DOE Bioenergy Technologies Office (BETO) 2023 Project Peer Review

Roads to Removal

April 4, 2023
Technology Area Session: Feedstock Technologies

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Project Overview

1st of its kind assessment: national-scale Carbon Dioxide Removal (CDR) potential available by 2050

County-level CO_2 removal capacity and costs

Land, water and energy demands, transport, lifecycle greenhouse gas impacts, soil and geologic storage, and social equity impacts

Targets BETO's goals for carbon drawdown—specifically the capacity to use biomass and organic wastes for CDR

Roads to Removal

Assessment. Not policy recommendations.

Capacity and cost in 5 key sectors, PLUS *durability, measurability, additionality*

Cross-cutting analysis: Environmental justice, land availability, resource availability (C-free energy, transport, water)

NOT a policy recommendation

Does not include surveys of social/EJ, enhanced rock weathering or macroalgae

<u>Key Milestones</u>

Phase 1: March 2022 "Initial Considerations for Large-Scale Carbon Removal in the United States: Description of Methods, Feedstocks, and Constraints" Complete

Phase II: Sept 2023, Final Report with associated peer-review publications

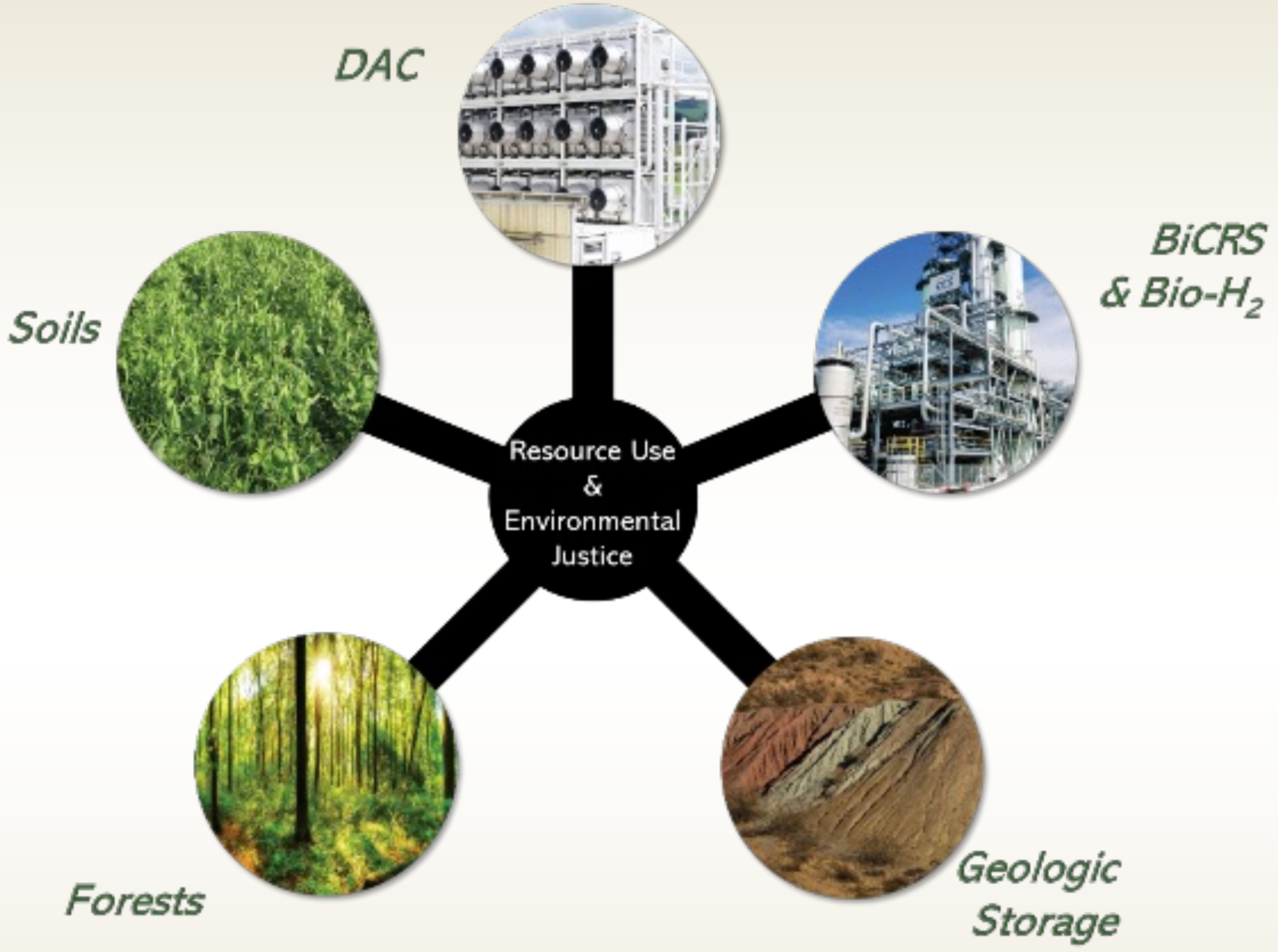
1 – Approach

CO_2 removals for the five major approaches:

1. Forests
2. Soils & Agriculture
3. BiCRS (Biomass Carbon Removal & Storage)
4. DAC (Direct Air Capture)
5. Geologic Storage)

Costs by technology and location (county-level where feasible) using existing data (e.g. *Billion Ton Report*), and new modeling

Our team has deep, multidisciplinary expertise; we also consider cross-cutting issues such as resource use and environmental justice.



Improved forest management

Use FIA and industry data to quantify the biophysical potential for change in (i) forest management, (ii) wood products, and (iii) wood-product fate to reduce future CO_2 in the air.

1) High-level evidence synthesis of the potential of regional strategies

2) County-level assessment of biophysical potential

- Plantation -> secondary forest; clear-cut -> shelterwood; fuel-reduction
- Pulp -> timber
- Non-structural timber -> mass timber

Soil and Agricultural Systems

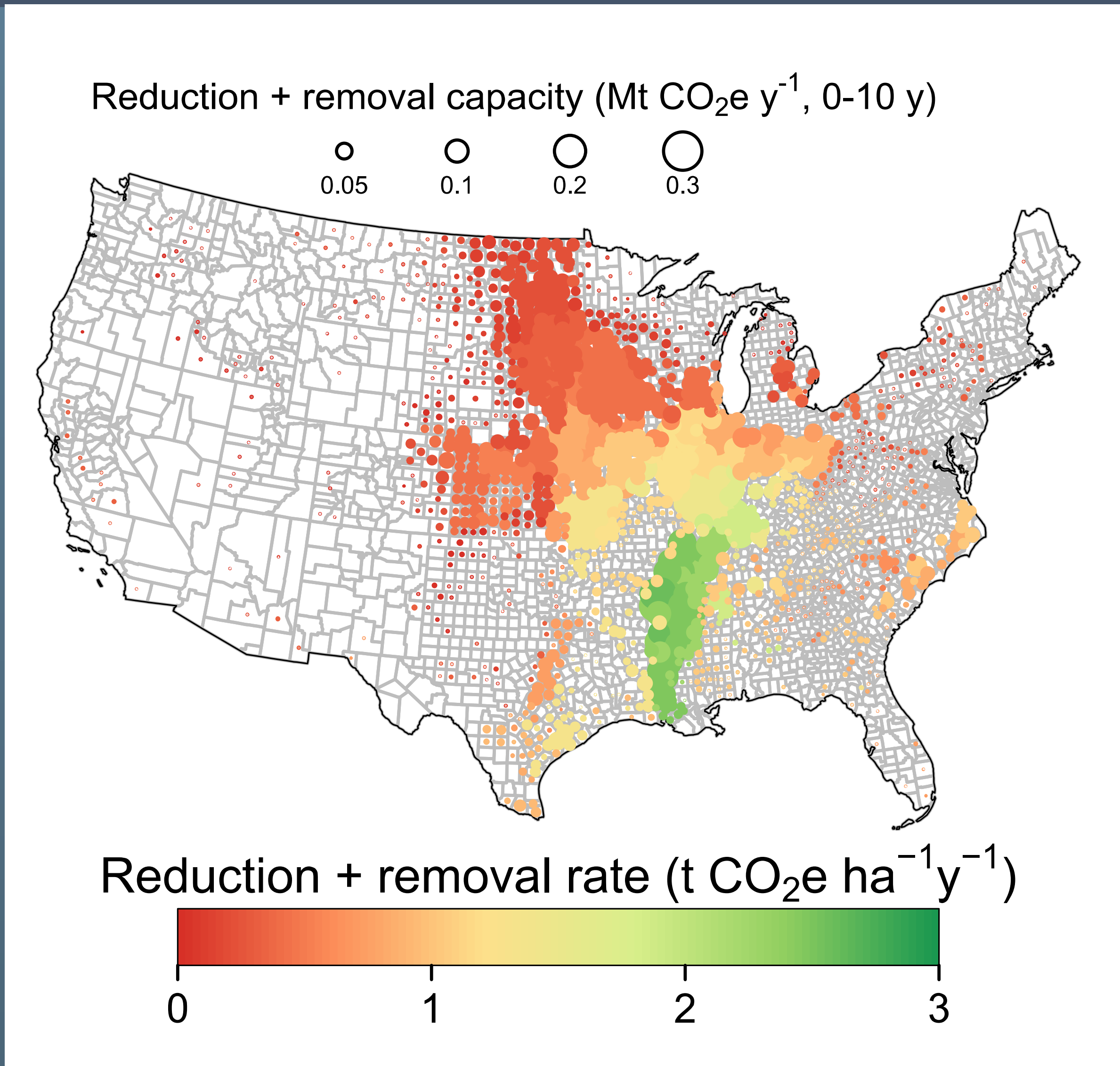
Assess ***ecological carbon storage*** *achievable by conservation agriculture (e.g., cover cropping) and perennial bioenergy systems.*

Measure biophysical outputs (using the COMET biogeochemical model):

1. Net increase in soil carbon stocks
2. Avoided emissions (e.g., from N_2O)
3. Yield & biomass supply

Major inputs & constraints:

1. Land availability
2. Carbon price, costs of production
3. Future climate (downscaled global climate models)
4. Biomass demand



Example: modelled capacity and emissions reductions + CO_2 removal rate for cover cropping, based on COMET Planner data. [*LLNL Microsoft report*]

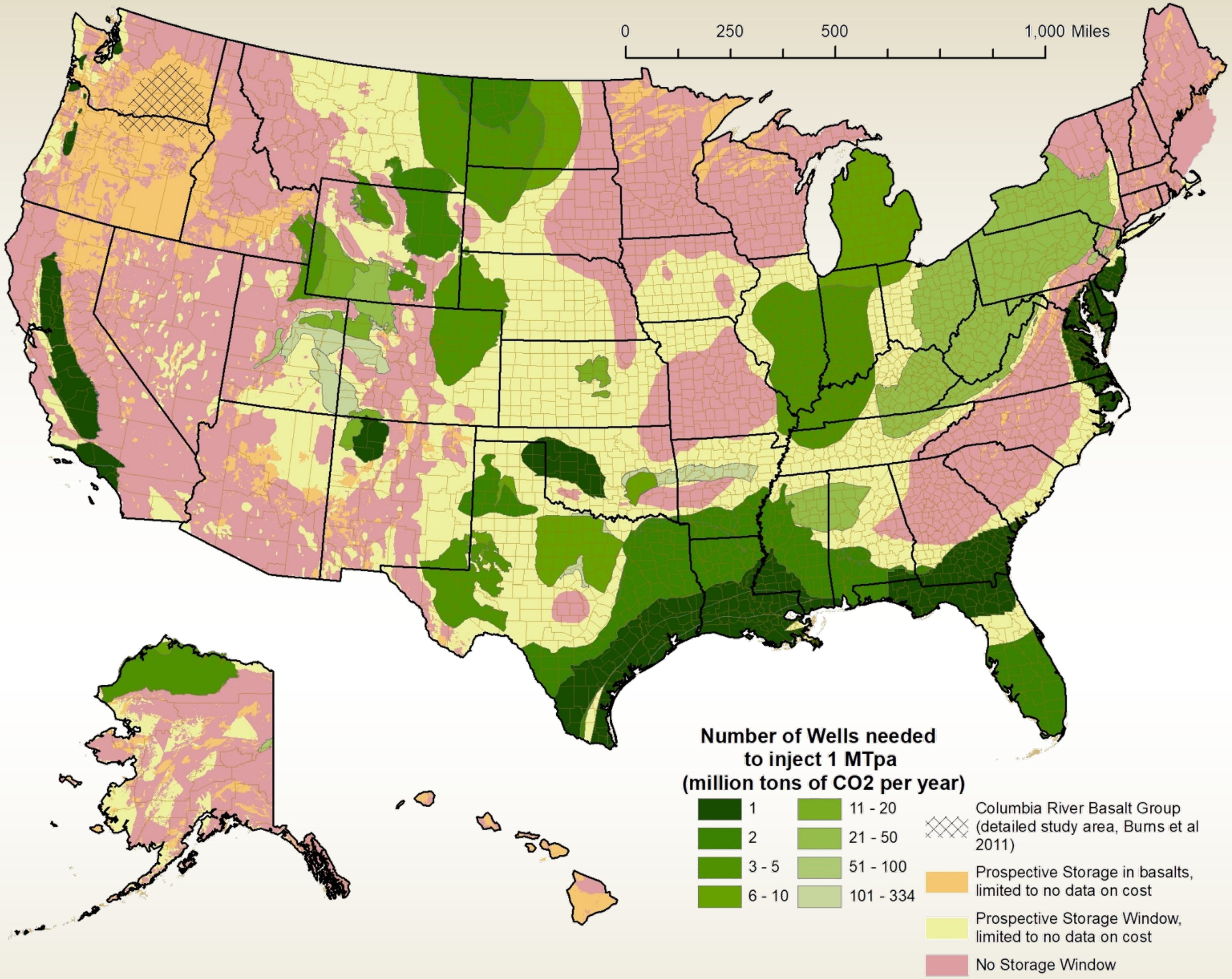
Geologic Storage

- Identify geologic storage options and costs
- Assess storage capacity in saline aquifers – and degree of confidence

Assignment for ~30 basins.

- Inventory of which units are available and their status.
- Proxy algorithms to infill missing data.
- Building uncertainty coverages.

First ‘reconnaissance’ look at Alaska.



BUREAU OF ECONOMIC GEOLOGY

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Biomass Carbon Removal and Storage

Provide regional understanding of impacts, opportunities, and barriers for BiCRS

Phase 1: assemble data

- Major county level biomass sources and methods; identification of analysis regions
- Identification of major technologies, pathways, and boundaries
- Identification of lowest cost, highest volume CO_2 technologies according to region; research needs and deployment barriers

Phase 2: systems analysis

- System level considerations and impacts-e.g. facility size, location, energy source
- Full county level system cost for selected regions
- Economic drivers and impacts of land use change (e.g. corn to bioenergy crops)
- Co-benefits: avoided emissions, social, environmental

Forest Treatment

Agriculture: residues and bioenergy crops

Wastes

Conversion Technologies: Cost and carbon removal potential

Transport and Storage

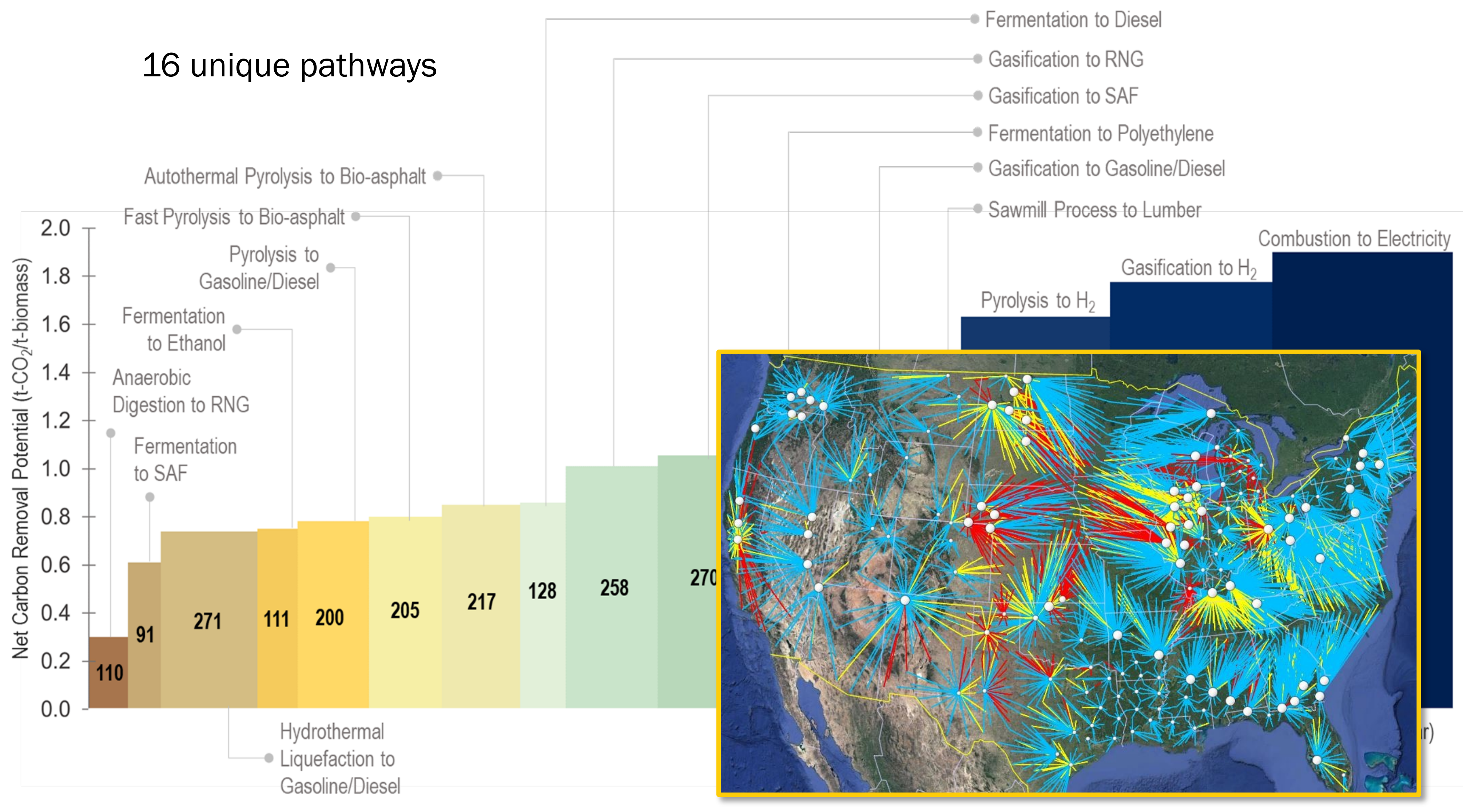
Managed Forests, pulp and paper

BiCRS Baseline: 0.5 GT net removal using waste biomass

Modeled in-depth TEA for 16 unique pathways TRL>8, with facility spatial optimization

Baseline is waste biomass (up to 300 million tons per year) with no CO_2 pipeline network

BILT model spatial optimization for biorefinery sizing, placement and assessment of transportation costs

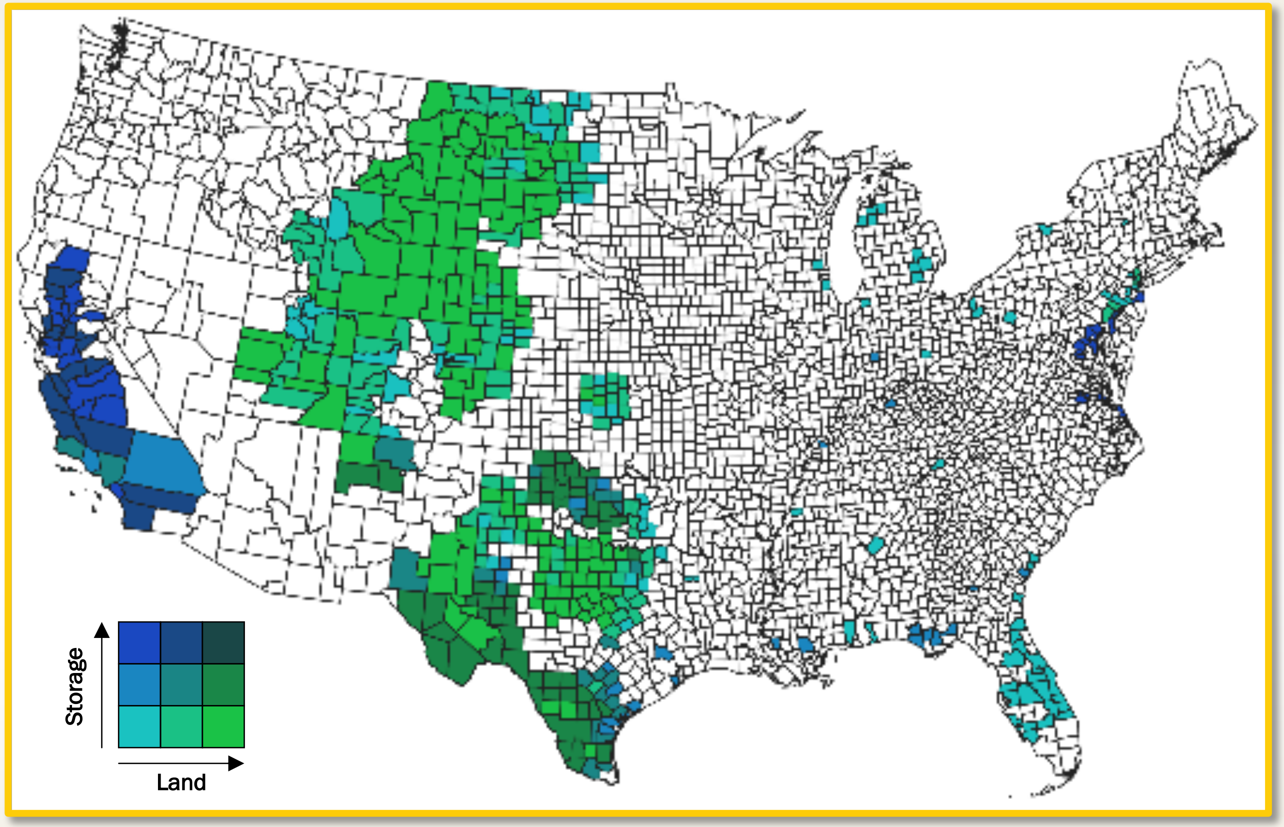


Direct Air Capture (DAC)

If you can build DAC anywhere, where do you build it? What will it cost?

Phase I:

- Review/revise current DAC costs and energy requirements
- Options for electrification
- Location-based costs and capacities
  - Regional climate
  - Land/resource availability
  - Energy infrastructure and potential
  - Sequestration sites



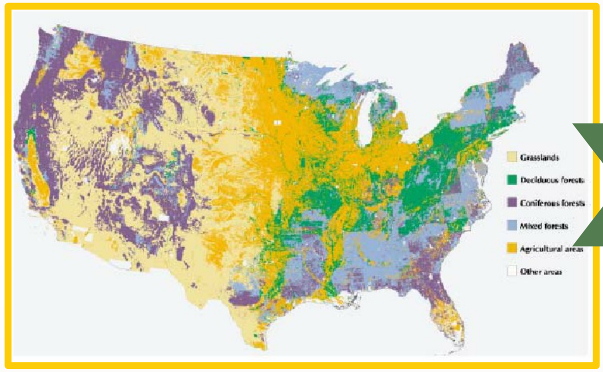
Priority DAC regions with geologic storage and land for renewable energy

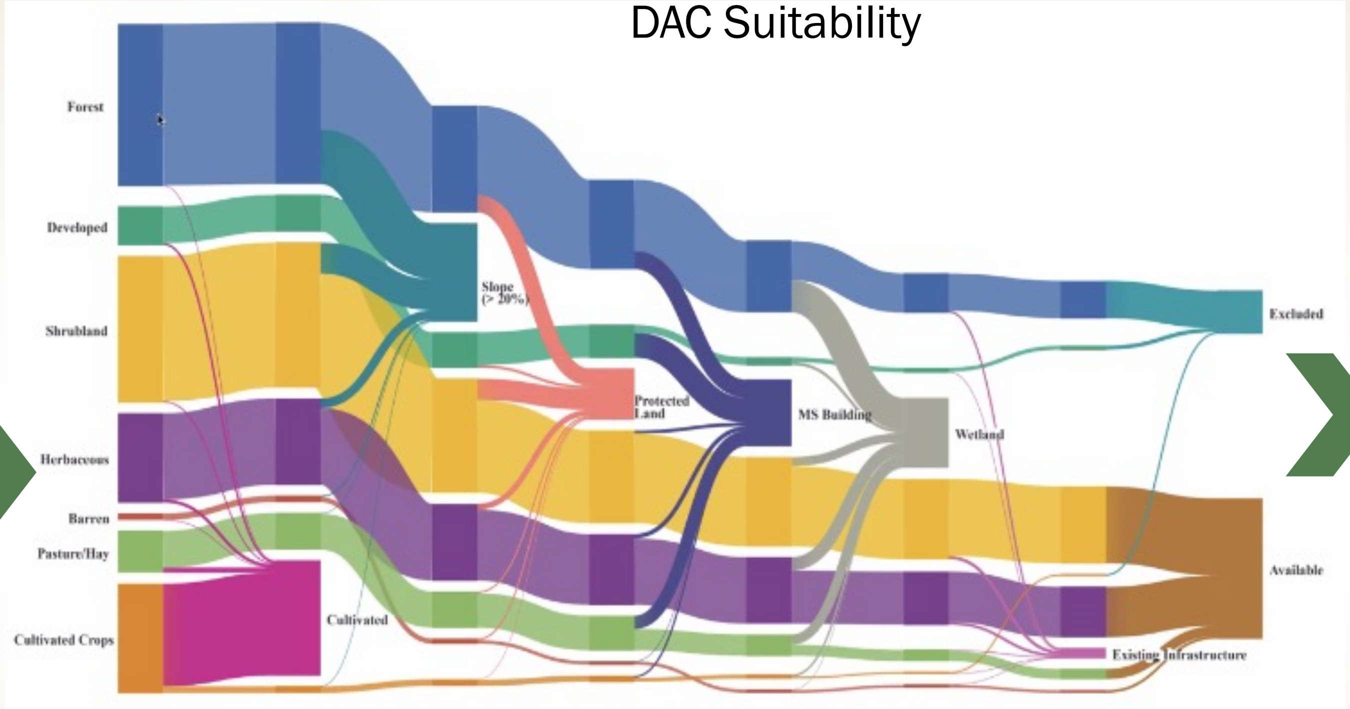
Phase II:

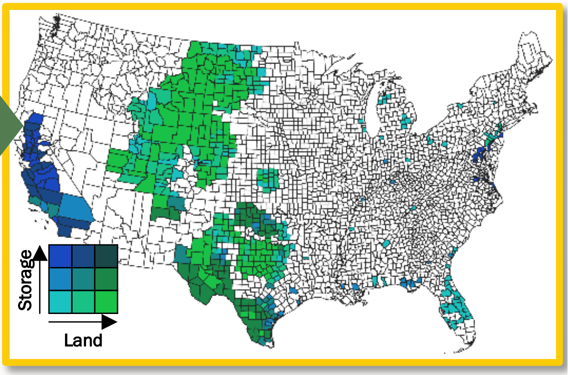
- New integration opportunities – costs, capacities, locations
- Learning curves and Nth plant costs – how do we get there?
- Justice, equity, diversity, and inclusion considerations

Renewable Energy, Biomass, and CO_2 Pipelines Dictate Distribution of DAC and BiCRS: *Example for DAC Analysis*

Natural resource distributions will result in a natural differentiation of ideal sites







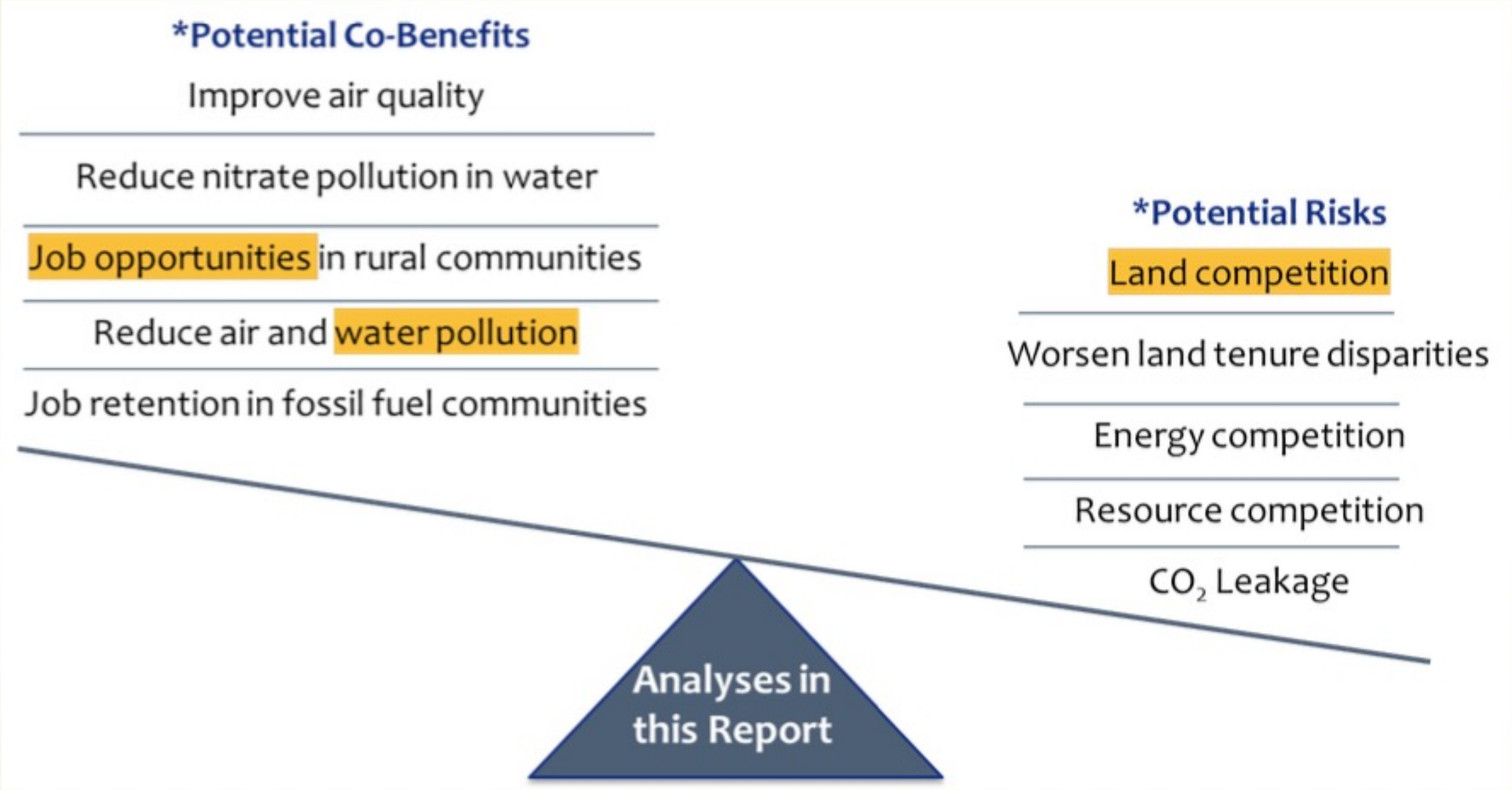
DAC potential concentrated in West (solar, wind, geothermal-rich areas on geologic storage or CO_2 pipelines)

Pioneered the use of Sankey diagrams to quantify resource availability and suitability

Cross-Cutting Analyses: we need to prioritize land/resource use & environmental justice

Strategic deployment of CO_2 removal has the potential to reduce pollution & replace lost jobs

Quantitative trade-off analysis



2 – Progress and Outcomes

March 2022

All funding received
Jan 2023

Analyses
complete
April 2023

Red-team review
July 2023

“Roll Out”
Sept-Nov 2023

Kick off
Nov
2021

Project Update for DOE
Sept 2022

U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

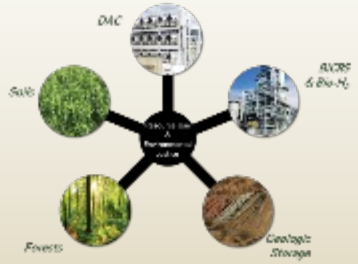
U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

RtR All Hands Mtg
Jan 2023

Draft text & figures
May-June 2023

Revisions, final
figure edits
Aug 2023

FINAL REPORT
Sept 2023



2 – Progress and Outcomes

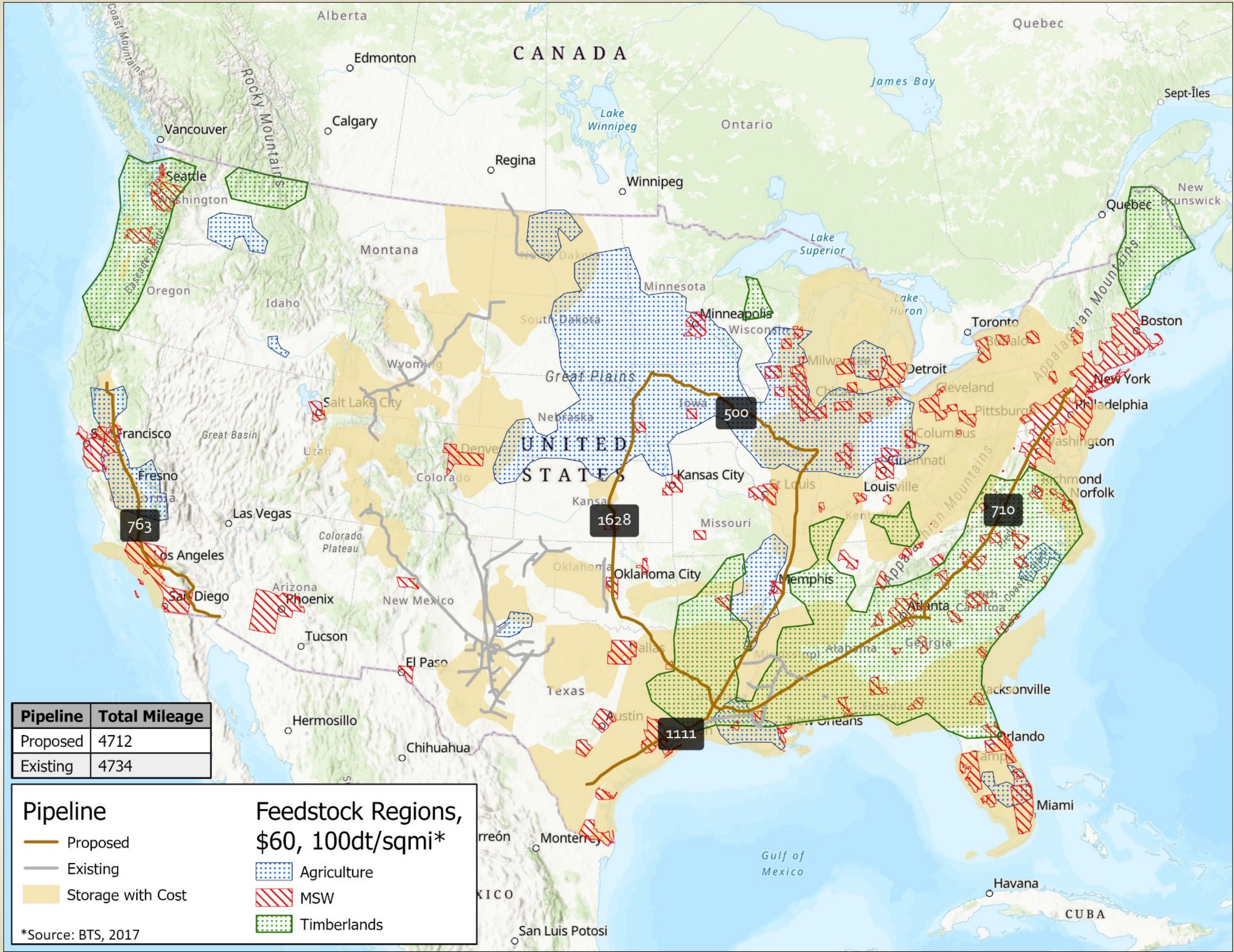
Collected **quantitative input data and defined boundary conditions** to identify regional-level strategies with high/low CDR potential

Published methodology and data sources in our March 2022 scoping report: '*Initial Considerations for Large-Scale Carbon Removal in the United States: Description of Methods, Feedstocks, and Constraints*'

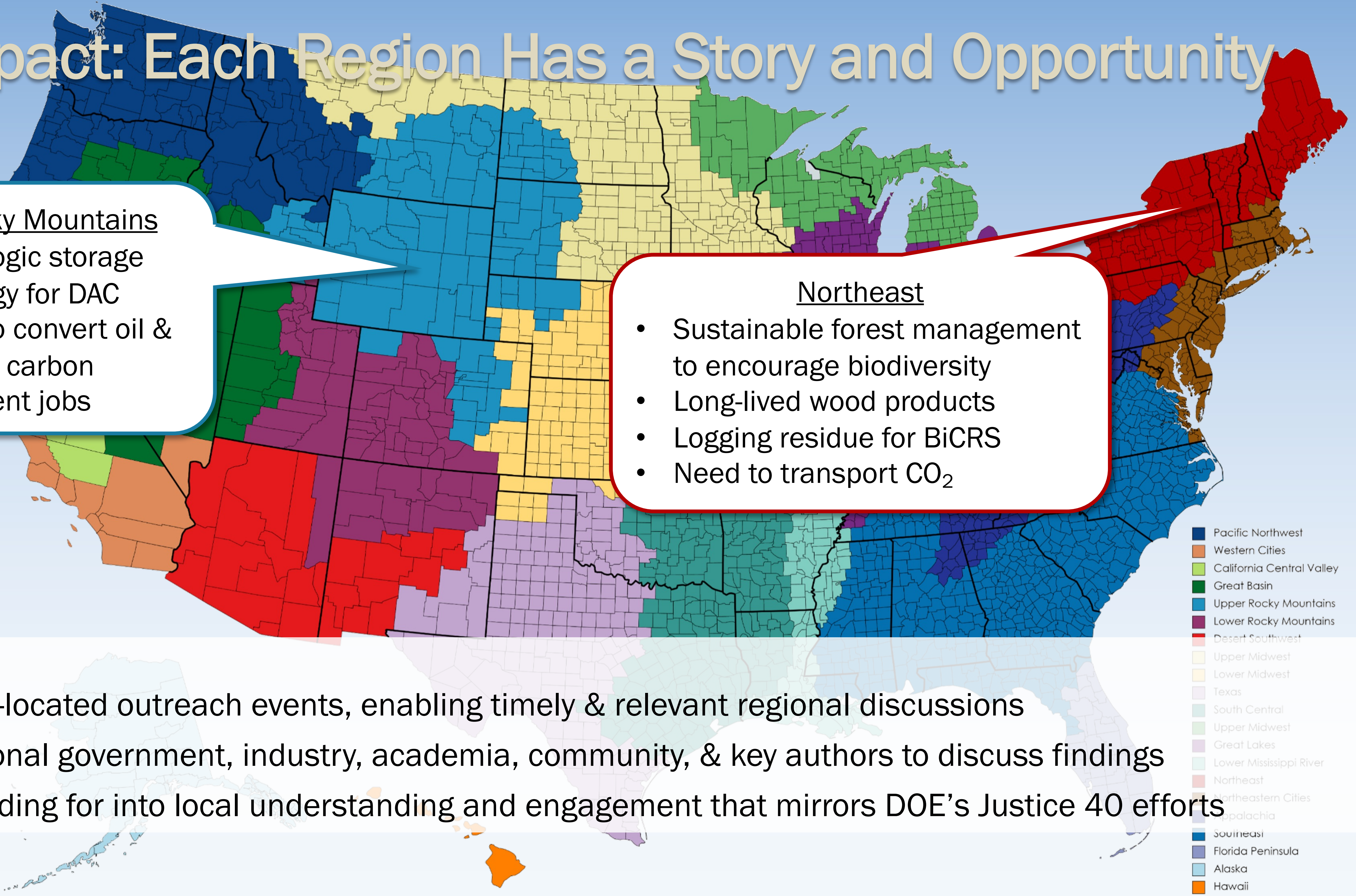
Presented initial results at the Dec 2022 American Geophysical Union Meeting

Held in-person All Hands meeting Jan 2023; harmonized analyses; developed outline for final report

Trunk CO_2 pipelines would reduce system cost and use the highest-quality storage sites



3 – Impact: Each Region Has a Story and Opportunity



Upper Rocky Mountains
- Local geologic storage
- Wind energy for DAC
- Potential to convert oil & gas jobs to carbon management jobs

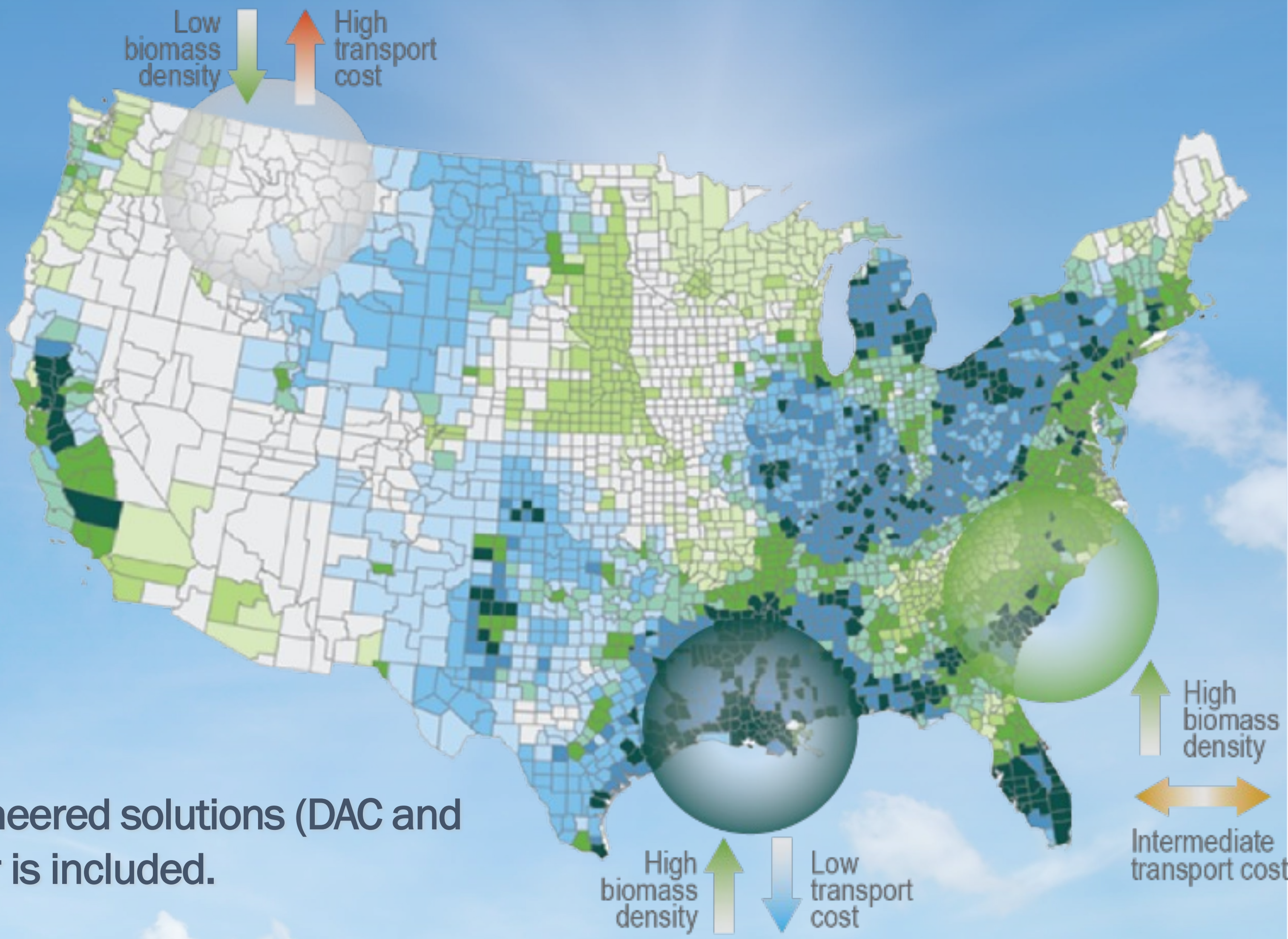
Northeast
- Sustainable forest management to encourage biodiversity
- Long-lived wood products
- Logging residue for BiCRS
- Need to transport CO_2

We propose:
- ➢ Strategically-located outreach events, enabling timely & relevant regional discussions
- ➢ Include regional government, industry, academia, community, & key authors to discuss findings
- ➢ Translate finding for into local understanding and engagement that mirrors DOE’s Justice 40 efforts

The United States has abundant resources for CO_2 removal and biofuel

We are completing a county by county assessment of resources and costs.

Both natural and engineered solutions are included, with an assessment of durability.



Permanent storage of CO_2 removed by engineered solutions (DAC and BiCRS) to ensure it does not return to the air is included.

We describe HOW we can accomplish CDR while improving the lives and prosperity of Americans, especially in communities with environmental justice concerns

Quad Chart Overview

Timeline

- *Project start date:* 9/01/2021
- *Project end date:* 9/30/2023

	FY22 Costed	Total Award
DOE Funding	(10/01/2021 – 9/30/2022) $802,661.64	Total: $1,800,000 (BETO portion; an additional $2.4M supplied by FECM)
Project Cost Share *	$100K from ClimateWorks	

TRL at Project Start: NA
TRL at Project End: NA

Project Goal

Produce a national-scale Carbon Dioxide (CDR) analysis – a bottom-up quantitative geospatial analysis of country-level CO_2 removal capacity and costs (a supply curve) in the terrestrial USA, to lay out CDR potential available for achieving net zero by 2050. Include a coherent analysis of land, water and energy demands, transport distances, lifecycle greenhouse gas impacts, opportunities for soil and geologic storage, and social equity impacts.

End of Project Milestone

Formal report summarizing detailed analysis of CDR supply curse at country / regional level.

Funding Mechanism

Agreement Number: NL0038728

WBS Number: 1.2.2.302

Project Partners*

ORNL, LBNL, NREL, UC Berkeley, Colorado State, Univ. Texas-TBEG, Michigan State, Univ. of Pennsylvania, Indiana Univ., Iowa State, Yale, North Carolina State Univ., Univ. New Hampshire

*Only fill out if applicable.