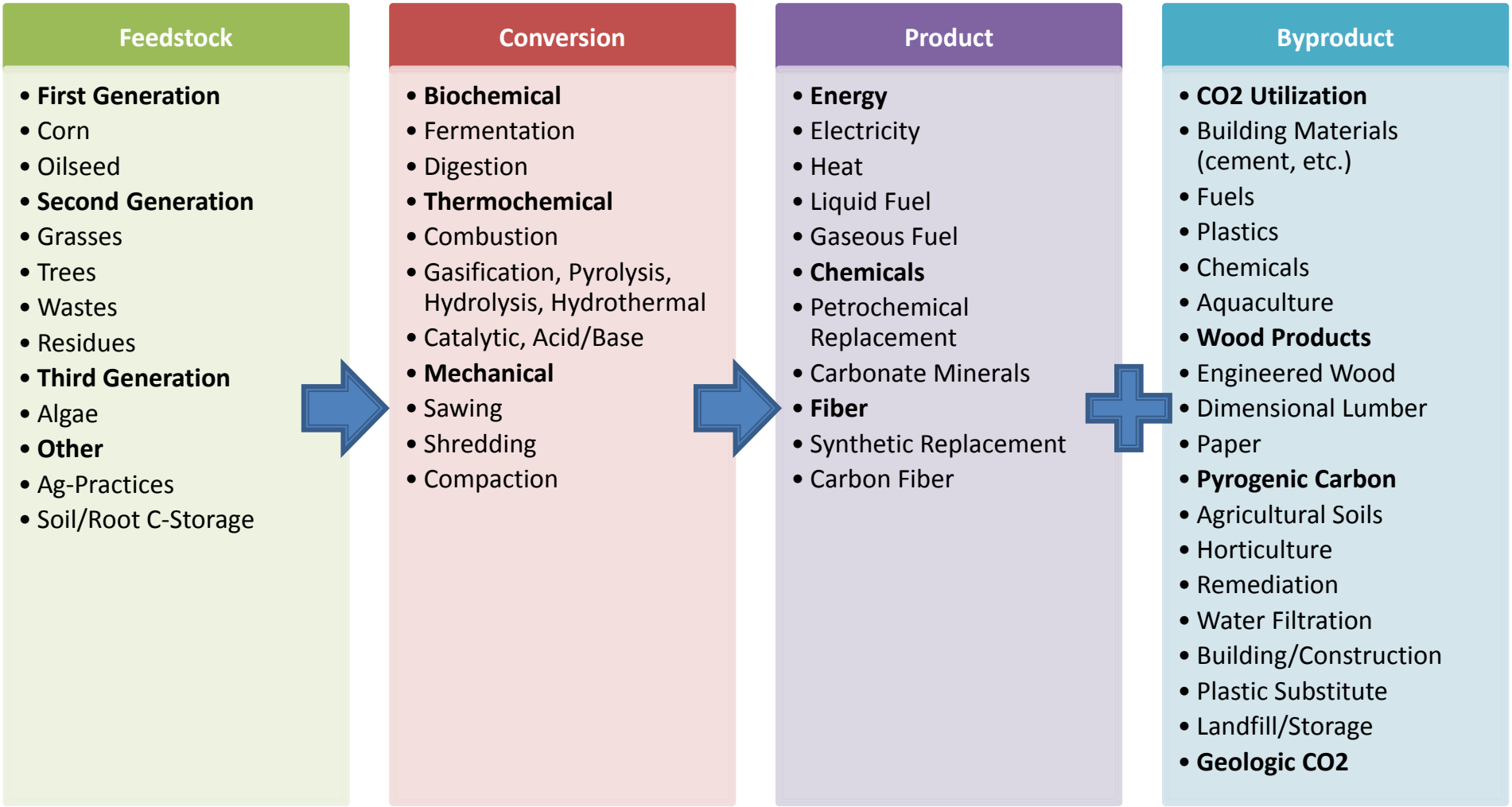
- This project is a collaboration between LLNL (prime) and UC Berkeley (subcontract). It combines the systems analysis expertise at LLNL with the subject matter expertise at Berkeley
  - LLNL is responsible for project management, reporting, strategic direction, LCA structure and coordination with DOE and other Carbon Drawdown projects
  - UC Berkeley is responsible for intellectual leadership, literature review and detailed LCA calculations.

- This project is *complementary* to Oak Ridge National Laboratory's (ORNL) "Bioeconomy Carbon Flux Assessment – BECCS"
  - LLNL is enumerating and assessing the full breadth of bioeconomy-enabled carbon drawdown pathways without regard to geospatial and market variability
  - ORNL is analyzing the supply curve for a single pathway, taking into account geospatial and other factors, to determine its carbon drawdown potential under various market conditions.

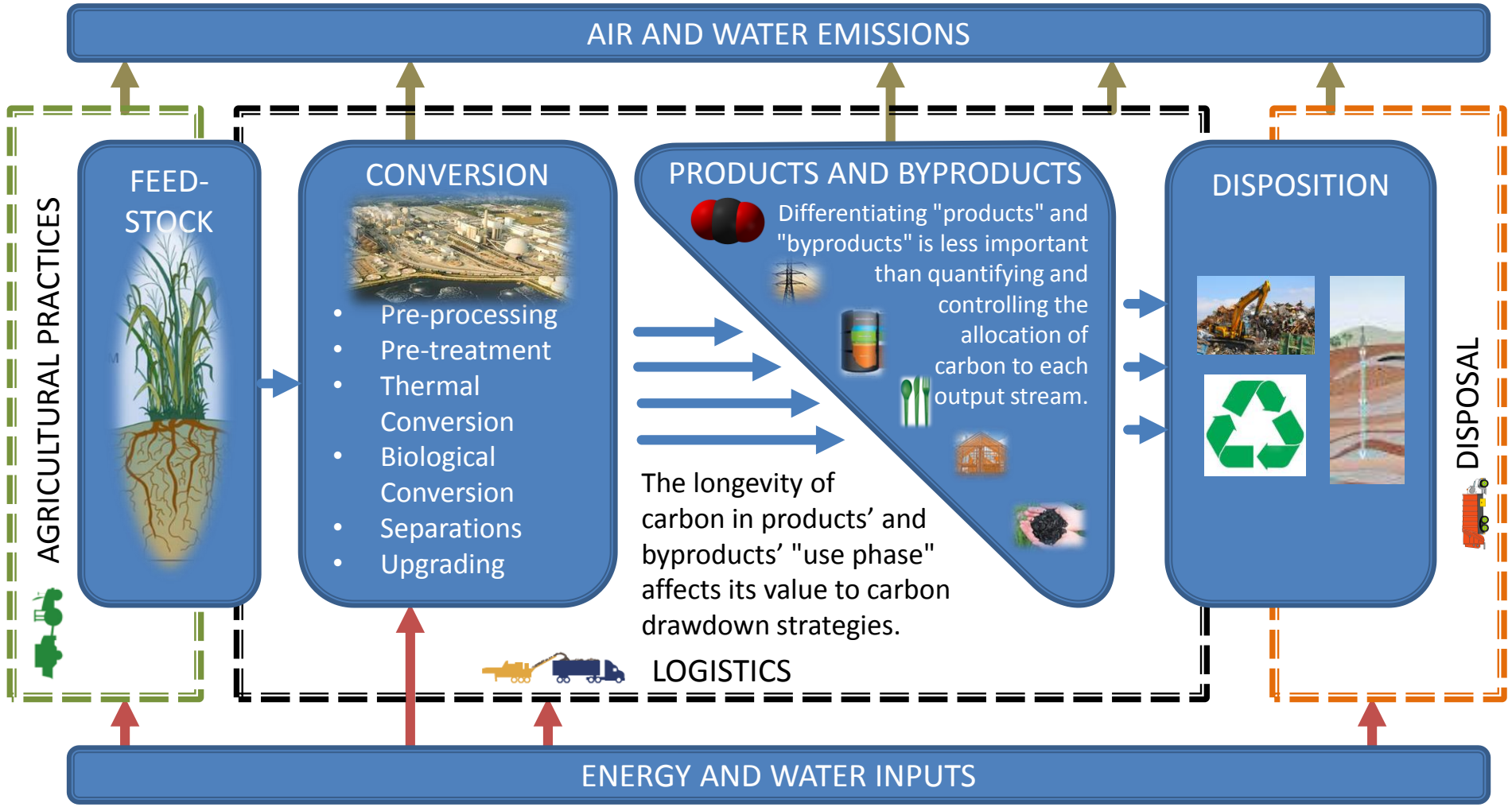
Approach (Technical)

- Enumerate the bioeconomy pathways that can lead to carbon drawdown
  - Challenge: Permutations of feedstock, conversion technology, product and byproduct create a large number of potential pathways
  - Challenge: “product” and “byproduct” are not well defined
- Down-select to a set of representative pathways covering emerging technology classes
  - Electricity/CCS (ORNL), Fuels/CCS, Bioplastics, Biochar, Roots
- Analyze each of these pathways on a lifecycle basis for cost and environmental impact
  - Challenge: Transform costs and impacts to a per-unit-carbon-removed basis

Accomplishments: Bioeconomy Carbon Drawdown Framework



Accomplishments: Bioeconomy Carbon Drawdown Framework



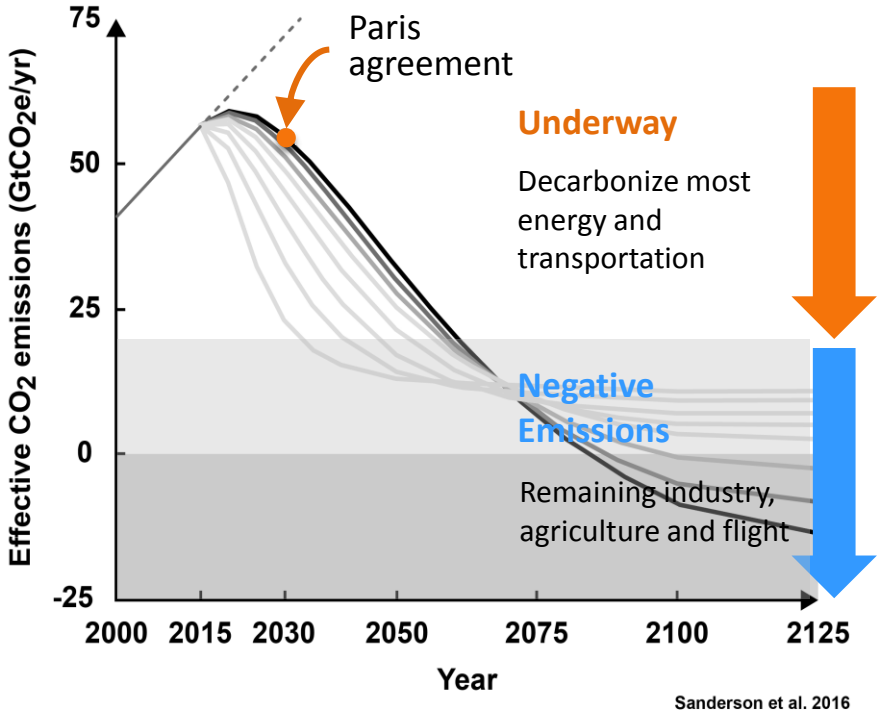
Work in Progress: Meta-Analysis of Pathways

	Characteristics									
		Feedstock Supply	*Feedstock Quantity*	*Conversion Technology*	*Products*	*Technology Readiness*	*Market Readiness*	Total	CO_2 Capture Potential	LCA Guidelines	Citation
Bio-economy Pathway	*Liquid Fuel with CCS*	Cellulosic Biomass		Fast Pyrolysis	Gasoline	2	2	4		Energy Content; Cradle-to-gate	[1], [2], [3], [4], [5], [6], [7], [8], [22], [23], [24], [25], [26]
				Hydrolysis/Fermentation	Ethanol	2	2	4			
				Gasification	Gasoline	1	2	3			
		Starches		Hydrolysis/Fermentation	Ethanol	3	2	5			
		Sugar		Fermentation	Ethanol	3	3	6			
	Bio-Plastics	Sugar		Fermentation	Coatings; Adhesives; Solvents; Textiles	3	3	6		Mass; Cradle-to-gate	[9], [10], [11], [12]
		Starches		Fermentation	Coatings; Adhesives; Solvents; Textiles	3	3	6			
	Bio-Lactic Acid	Lignocellulose		Fermentation	Solvents; Coatings; Pharmaceuticals; Plasticizers	2	2	4		Mass; Cradle-to-gate	[13], [14]
		Starches		Biological	Solvents; Coatings; Pharmaceuticals; Plasticizers	3	3	6			
		Sugar		Biological	Solvents; Coatings; Pharmaceuticals; Plasticizers	3	3	6			
	Bio-Power with CCS	Commerical Waste		Combustion	Power/Heat	3	2	5		Energy system with and without energy storage; cradle to grave for storage system and gate to gate for energy system in which the storage system operates	[15], [16], [1], [2], [17], [5], [18], [22], [25], [27]
				Co-Firing	Power/Heat	1	2	3			
		Forest Products		Combustion	Power/Heat	3	3	6			
				Gasification	Power/Heat	2	3	5			
				Co-Firing	Power/Heat	1	2	3			
		Agriculture Wastes		Anaerobic Digestion	Power/Heat	2	2	4			
	Biochar	Agriculture Wastes		Pyrolysis	Soil	1	2	3		Technical Performance; cradle-to-grave	[15], [1], [16], [19], [5], [20], [21]
		Forest Products		Pyrolysis	Soil	1	2	3			

Technology Readiness	Market Readiness
Low (= 1)	Low (= 1)
Medium (= 2)	Medium (= 2)
High (= 3)	High (= 3)

Relevance: Options for negative emissions are mostly limited to air-capture and *bioeconomy pathways*.

- BETO Mission: Develop and demonstrate transformative and revolutionary bioenergy technologies for a sustainable nation.
- BETO Goal (2): Encourage the creation of a new domestic bioenergy and bioproduct industry.



How do we harness the bioeconomy to achieve net emissions reductions?

Relevance

- Advance scientific methods and models for measuring and understanding bioenergy sustainability across the supply chain
  - A molecule of biogenic CO_2 has the same radiative forcing as any other molecule of CO_2; and the avoidance of its emission has the same value
  - The traditional assumption of excluding biogenic CO_2 from emissions accounting is insufficient to capture the value of bioeconomy pathways.
  - **This project advances methods for carbon accounting in scenarios that include negative emissions**.
- Ensure high-quality, consistent , reproducible peer-reviewed analysis
  - There is ample literature on the potential for bioenergy deployment, including definitive BETO resources (e.g., Billion Ton)
  - Bioeconomy-enabled carbon drawdown is an active field of research
  - **This project is a first step to assess emerging drawdown technologies in a consistent analytical framework**

Future Work

- Conclude preliminary assessment of bioeconomy-enabled carbon drawdown pathways
  - April, 2019: Enumeration of feasible pathways
  - July 2019: Qualitative evaluation of reasonable pathways
  - September 2019: Lifecycle Assessment of selected pathways
    - Overcome challenges to comparing vastly different technology pathways with carefully chosen metrics
    - Publish results
- Continue coordination with ORNL
- Beyond September 2019:
  - Further develop LCA methodology
  - Expand application of LCA to additional pathways
  - Integrate ORNL geospatial/market analysis with selected alternative pathways

Summary: Harnessing the Bioeconomy for Carbon Drawdown: Potential and Innovation Needs

- Overview: This project seeks to assess, on a consistent basis, the carbon drawdown potential of a broad range of bioeconomcy technologies.
- Approach: This collaboration between LLNL and UC Berkeley assesses carbon drawdown pathways with lifecycle tools. It is complementary to ORNL's deep geospatial assessment of biopower-with-CCS.
- Accomplishments: Since October 2018, our team has developed a framework, enumerated pathway components, qualitatively assessed a selection of pathways and initiated LCA.
- Relevance: This project advances methods for understanding the sustainability of bioeconomy technologies and contributes to reproducible, peer-reviewed analysis.
- Future Work: Further LCA and integration between ORNL's deep analysis and LLNL's broad assessment