DOE Bioenergy Technologies Office (BETO) 2023 Project Peer Review

Project 1.1.1.3 – Supply Scenario Analysis

April 3rd, 2023

Feedstock Technologies

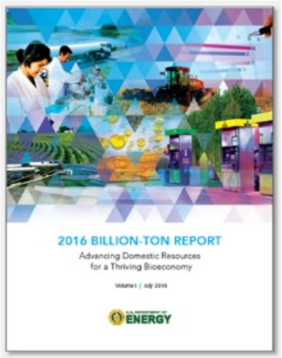
Matthew Langholtz (PI)

Oak Ridge National Laboratory

Overview: Two Resource-based Tasks

Task 1: Billion-ton Report

2016 (BT16)

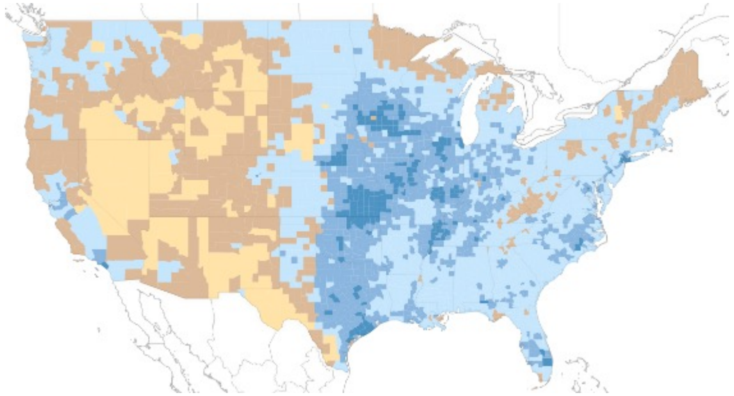


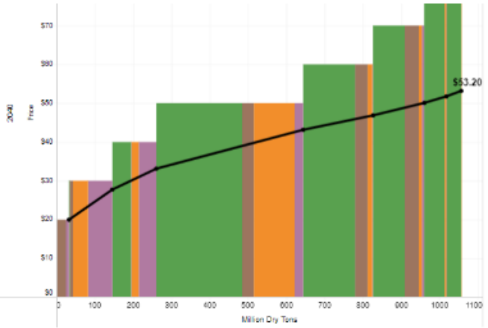
2023 (BT23)

Conducts biomass resource assessments

- Quantities
- Prices
- Spatial distribution
- Market maturity

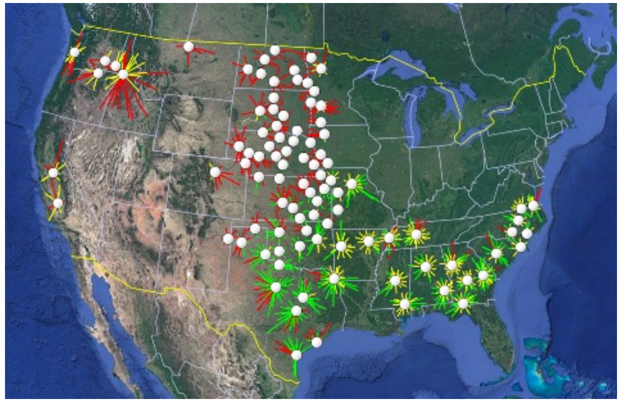
County Resolved Feedstock Data (Quantity and Cost)



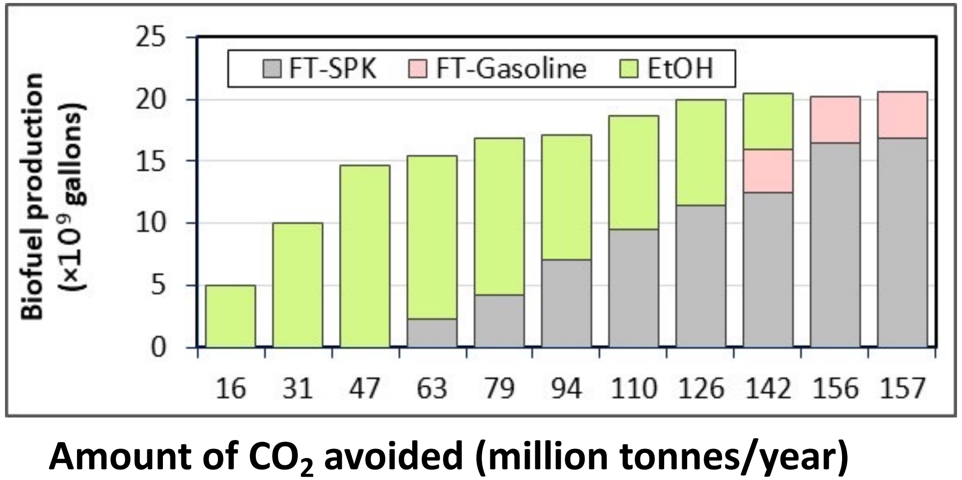


Task 2: Best Use of Biomass

- Assesses optimal biomass allocation to pathways and products



- Calculates \$/tonne CO_2 Carbon Abatement Cost



Agenda

- Project overview
- 1 - Approach
  - Billion-ton Reports (BT23)
  - Best Use of Biomass (BUoB)
- 2 - Progress and Outcomes
  - Billion-ton Reports (BT23)
  - Best Use of Biomass (BUoB)
- 3 - Impact
- Summary

Approach for 2023 Billion-ton Report

BT23 Team & Collaborators

Scott Curran
Currently Used
ORNL

Maggie Davis
Forestland Resources
ORNL

Erin Webb
Delivered Analysis
ORNL

Esther Parish
Data Dashboard
ORNL

Chad Hellwinckel
Ag Land Resources
ORNL

Anelia Milbrandt
Wastes
NREL

Ryan Davis
Microalgae
NREL

Anne Otwell
Macroalgae
DOE

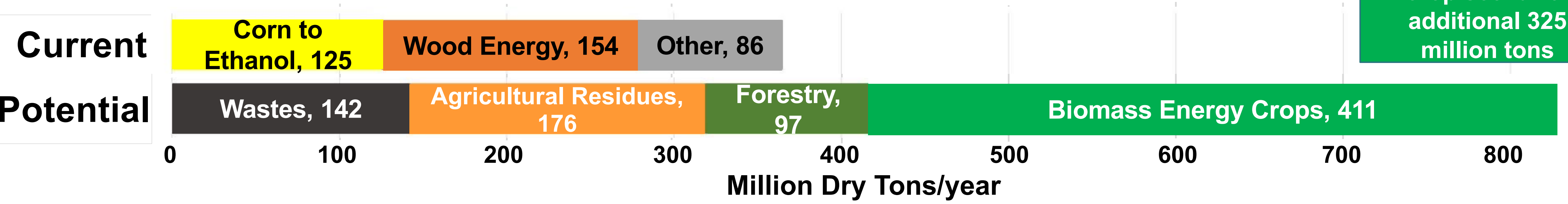
Damon Hartley
Logistics Harmonization
INL

Matthew Langholtz
PI
ORNL

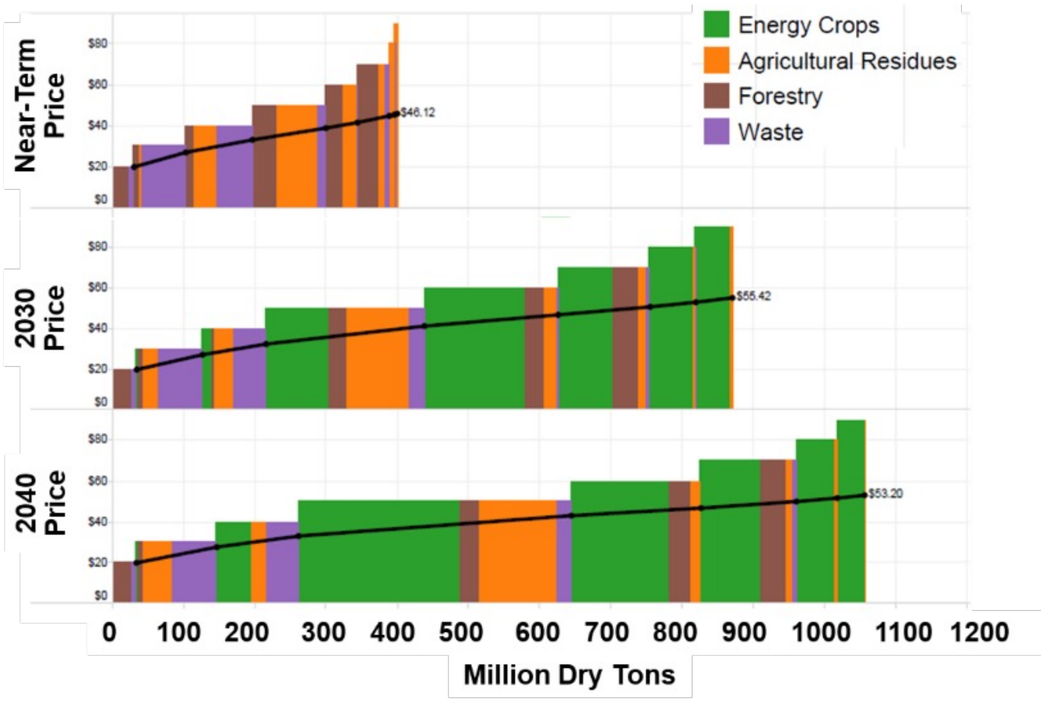
Building on the State-of-the-Art: BT16

Conclusion: can ~triple current bioeconomy to ~1 billion tons per year

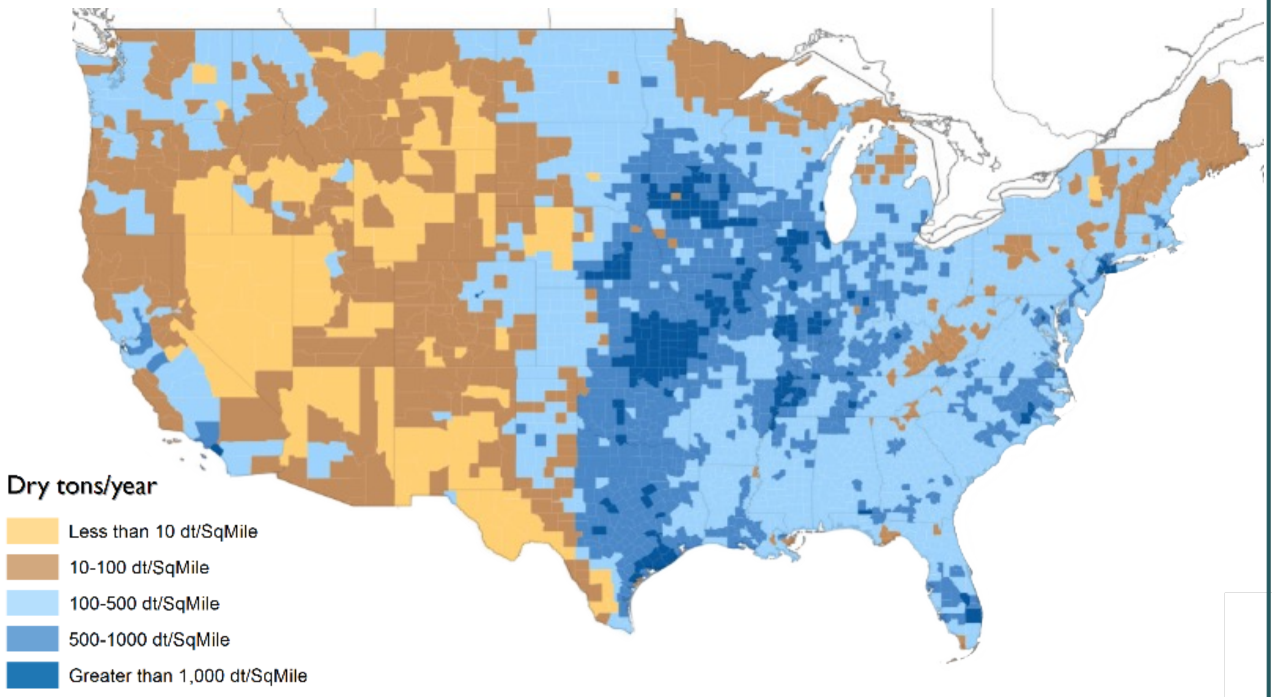
High-yield biomass crop scenario: additional 325 million tons



Supply varies with price and time



County-level results downloadable



BT23 – Forestry modeled on yield and economics

Resource

Forest thinnings

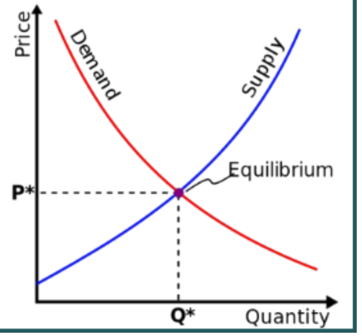
Plantations

Collaboration	Analysis	Region
UT, OSU	Forest Sustainability and Economic Assessment Model (ForSEAM)	Conterminous US
NC State	Subregional Timber Supply Model (SRTS)	SE US
US Forest Service, Department of Agriculture	Bioregional Inventory Originated Simulation Under Management (BioSUM)	Western fire-prone forests

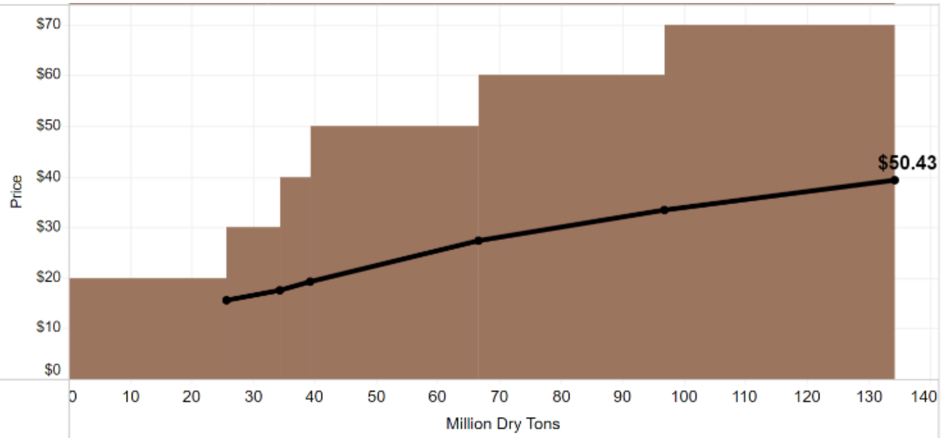
NEW!

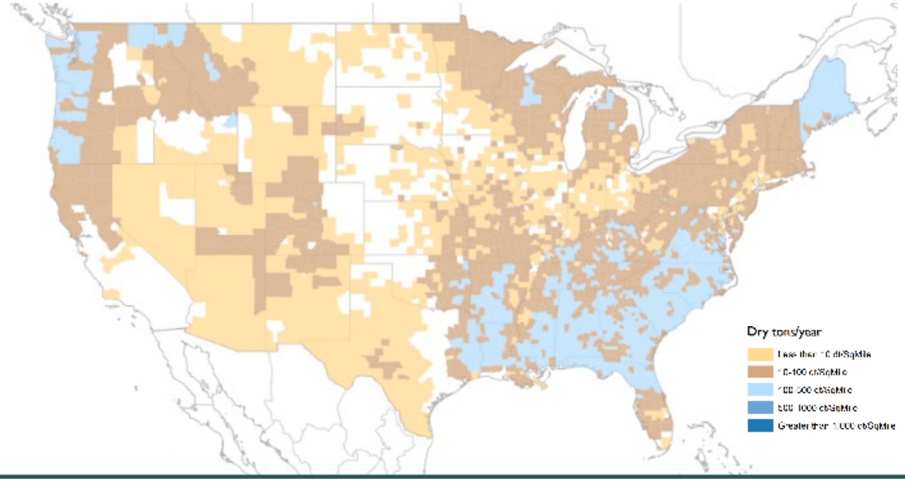
Inputs

- Inventory from USFS Forest Inventory and Analysis (FIA) data
- Conventional demands (sawtimber and pulpwood) from Forest Resource Outlook Model
- Growth & yield data
- Operational costs



Outputs: County-level supply curves





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BT23 – Agriculture partial equilibrium economic model

Resource

Switchgrass

Willow

Oil seeds

NEW!

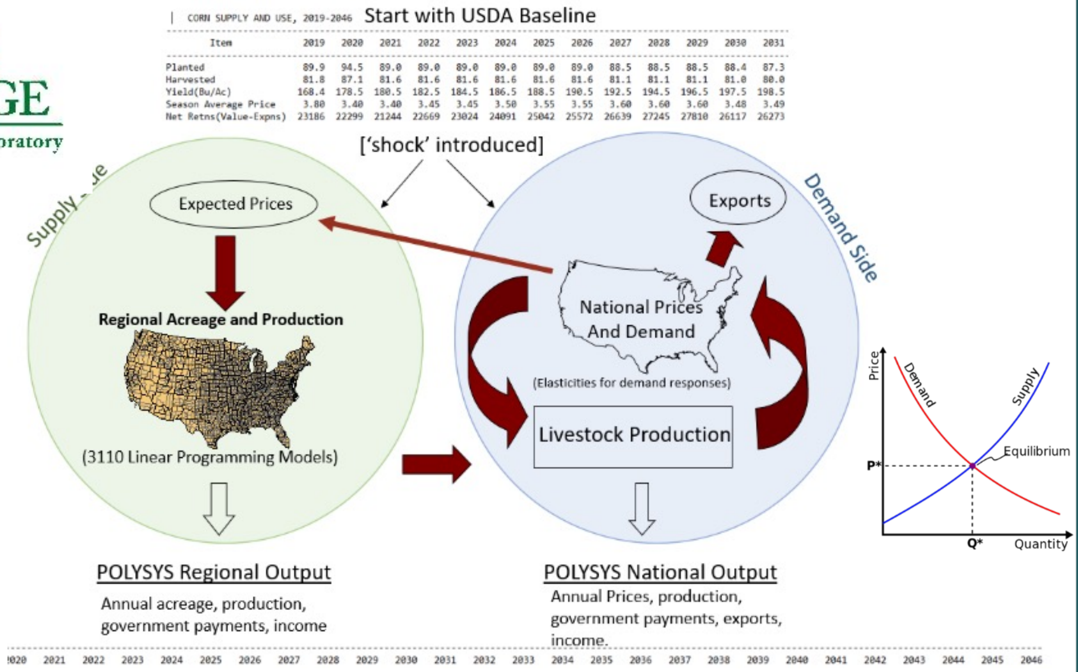
Analysis

Model: Policy Analysis System (POLYSYS)

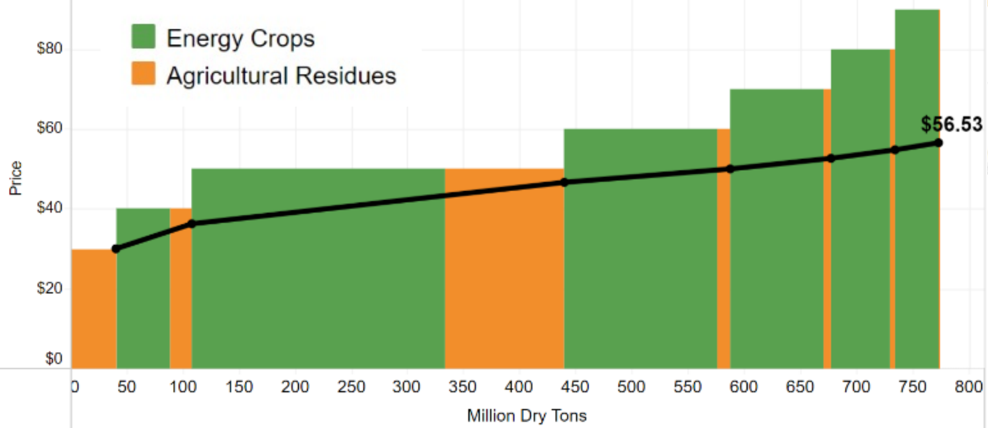
Inputs:

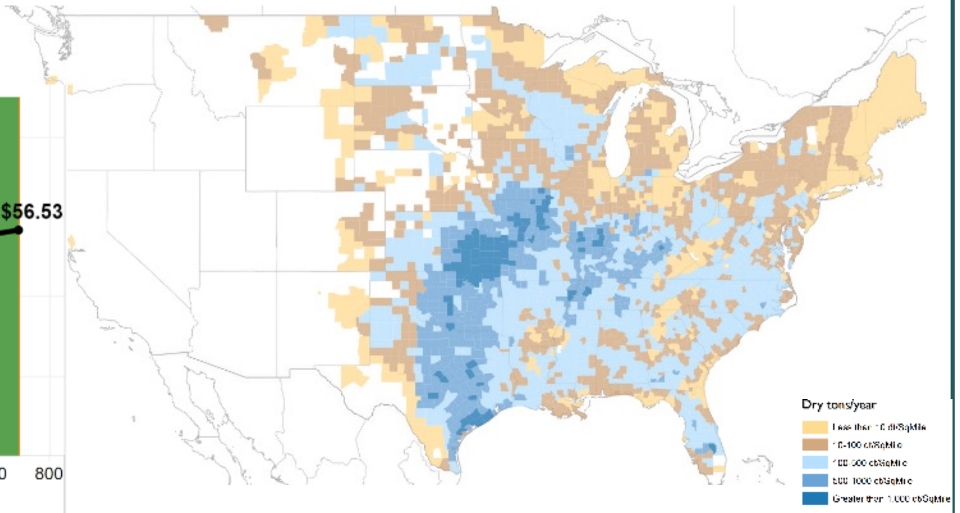
- Conventional (food, feed, fiber, export) demands from 2023 USDA Baseline Projection
- Crop yields (tons/acre/year) from SunGrant Regional Feedstock Partnership
- Crop production budgets from surveys
- 30-meter resolution (2022 Cropland Data Layer)

NEW!



Outputs: County-level supply curves

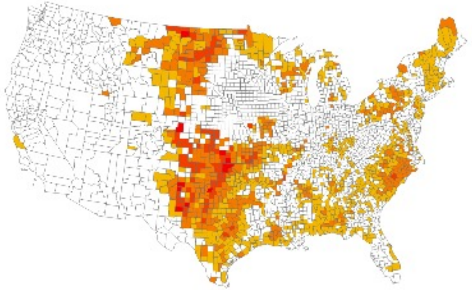




UPDATING in BT23

Economic and spatial data

- 2023 USDA baseline data
- Updated costs & food demands
- 2022 Spatial data for environmental effects

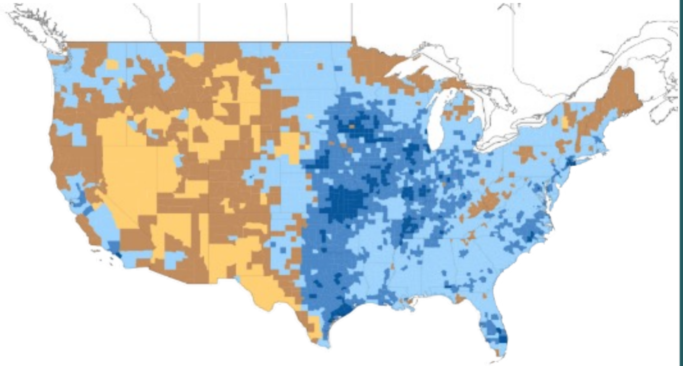


Wastes

- Adding county-level fats, oils, and greases
- Accounting for mature-market price competition

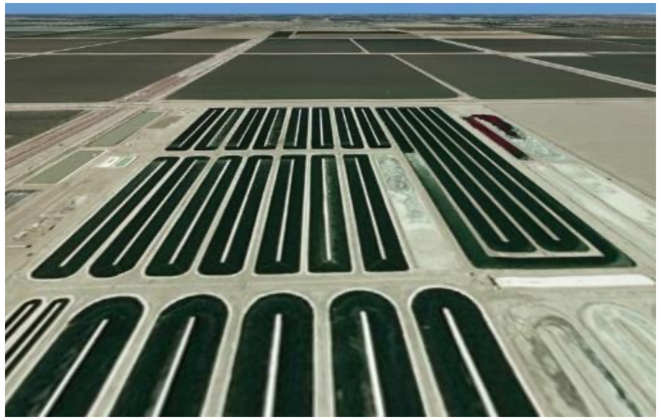
Ag and Forestry

- Ag residues (e.g. corn stover)
- Logging residues, thinnings, pine plantations
- Biomass crops



Micro- ("pond") algae

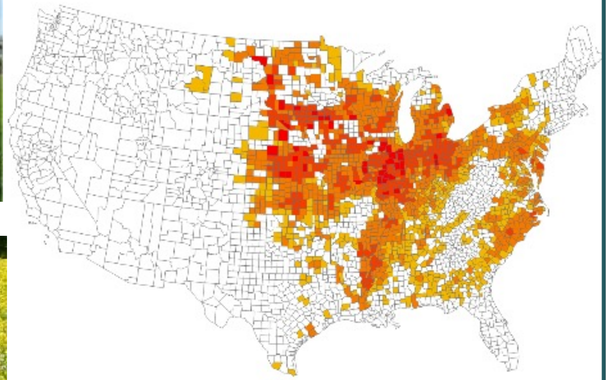
- Updating to 2021 Microalgae Harmonization
- Updating to latest microalgae yield and costs



NEW in BT23

NEW!

Oilseed crops for SAFs



Macro- ("seaweed" algae)

- Collaboration with ARPA-E

OceanReports
A BOEM/NOAA PARTNERSHIP

MarineCadastre.gov

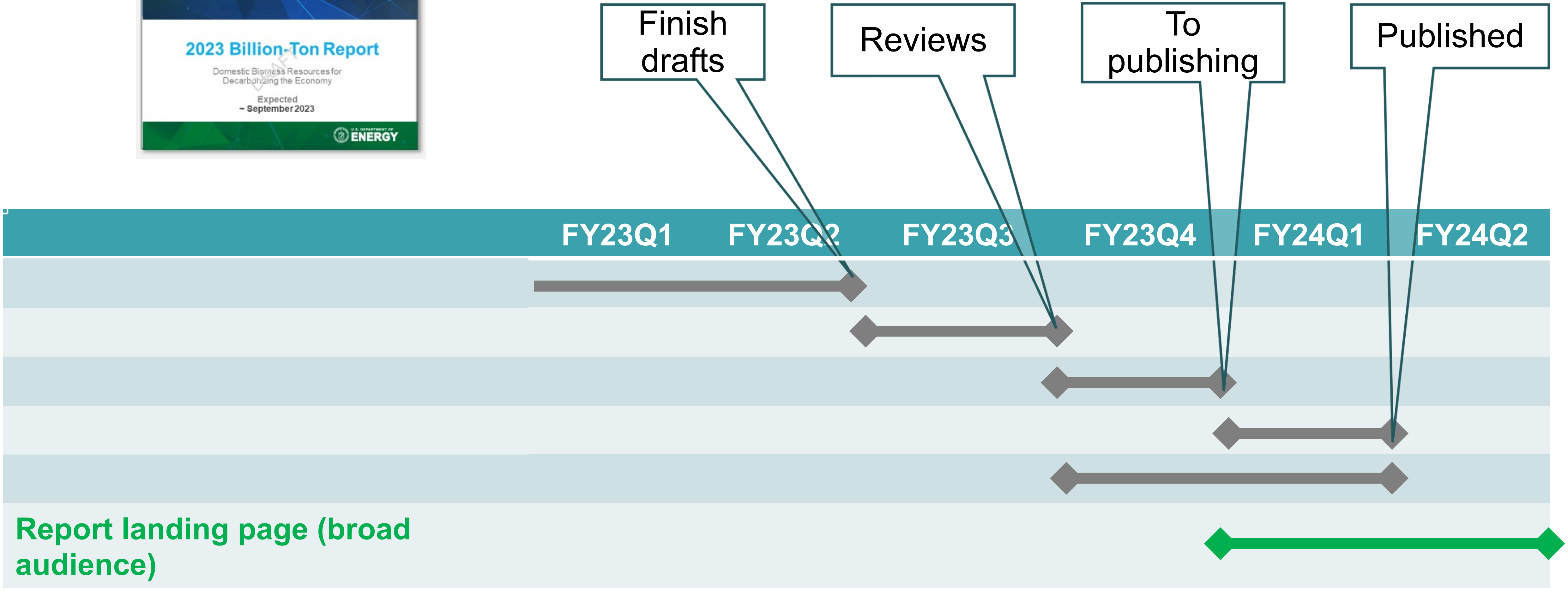
Western Forest Fuels for biomass with USFS

- Biomass from 2022 USFS Wildfire Crisis Strategy

CO_2 to e-fuels

- Proximity to renewable electricity
- High concentration (e.g. fermentation)

BT23 Timeline



Approach for Best Use of Biomass (BUoB)

BT23 Team & Collaborators

Dipti Kamath

- Environmental engineering
- Life cycle assessment
- Technoeconomic analysis

Oluwafemi Oyedeji

- Biosystems and chemical engineering
- TEA and LCA data integration
- Biomass feedstock and conversion pathway

Ingrid Busch

- Transportation Analyst
- Optimization
- Network analysis

Matthew Langholtz

- Natural Resource Economist
- Biomass resource economics
- Bioenergy with carbon capture and sequestration

Scott Curran

- Energy Science and Engineering
- End-use applications of biofuels
- Well-to-wheel analysis

Tim Theiss

- BETO Laboratory Relationship Manager

BUoB: Integrated Carbon Management Approach using BILT Model

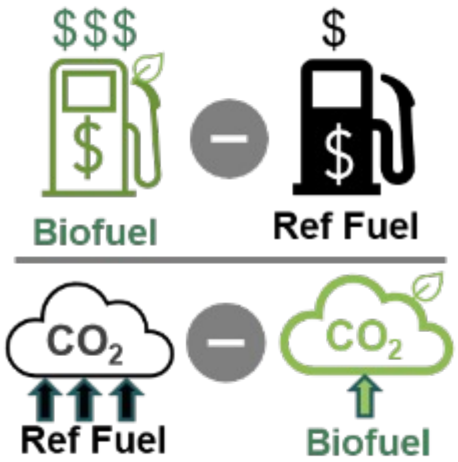
Metric = Marginal Carbon Abatement Cost

- **Metric:** Marginal **Carbon Abatement Cost** (CAC)
- Compared to a reference fuel scenario that is being replaced by biofuel taking care to keep consistent reference case for each end-use sector (aviation, marine, rail, on-road)

$$\text{Carbon Abatement Cost} = \frac{\text{Increase in cost of biofuel}}{\text{Decrase in carbon from reference}} = \frac{\Delta\,\$}{\Delta\,\text{Tonne } CO_2} = \frac{\$}{\text{Tonne } CO_2}$$

Example:

(corn stover Gasification-FT to jet fuel)



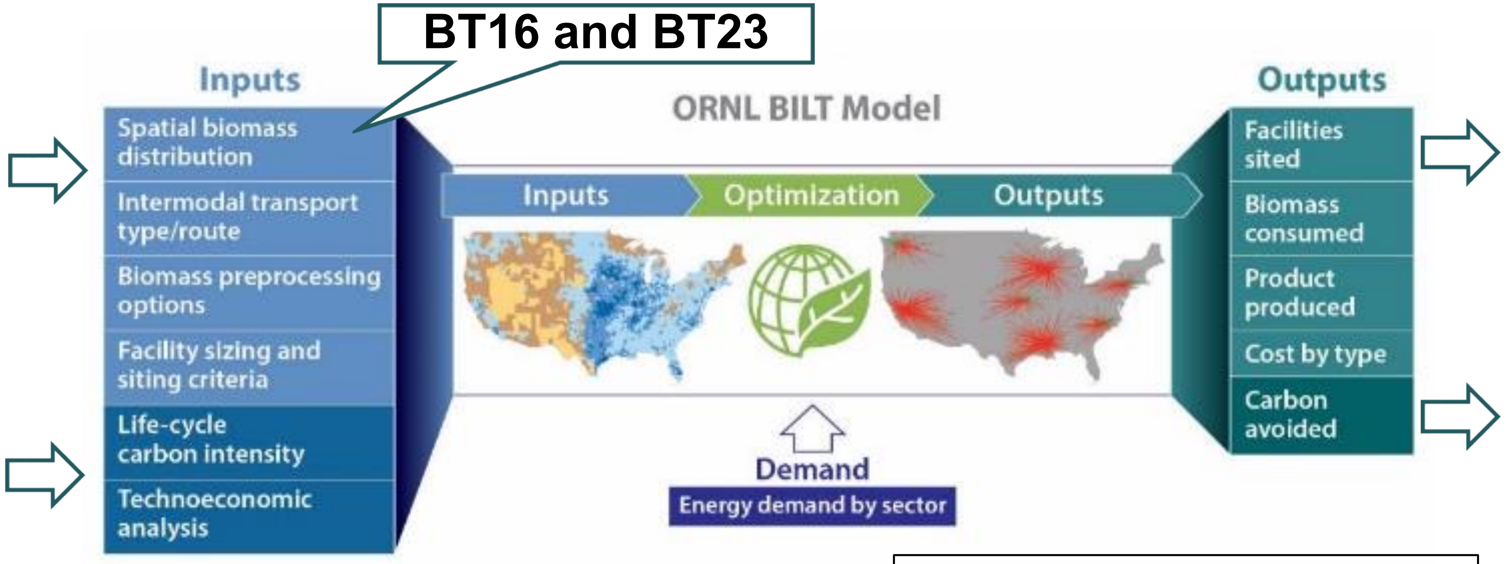
$$= \frac{\Delta\,\$}{\Delta\,\text{Tonne } CO_2} = \frac{\$3.00/gal}{0.04\,\text{Tonne } CO_2/gal} = \frac{\$75.00}{\text{Tonne } CO_2}$$

BuOB: BILT Model - biomass allocation model to provide insight for decarbonization across competing pathways or sectors

- **Uses spatially resolved BT16 data** *(BT23 in future)*
- Relies on from peer-reviewed TEA and LCA data (or from other NLs)

Overall Goal: Compare competing decarbonization strategies using spatially distributed biomass resources

- Current results – biofuel pathway only



Methods described in Curran et al. (2022)

Selected analysis for answering key questions

- Biorefinery facility size and number
- Compare CAC of pathways
- Sensitivity to TEA/LCA

Carbon Avoidance Cost as Comparison Metric

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Progress and outcomes for 2023 Billion-ton Report

BT23 Progress and Stakeholder Feedback

Changes in BT23:

- New resources
  - Oilseed cover crops
  - Macroalgae
- Modeling updates
  - Economic conditions
  - Modeling inputs (cropland area, forest inventory, conventional prices)
- Shorter - improved communication
- Wildfire Crisis Strategy – USFS collaboration
- Revised data download tool

Stakeholder engagement is ongoing!

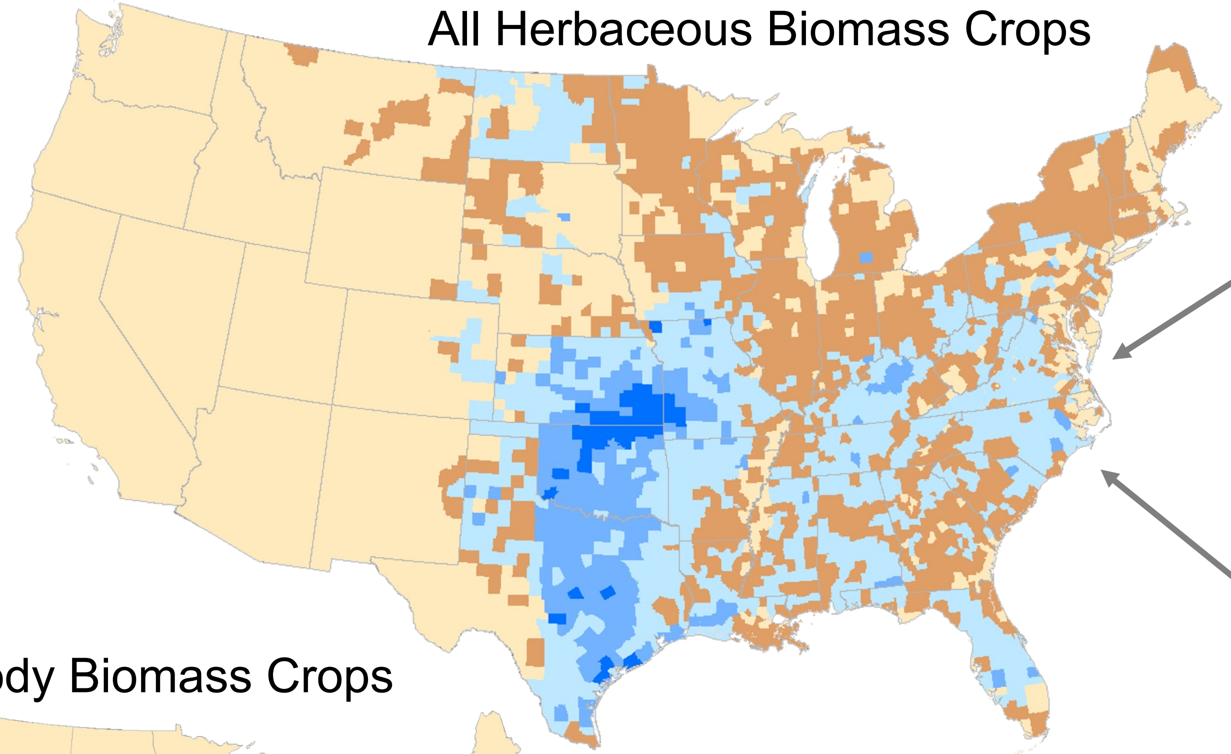
Early Feedback:

- Distinguish lipids from cellulosics
- Add Carbon Intensity values
- Add RFS qualification table
- Report near-term and mature-market scenarios
- Identify sustainability risks and modeling limitations
- Modifications to crop budgets

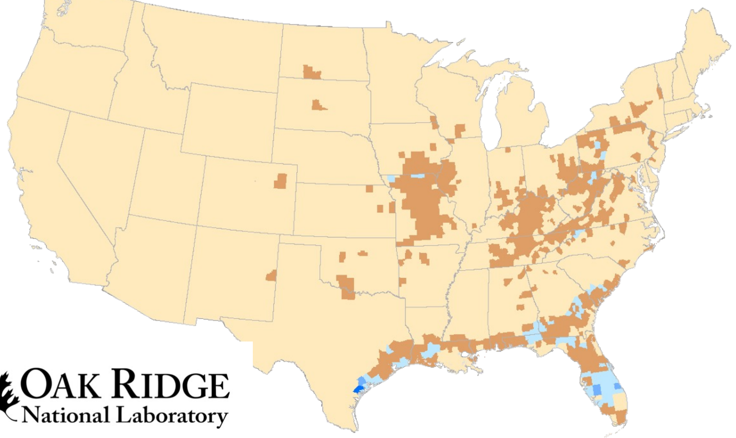
UPDATED

Lignocellulosics: ~400 million tons
Preliminary Results - ($70/ton)

All Herbaceous Biomass Crops

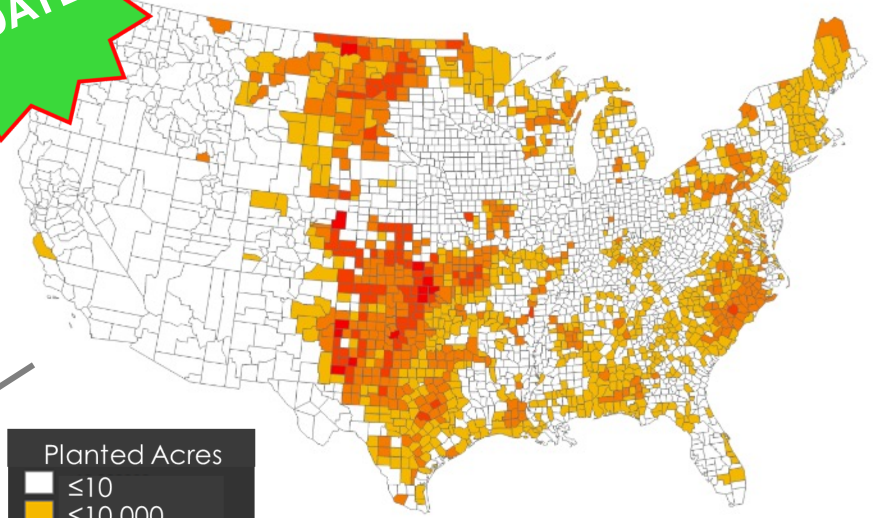


Woody Biomass Crops



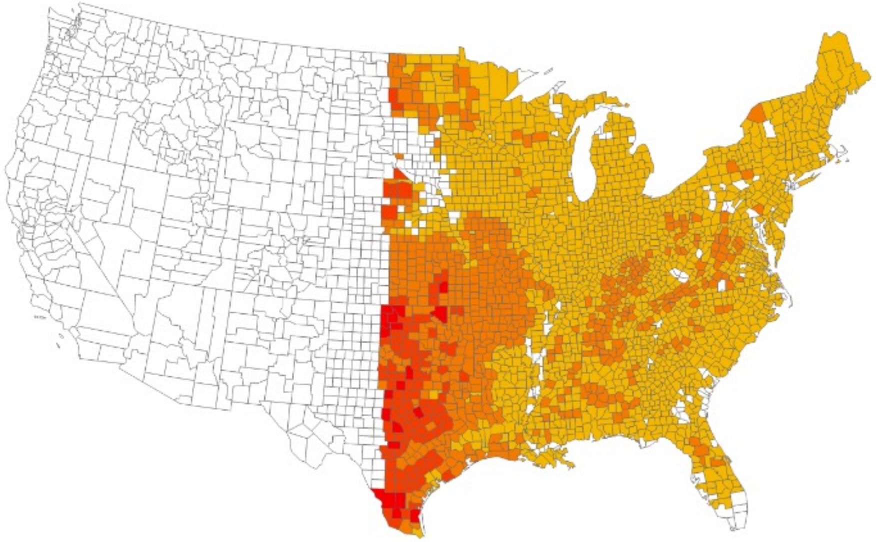
Production Density
tons per sq mile
- < 10
- 10-100
- 100-500
- 500-1,000
- > 1,000

Herbaceous on Cropland



Planted Acres
- ≤10
- ≤10,000
- ≤75,000
- ≤150,000
- ≤493,000

Herbaceous on Pastureland



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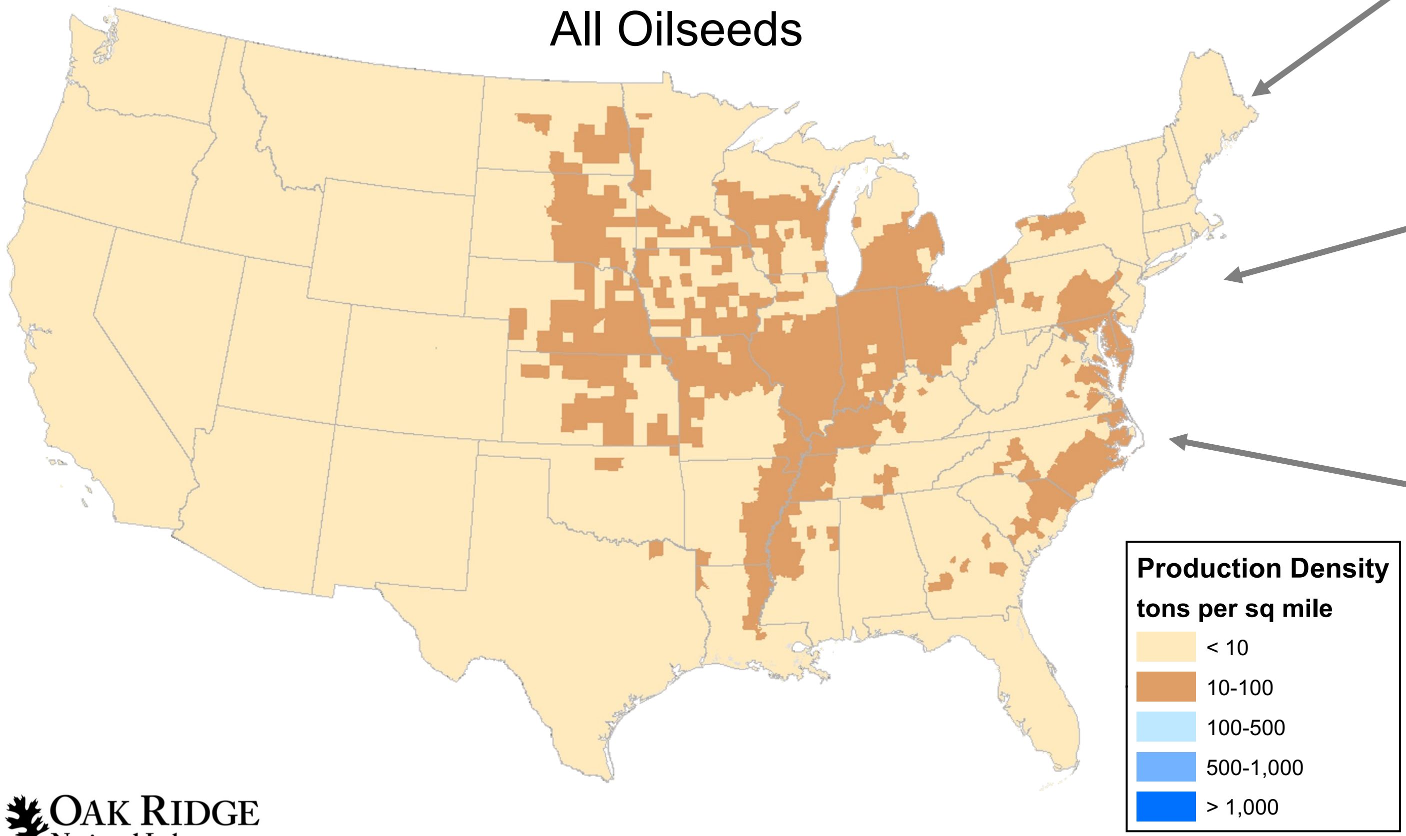
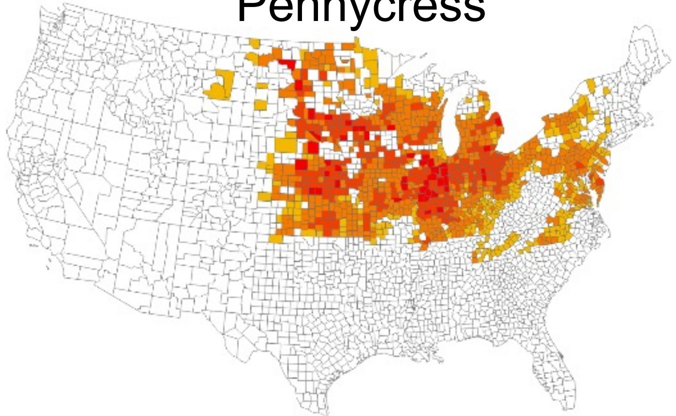
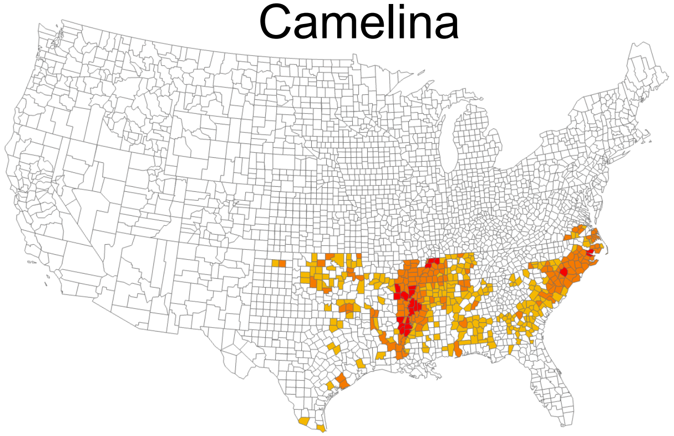
NEW!

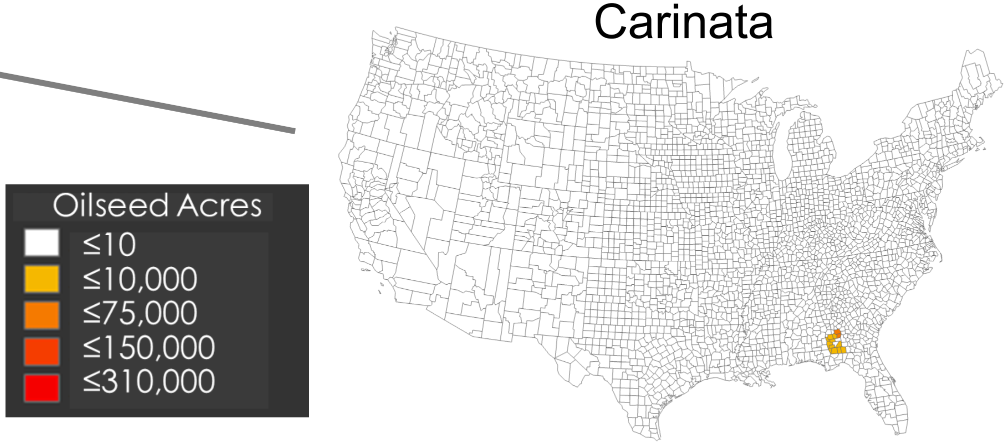
New Oilseeds Cover Crops Analysis Suggests ~22 million tons, =~3 billion gallons SAF

Preliminary Results - ($0.15/lb)









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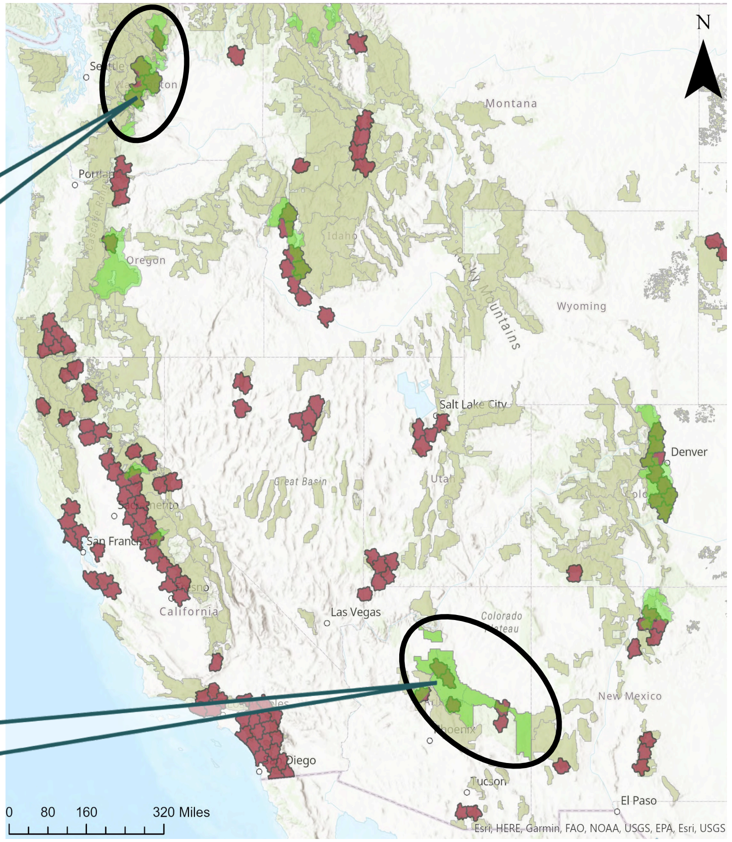
New in BT23: Biomass from fire reduction treatments With USFS

- National Wildfire Crisis Strategy: Enhance fire resistance of 50 million ac.
- Biomass from forest fuel reductions
- ~16 million acres of forest/wildland
- High cost, with externality benefits

NEW!



Central Washington Initiative

10 initial areas
Priority firesides
NFS lands

Four Forest Restoration Initiative

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BT23, Macroalgae

NEW!

UCI University of California, Irvine

Pacific Northwest NATIONAL LABORATORY

arpa·e

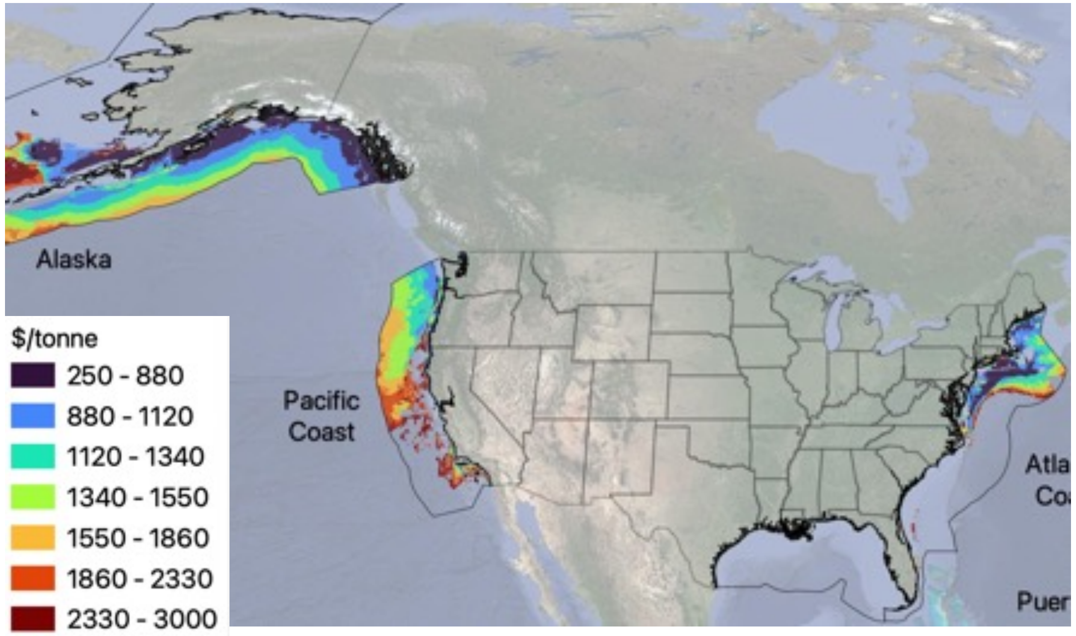
Biomass Model

MACMODS
MacroAlgae Cultivation MODeling System

Screening tool

OceanReports
A BOEM/NOAA PARTNERSHIP

MarineCadastre.gov



Preliminary Findings

- 3.9 Gt/yr potential in all screened US EEZ (regardless of cost)
- 3.3 Gt/yr potential ≤ $3k/tonne cost
  - 3.01 million km^2

BT23 Communication and Stakeholder Input

- Workshop series:
  - National labs (Feb-Mar 2022)
  - USDA (Dec-Nov 2022)
  - EPA (Dec-Feb 2023)
- Feedback:
  - Advanced Biofuels Association (Feb 2023)
  - Industry group: Advanced Bioeconomy Leadership Conference (Mar 2023)

- Communication plan
  - <u>For Broad audience</u>: Interactive BT report landing page (EERE)
  - <u>For Researchers</u>: BT data dashboard (KDF)

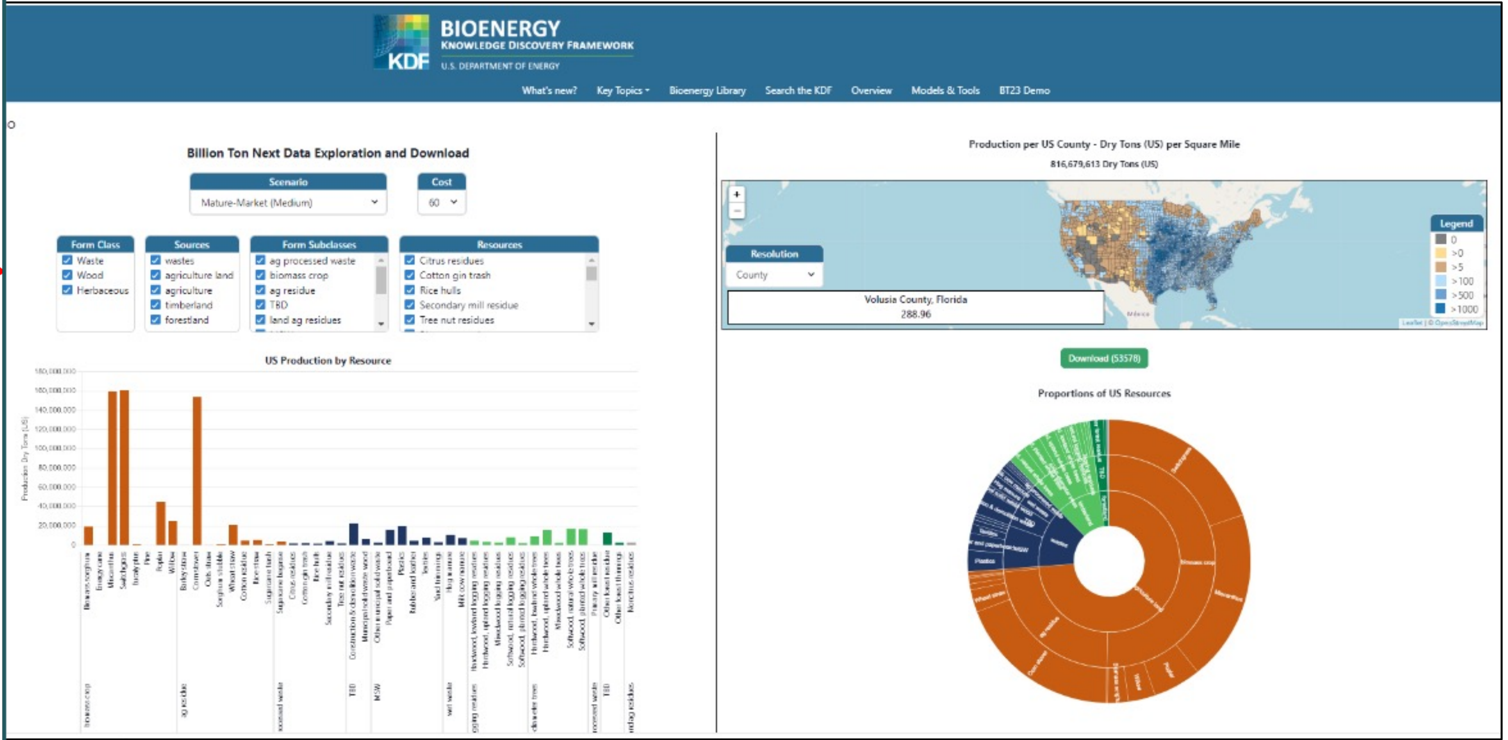
NEW!

BIOENERGY KNOWLEDGE DISCOVERY FRAMEWORK

KDF

U.S. DEPARTMENT OF ENERGY

Proposed BT23 Data Dashboard

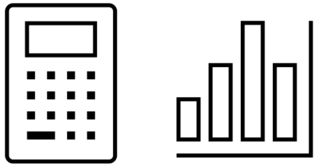


Progress and Outcomes for Best Use of Biomass (BUoB)

Insights into understanding the number of biorefineries needed

- **Compare simple analysis of number of facilities needed to utilize all biomass to BILT model**
  - Spatially-agnostic analysis
- **BILT model analysis: Facility location with spatially resolved feedstock and spacing constraints**
  - Single 2,200 dry tons (2,000 tonnes) /day facilities **[2.2K Plant - model biorefinery]**
  - Multiple smaller facilities co-located (no economy of scale) **[Stacking]**
  - Larger facilities leveraging economies of scale for CAPEX/OPEX [Large biorefineries] Not Presented Today

Spatially-agnostic analysis

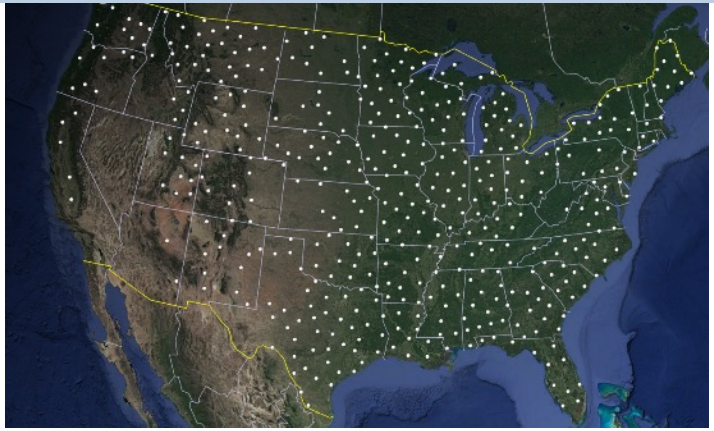


- BT16: ~880M tons biomass per year
- Model facility is 2,200 dry tons/day, i.e.: ~0.8M tons per year

- ~ **1,100** 2,200 dry tons/day **facilities needed to consume the BT16 potential biomass supply**

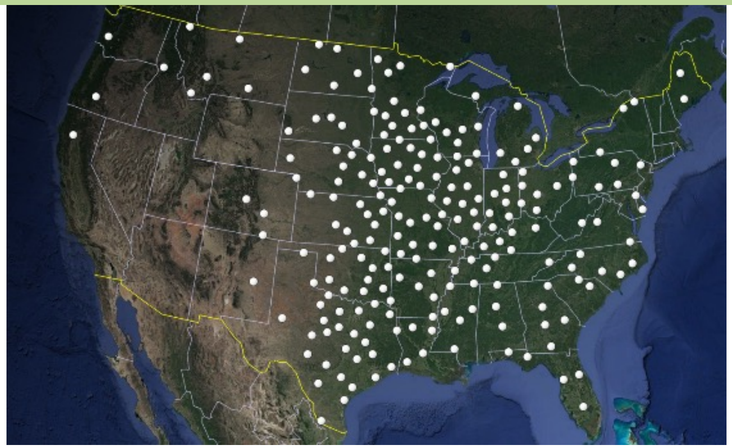
Where to site 1,100 model biorefineries?

BILT Model – 2.2K Plant, 50 mile



- **469 unique 2,200 dry tons/day facilities** possible with 50-mile spacing constraints
- ~358 million dry tons used >40%

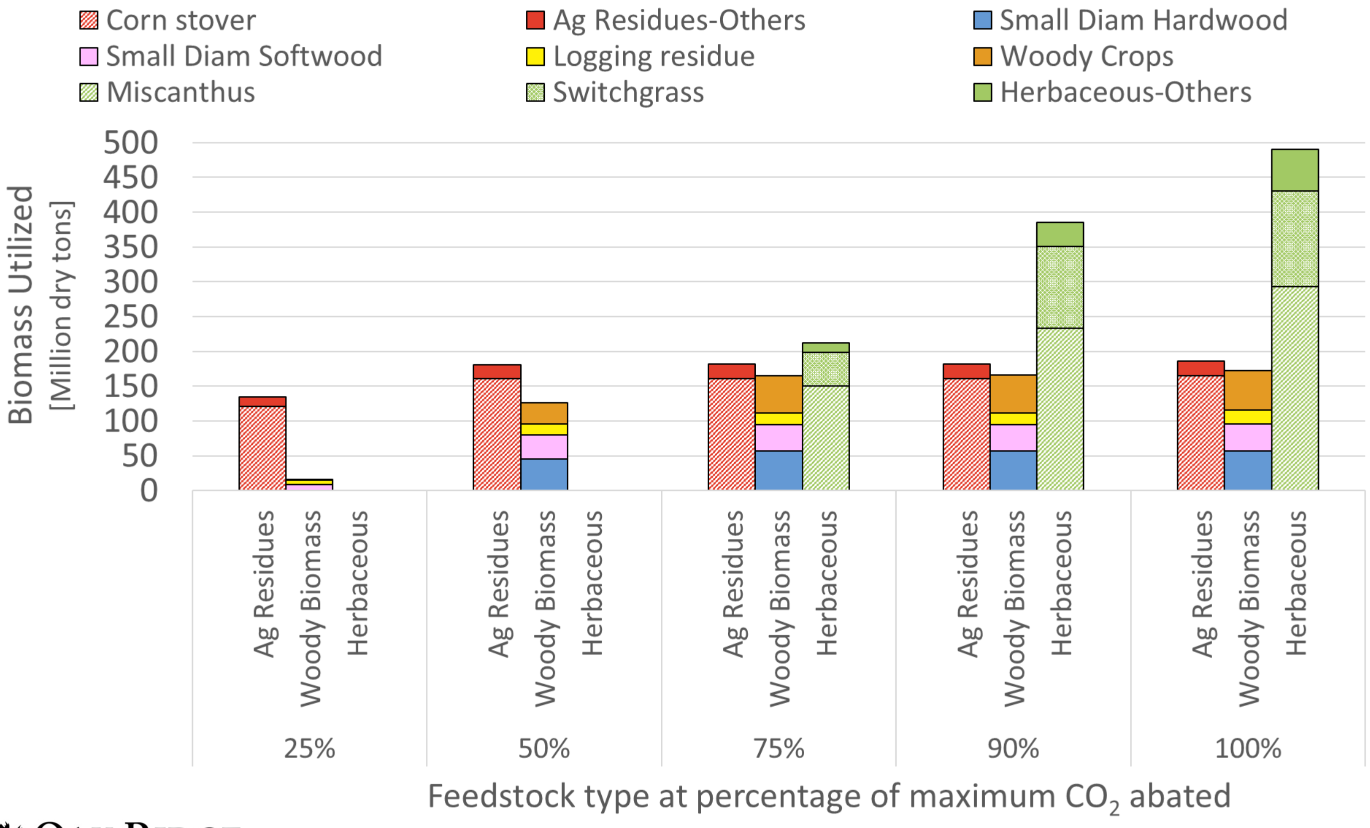
BILT Model – 5x stacked 2.2K Plant



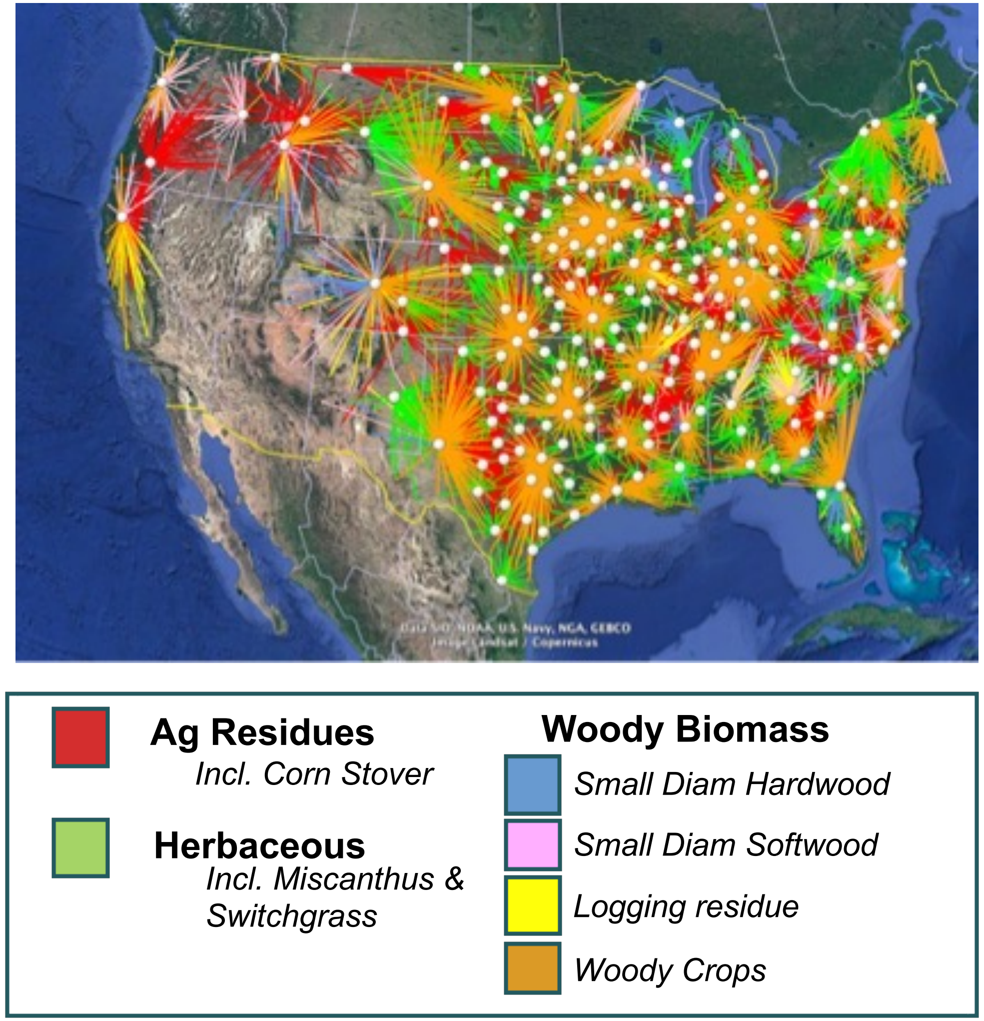
- **223 stacked 5 x 2,200 dry tons/day facilities**:
- ~850 million dry tons used > 90%

Results: Insights into where feedstocks pulled from, where least expensive and least travel distance: FT-Gasification example

- Cheapest resources used first
- Will be competition for some biomass resources
- Can exceed conventional rule-of-thumb distances when objective is carbon abatement



Example details: **FT- Gasification**
With stacking, 90% of Biomass Case



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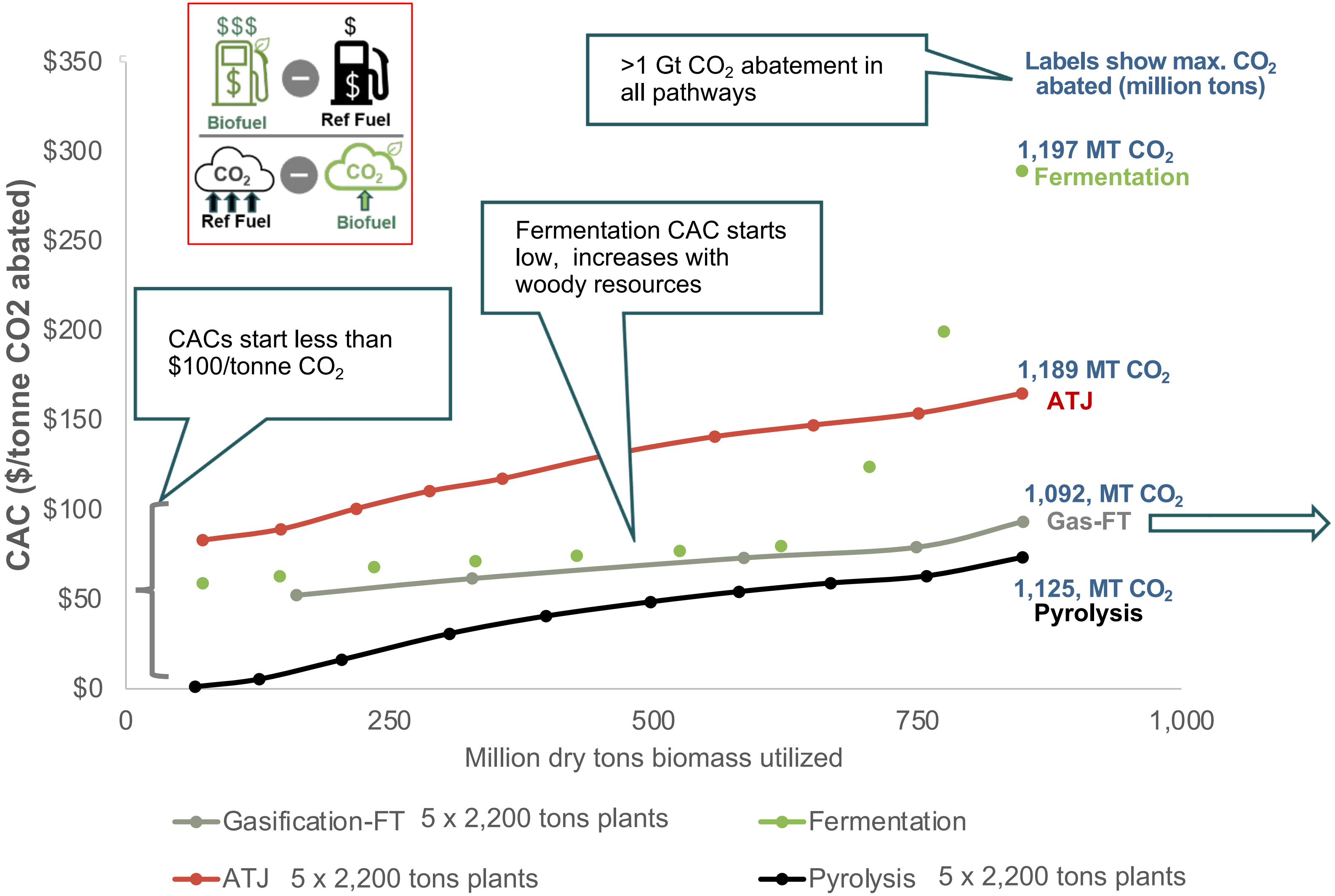
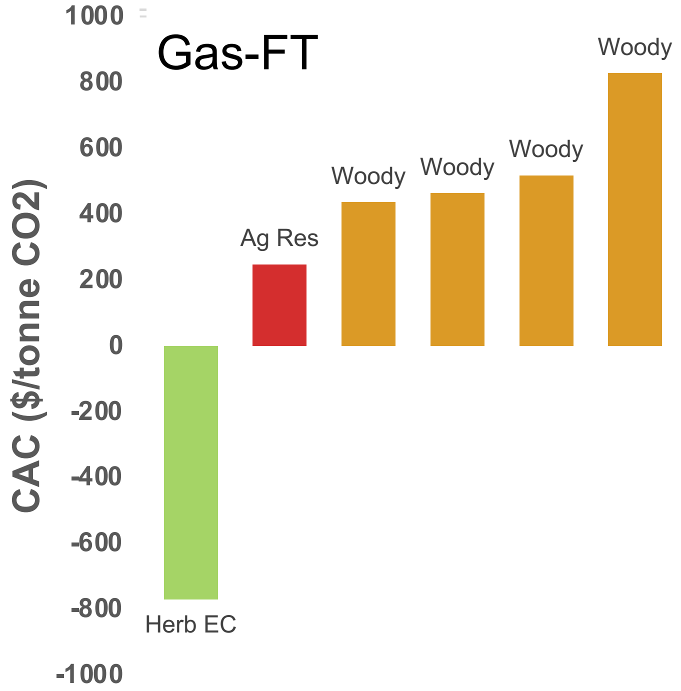
CAC Comparisons for Selected Pathways as a Function of Biomass Utilized



CAC for Gasification-FT by Feedstock from Literature



- CAC calculated from reported LCA/ TEA data show wide range
- Few studies conduct LCA and TEA simultaneously
- Drives variability of BILT results
- Sensitivity analysis underway

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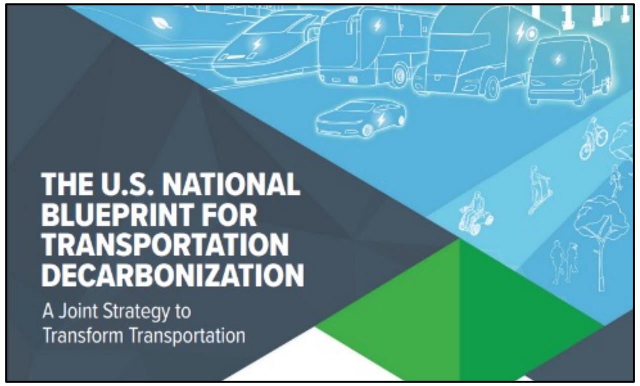
Impact – National Relevance

- Resource is Foundational to Bioeconomy
  - Referenced in national policy documents
    - DOE SAF Grand Challenge Roadmap
    - U.S. National Blueprint for Transportation Decarbonization
    - DOE Carbon-Negative Earthshot
  - Referenced in BETO program documents
    - BETO State of Technology Reports
    - BETO Multi-Year Plan
  - >4,000 citations of BT reports – peer-reviewed publications
  - >10k KDF landing page visits and data downloads
  - Supports State and Regional Analyses
- Best Use of Biomass
  - Implications for national decarbonization strategies with ~1 billion tons biomass/year



Summary:

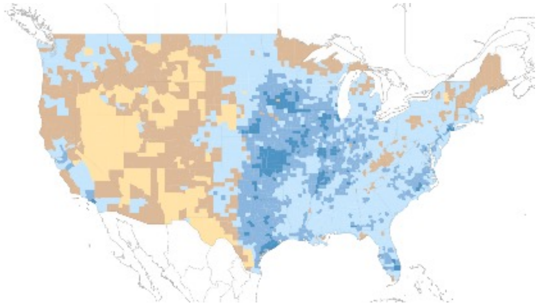
- <u>Overview</u>: Building on previous biomass supply analysis to provide robust feedstock supply information. End-use agnostic in BT, end-use explicit in BUoB.

- <u>Approach</u>: Using economic and logistics simulation models and data visualization.

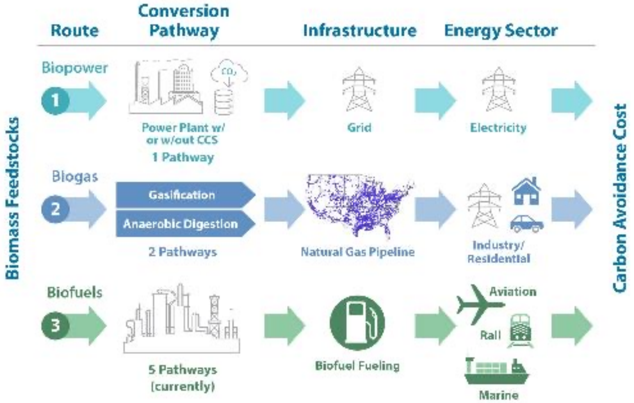
- <u>Progress and outcomes</u>: BT23 and BUoB targeting publication in 2023.

- <u>Impact</u>: Provides data for national reports, federal programs, BETO SOTs, MYP targets, data requests for other FT and DMA projects. Thousands of citations and KDF data downloads.

2023 (BT23)



Best uses of Biomass



Quad Chart Overview

Timeline

- *Project start date: 10/1/2020*
- *Project end date: 9/30/2023*

	FY22 Funding	Total Award
DOE Funding	*$900k*	*$3,182k*

TRL at Project Start: N/A (Strategic Analysis)
TRL at Project End: N/A (Strategic Analysis)

Project Goal

- *Provide objective feedstock supply & cost data to other projects and platforms.*
- *Assess optimal biomass allocation across pathways.*

End of Project Milestone

- *Provide BETO and bioeconomy stakeholders with scenario-specific biomass feedstock quantity and cost information.*
- *Publish peer-reviewed manuscripts quantifying optimal uses of biomass for decarbonization.*

Funding Mechanism

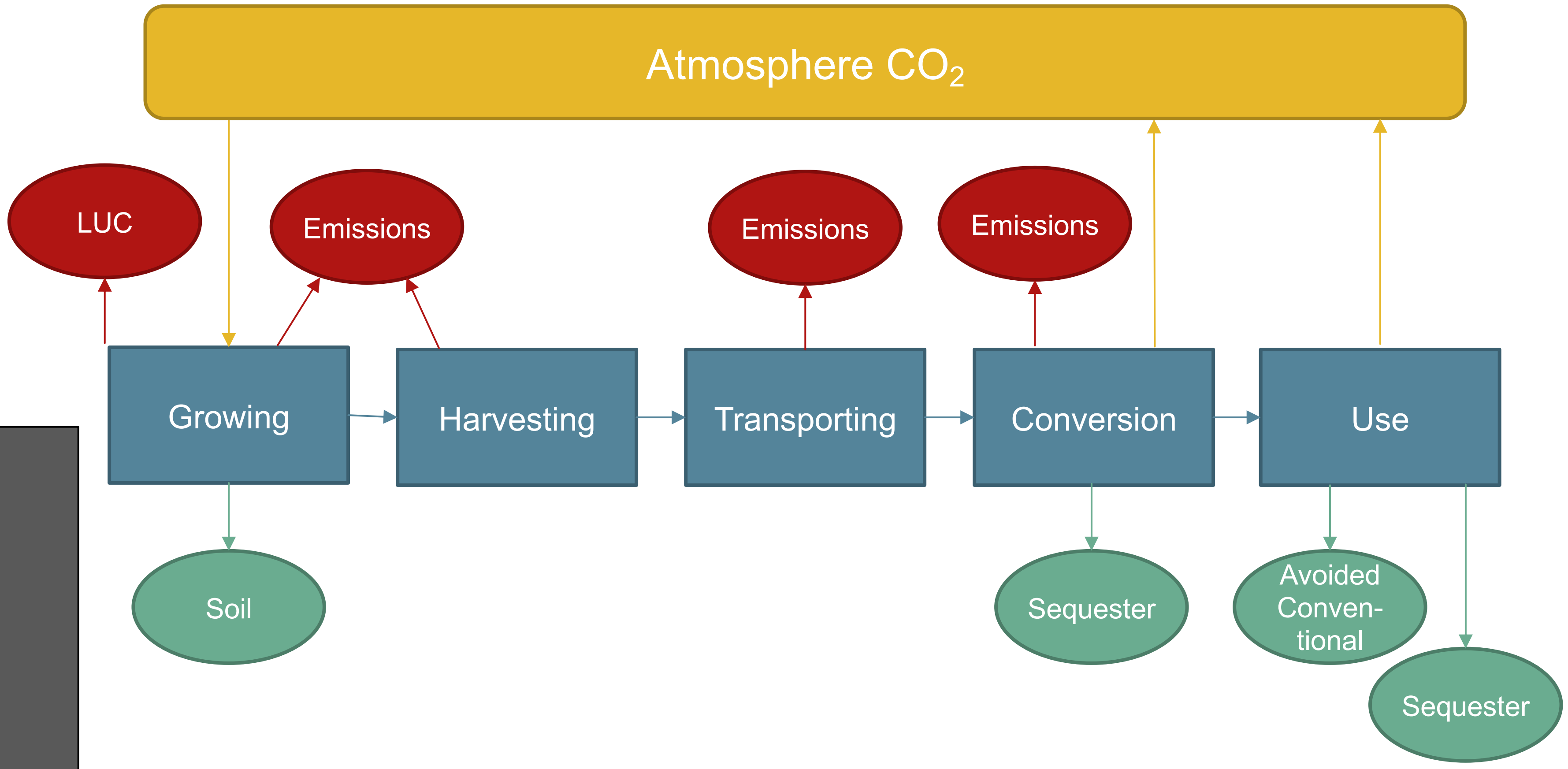
Annual Operating Plan

Project Partners

- INL – Feedstock logistics, quality attributes
- NREL – Microalgae, wastes, CO_2
- ANL – GHG emissions
- ARPA-E and PNNL – Macroalgae
- USDA – Agricultural residues, Oilseed crops, Biomass crops
- USFS – Western forest fuel reduction
- OSU, NCSU, UTK – Forest biomass

Additional Slides

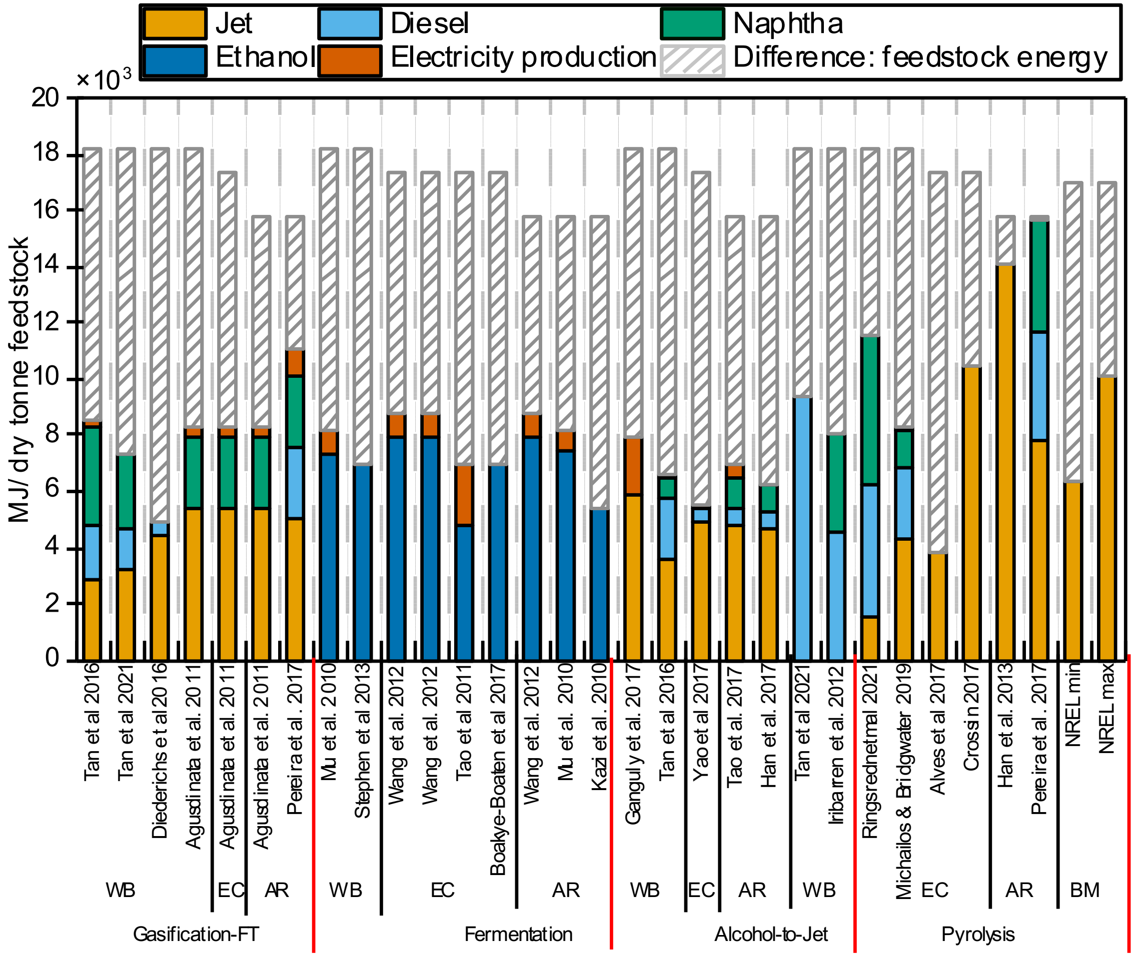
Carbon accounting - Best Use of Biomass

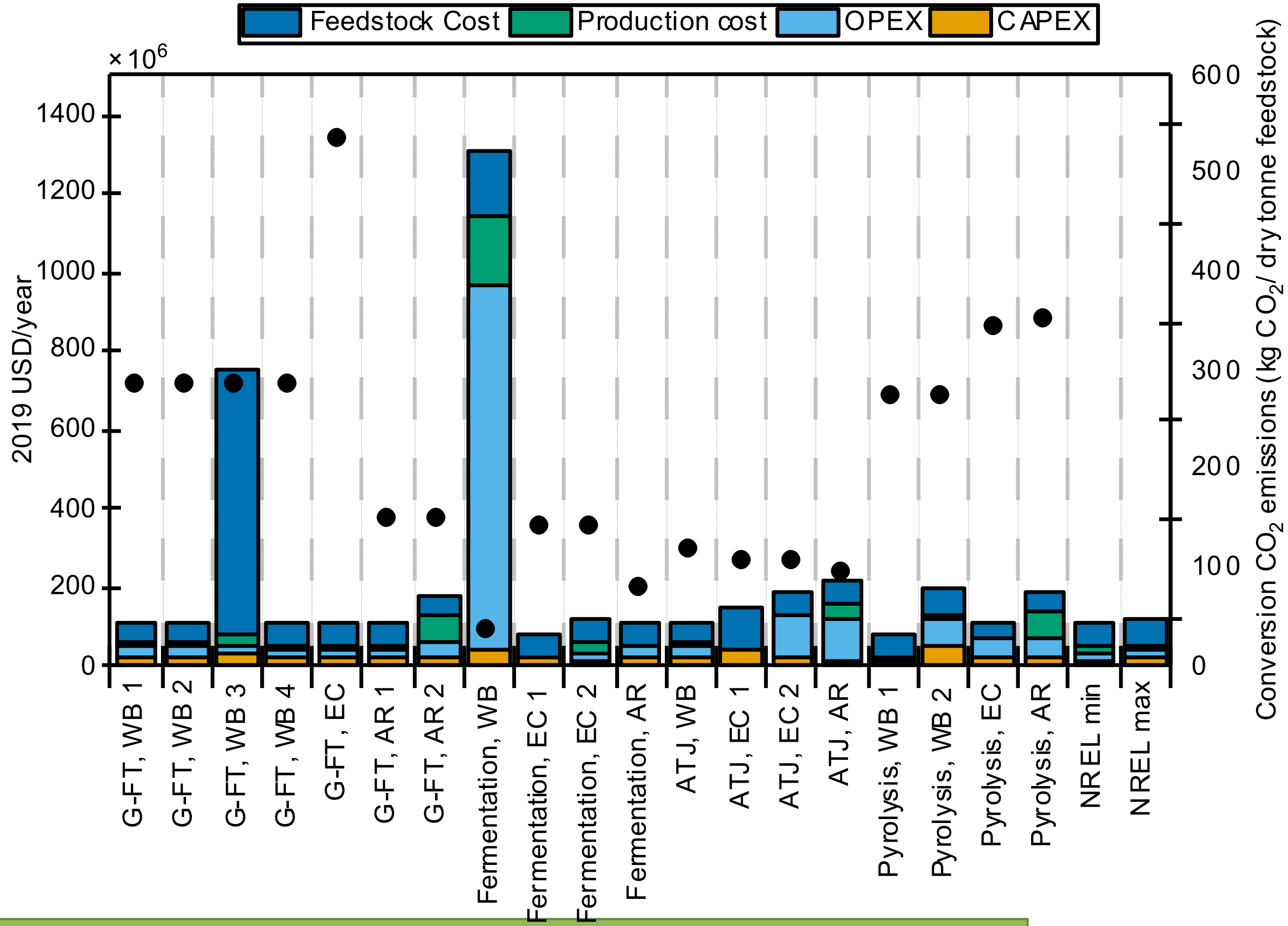


Net benefit:
+ soil storage
- emissions
+ sequestration
+ avoided conventional carbon

Wide variation in LCA and TEA studies impact CAC calculations

Peer-reviewed LCA/TEA studies collected; yields, costs, carbon emissions compared to choose pathways to run in BILT





Most studies **do not** conduct LCA and TEA simultaneously; a limitation in data collection from peer-reviewed publications => impacts CAC calculation.

Responses to Previous Reviewers' Comments

- Mitigate resource supply and cost data uncertainty with field confirmation – We agree with this comment and 1) will build new field data based on the 2022 Cropland Data Layer, and 2) will include crop yields modeled in the SunGrant Regional Feedstock Partnership.
- Include simulations of Best Management Practices – We agree that BMPs are important and will include a binding analysis of sustainability constraints.
- Consider competition for biomass resources among new end uses – We will incorporate new uses in the Best Use of Biomass analysis framework.
- FY22 Go/No-go: Revised extended agricultural baseline is included in the agricultural modeling.

Select Recent Publications and Presentations

- Setting the Scene – The Impact of FOGs as a Near-Term Feedstock for Biodiesel, Renewable Diesel, and Sustainable Aviation Fuels – Currently Used and Future Potential, IEA Workshop: Avoiding a Supply Chain Crunch for Liquid Biofuels, March 7th, 2023, Washington, DC.
- Tri-State Regional SAF Workshop (NY, NJ & CT), New York, New Jersey, Connecticut: Tri-State Region Sustainable Aviation Fuel (SAF) Workshop, Feb 23rd, 2023, New York, NY.
- A Fuel and Feedstock View from the Present into the Future, Advanced Biofuels Leadership Association, March 5th 2023.
- A Fuel and Feedstock View from the Present into the Future, SAE International Government/Industry Meeting, Jan 17th 2023, Washington DC.
- US DOE's Bioenergy Technologies Office's Resource Assessment for Sustainable Biomass for use as a fuel feedstock in the contiguous US:
  DOE Billion-ton Reports (2005, 2011, 2016, 2023), Virtual Roundtable | Sustainable Biomass Availability Estimates, Dec 7th 2022.
- How best to allocate US biomass resources for least-cost decarbonization, ASABE Annual International Meeting 2022, July 18th 2022, Houston, TX.
- SRWC Eucalypts for Carbon Sequestration and Biochar Production in Florida, USA, 2022 Short Rotation Woody Crops International Conference, May 2nd 2022, Asheville, NC.
- Sustainable US Biomass Potentials, Bioenergy with Carbon Capture & Storage, March 16th 2022, Virtual.