The Impact of Regional Resources and Technology Availability on Carbon Dioxide Removal Potential in the United States

Parisa Javadi[1], Patrick O'Rourke[2], Jay Fuhrman[3], Haewon McJeon[4], Scott C. Doney[5], William Shobe[6], and Andrés F. Clarens[1]

26th September 2024

[1] Department of Civil and Environmental Engineering, University of Virginia.

[2] School of Public Policy, University of Maryland.

[3] Joint Global Change Research Institute, Pacific Northwest National Laboratory.

[4] Graduate School of Green Growth & Sustainability, KAIST.

[5] Department of Environmental Sciences, University of Virginia.

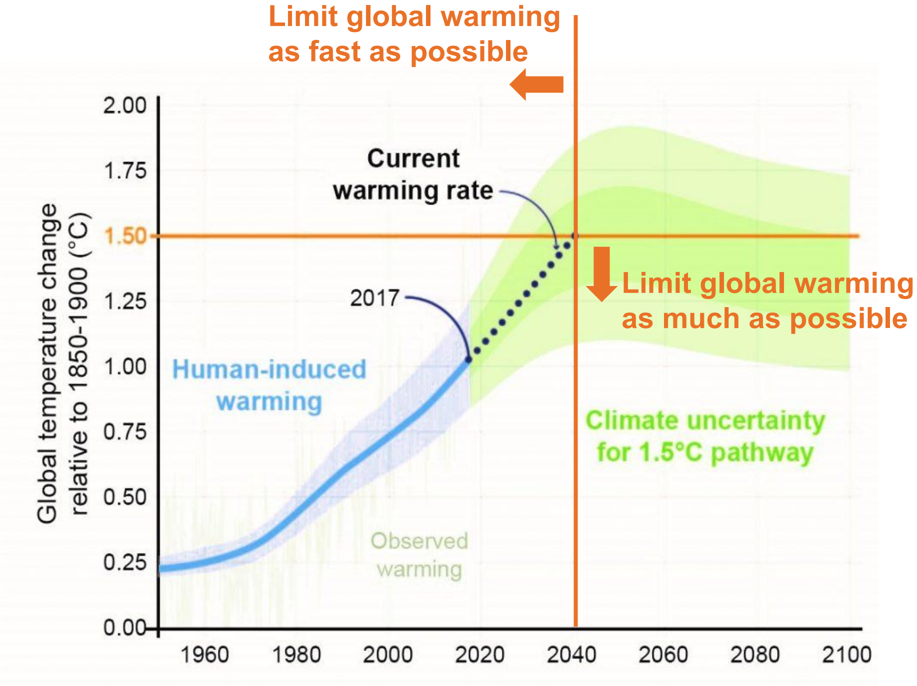
[6] Batten School of Leadership and Public Policy, University of Virginia.

Pacific Northwest NATIONAL LABORATORY

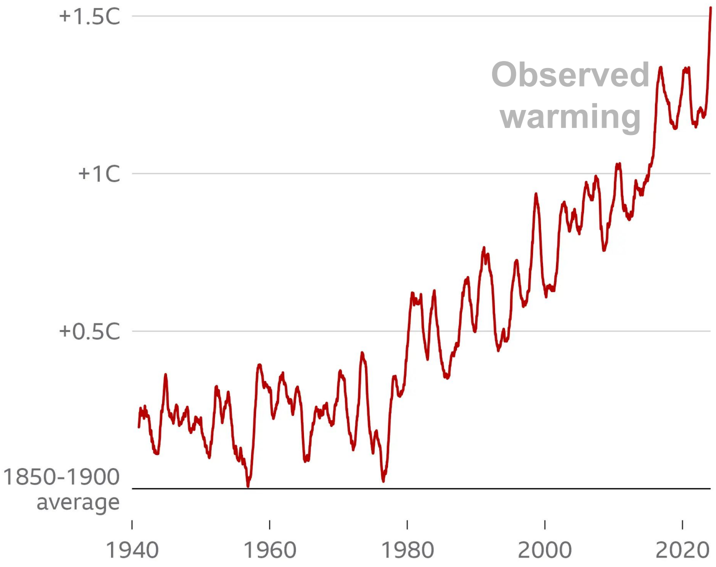
UNIVERSITY of VIRGINIA

Introduction

How close are we to 1.5°C?

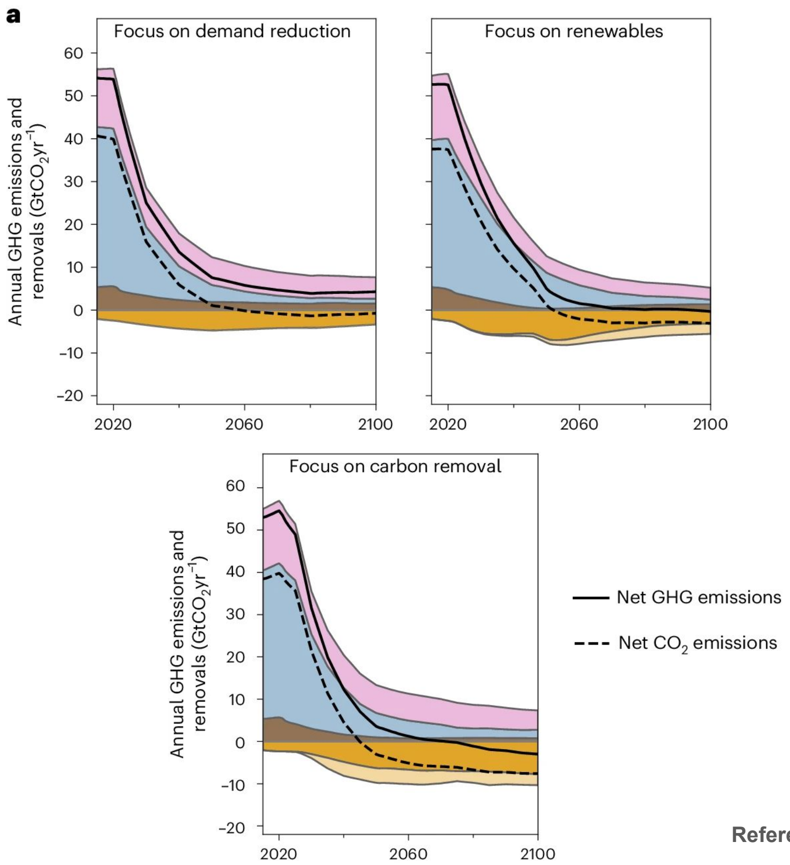


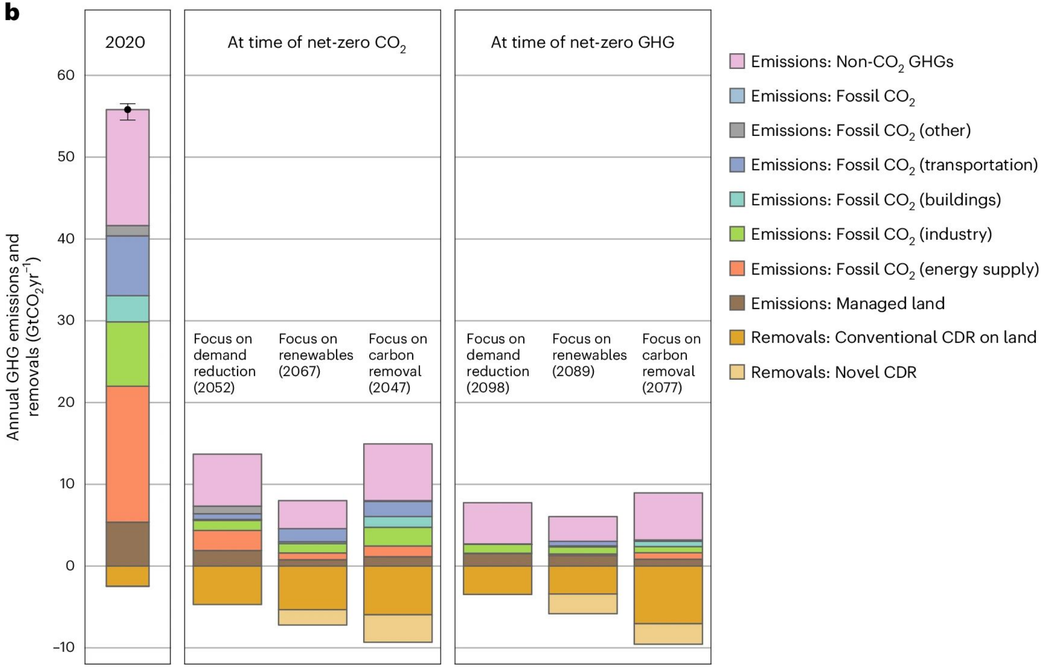
Reference: IPCC, 2018. Chapter 1: Global Warming of 1.5°C



Reference: ERA5, C3S/ECMWF

Introduction





Reference: Lamb, William F., et al. "The carbon dioxide removal gap." Nature Climate Change (2024)

Motivation and Objectives

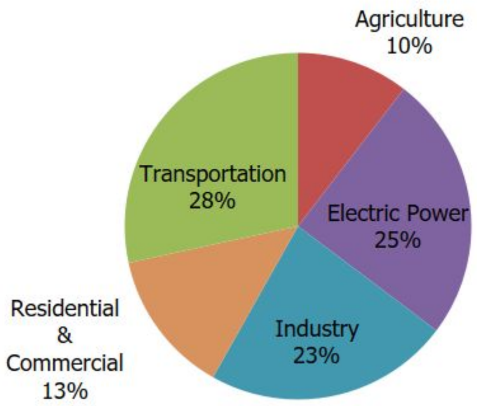
- The U.S. has committed to achieving net-zero GHG emissions by 2050 to combat climate change

- The U.S. may need to rely on CDR to offset emissions from difficult-to-decarbonize sectors

- CDR can be delivered using many approaches with different requirements for:

    Land, water, energy, geologic carbon storage capacity, and other resources

Total U.S. Greenhouse Gas Emissions by Economic Sector



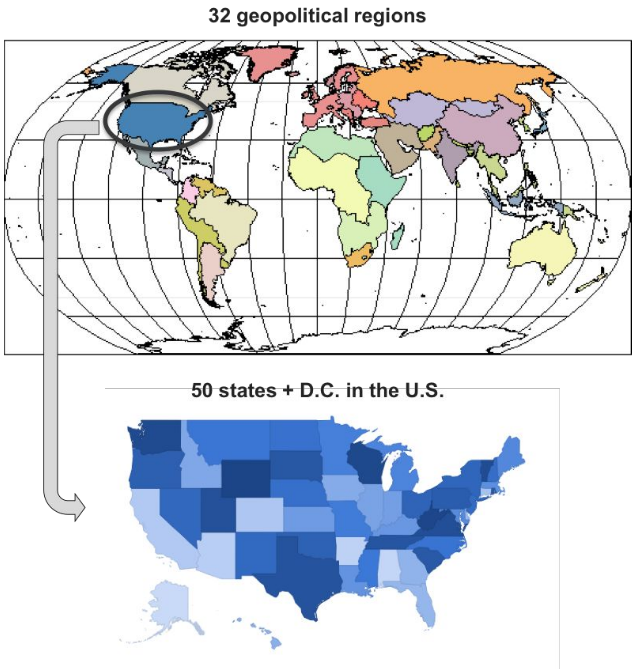
Research Questions

1- How do regional resources and technology availability influence the deployment and effectiveness of CDR approaches across different U.S. states to reach net-zero emissions by mid-century?

2- What are the implications of the U.S. net-zero emissions goal and large-scale CDR deployment, particularly in terms of regional impacts on energy, water, and land?

Global Change Analysis Model

GCAM-USA

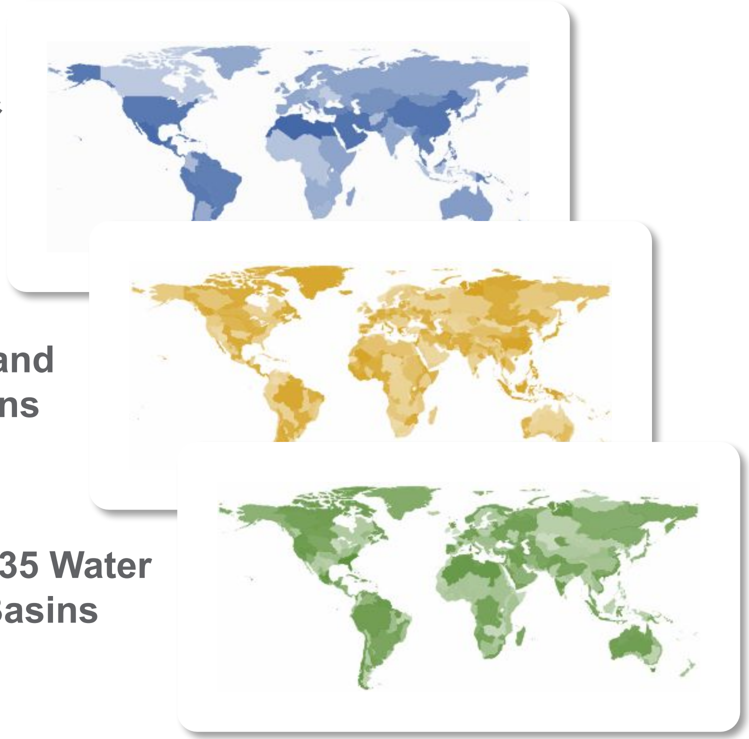


Model Coverage

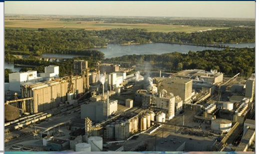
32 Energy & Economy Regions

384 Land Regions

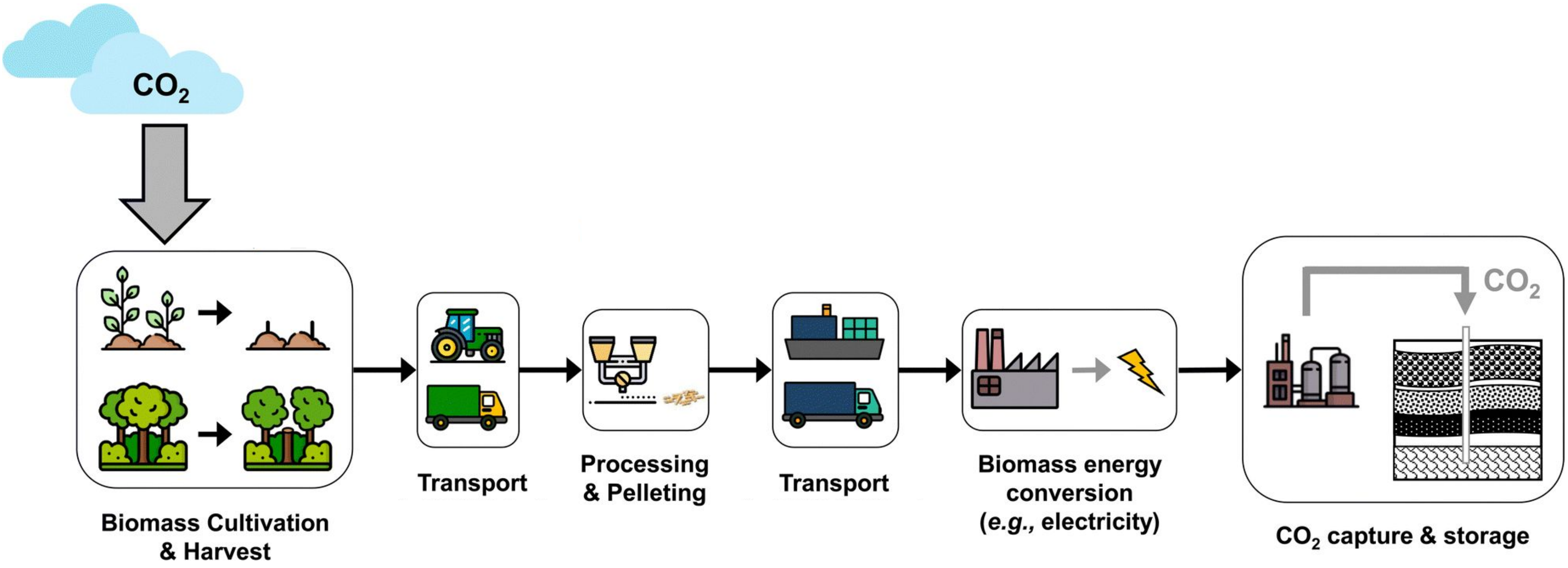
235 Water Basins



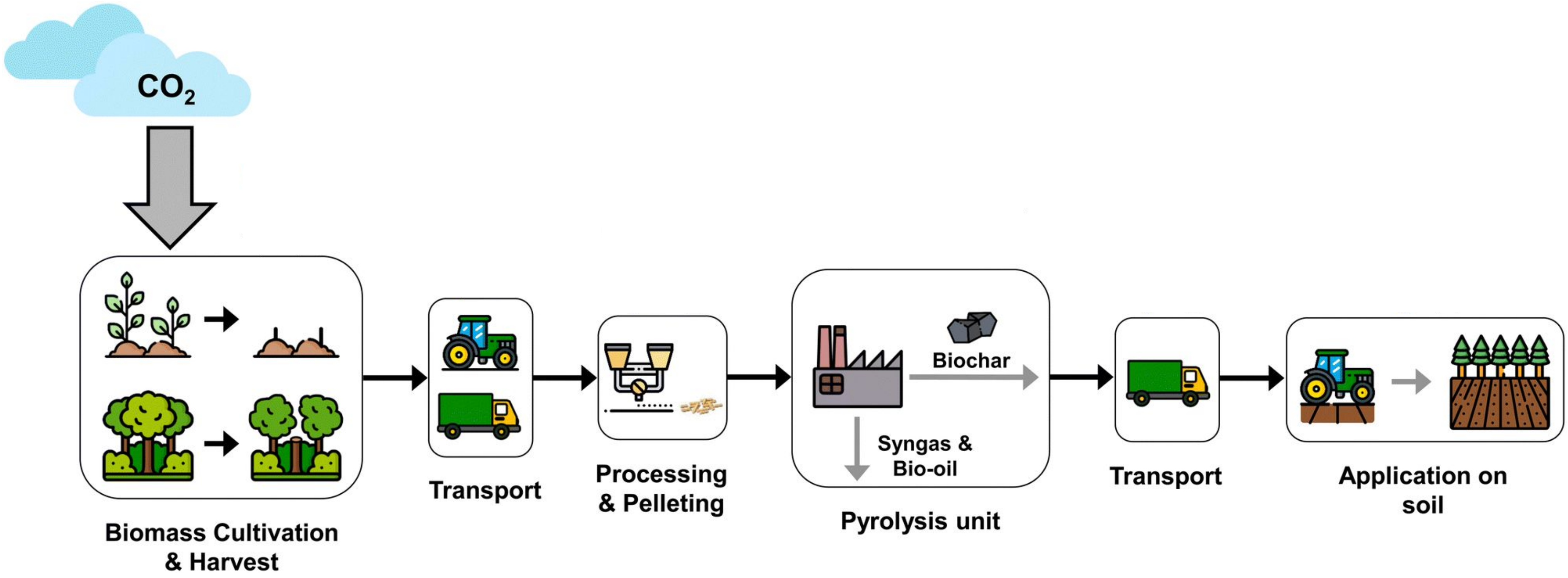
GCAM-USA Capability

CDR technology	Description	
Bioenergy with Carbon Capture and Storage	Biomass paired with geologic carbon storage for electricity, liquid fuels refining, hydrogen production, and industrial energy use	
Afforestation	Storage of atmospheric carbon by restoring deforested lands or planting new forests where none existed previously	
Direct Air Capture with Carbon Storage	Solvent and sorbent-based processes using a combination of electricity and natural gas to separate and geologically store CO_2 from the atmosphere	
Enhanced Rock Weathering	**Crushed basalt application to croplands**	
Biochar	**Slow pyrolysis of second-generation biomass**	
Direct Ocean Capture	**Electrochemical stripping of CO_2 from seawater paired with geologic storage**	

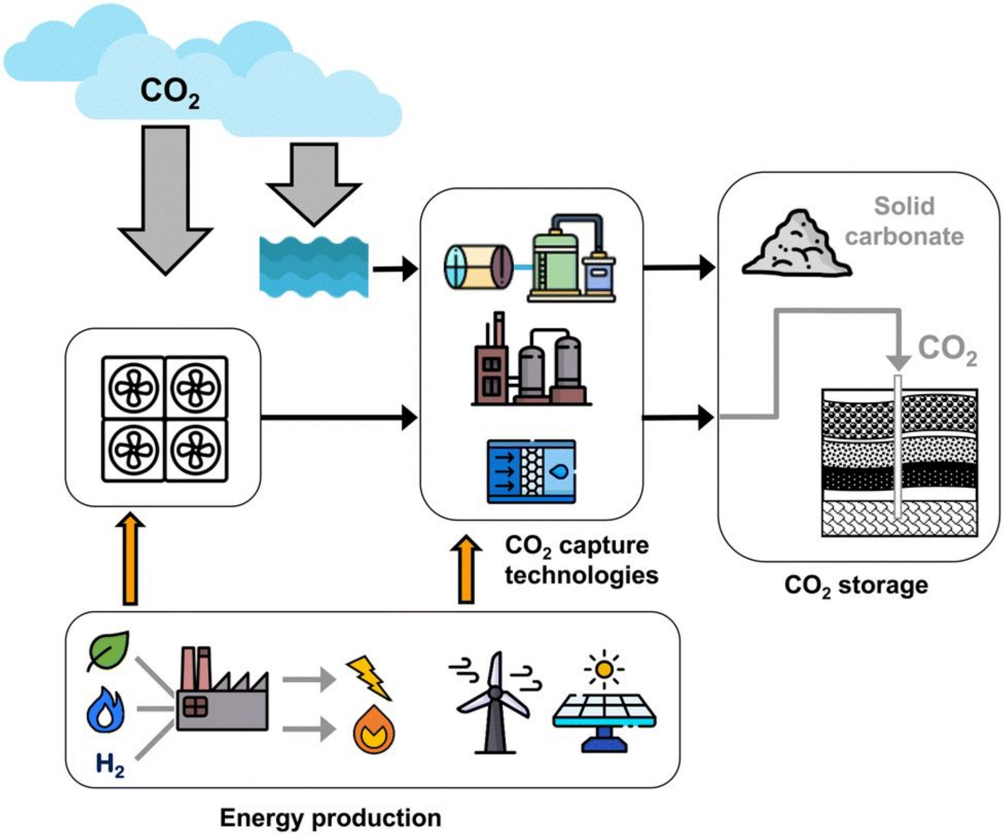
Bioenergy with CO_2 Capture and Storage



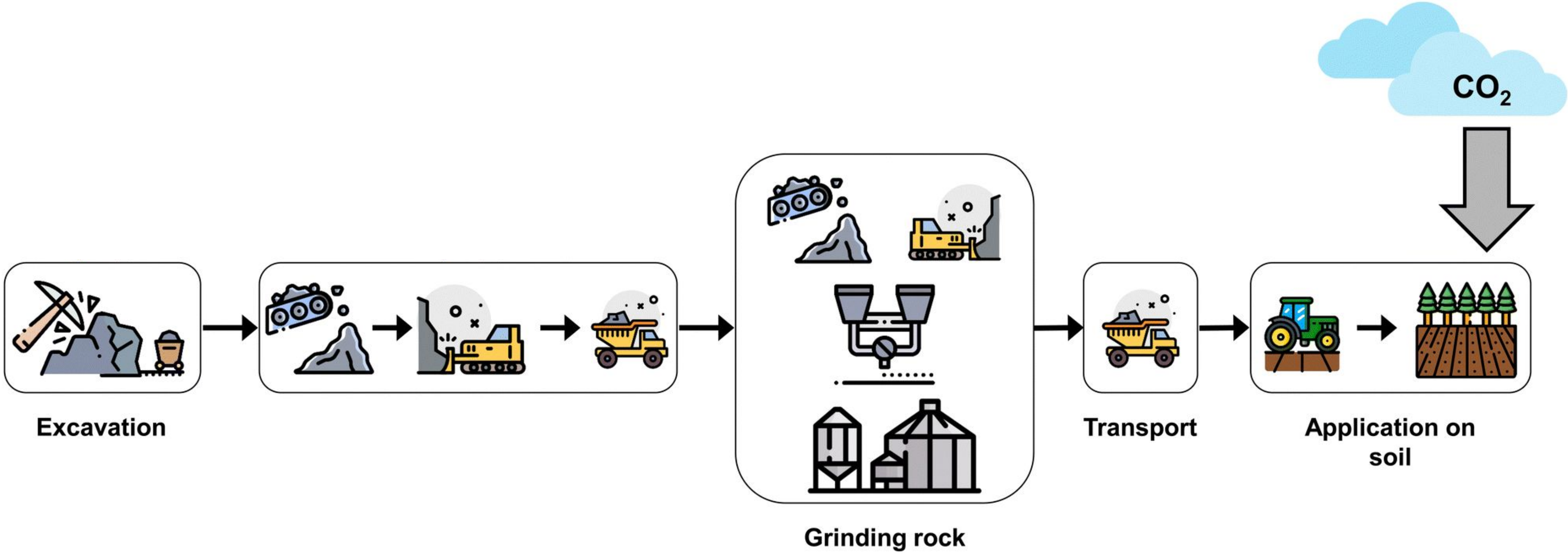
Biochar for Soil Enhancement



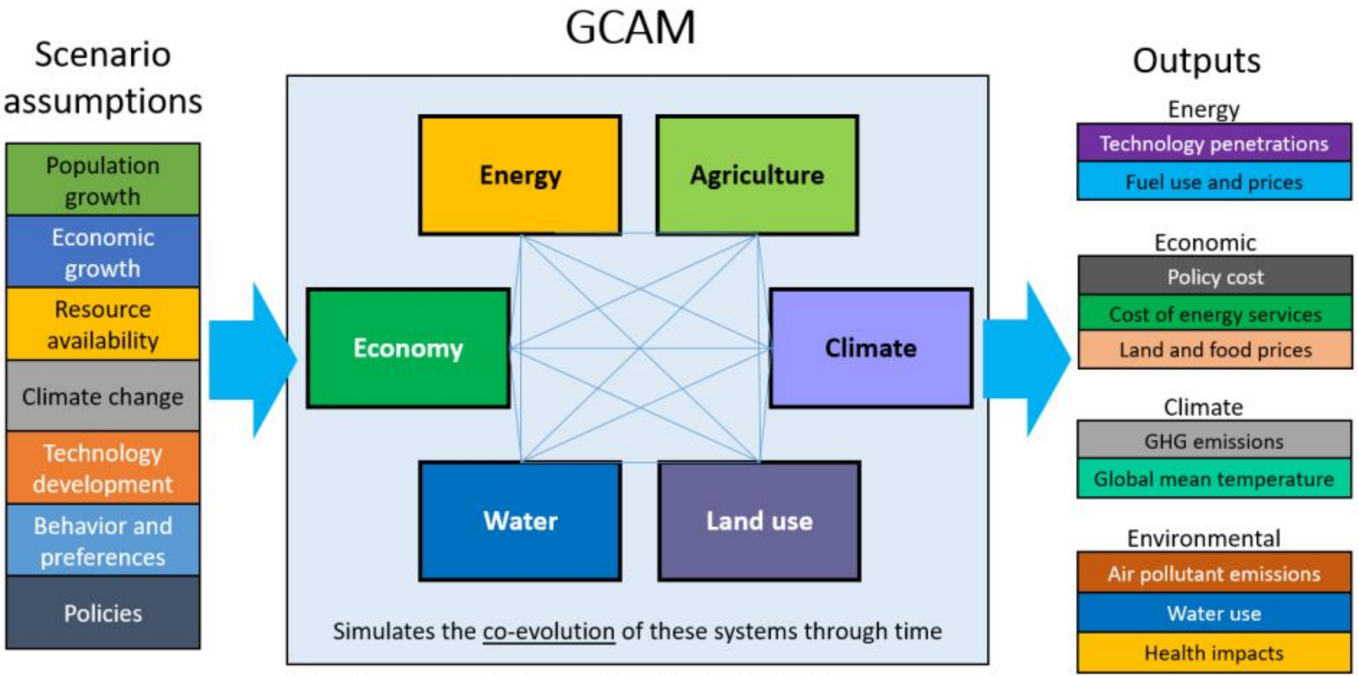
Direct CO_2 Capture from Air and Ocean with Storage



Enhanced Rock Weathering

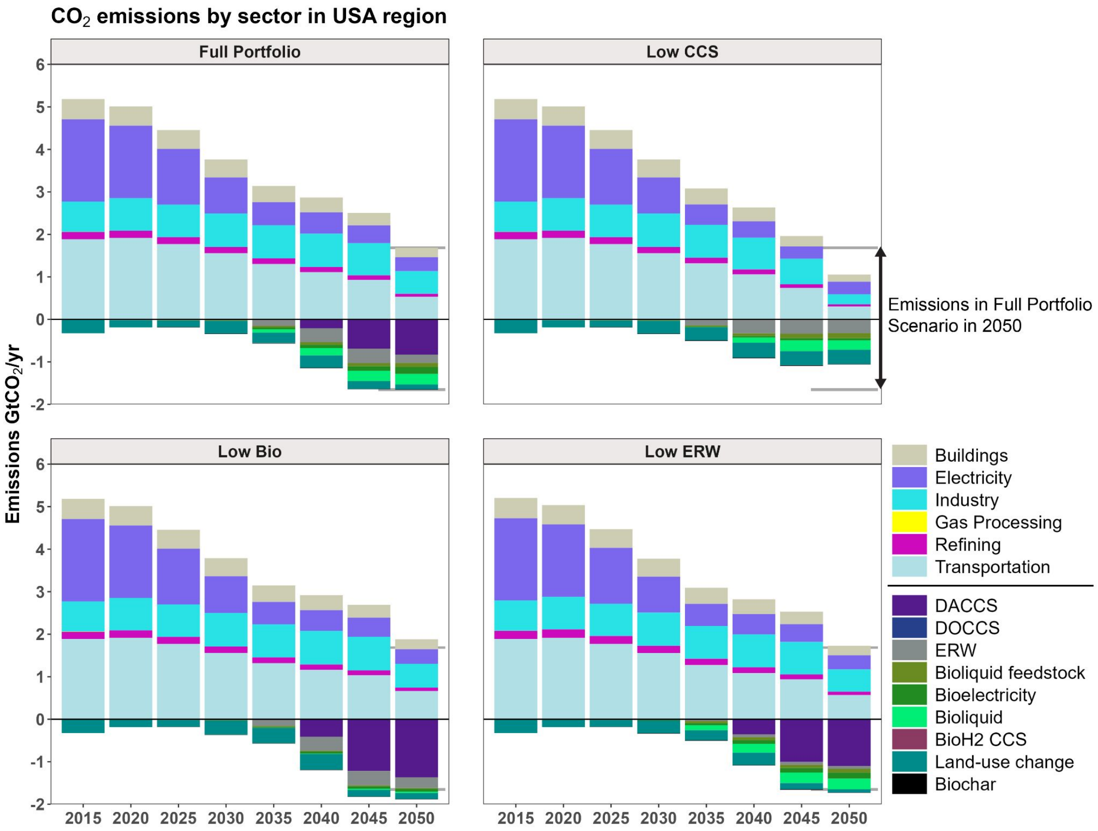


Global Change Analysis Model



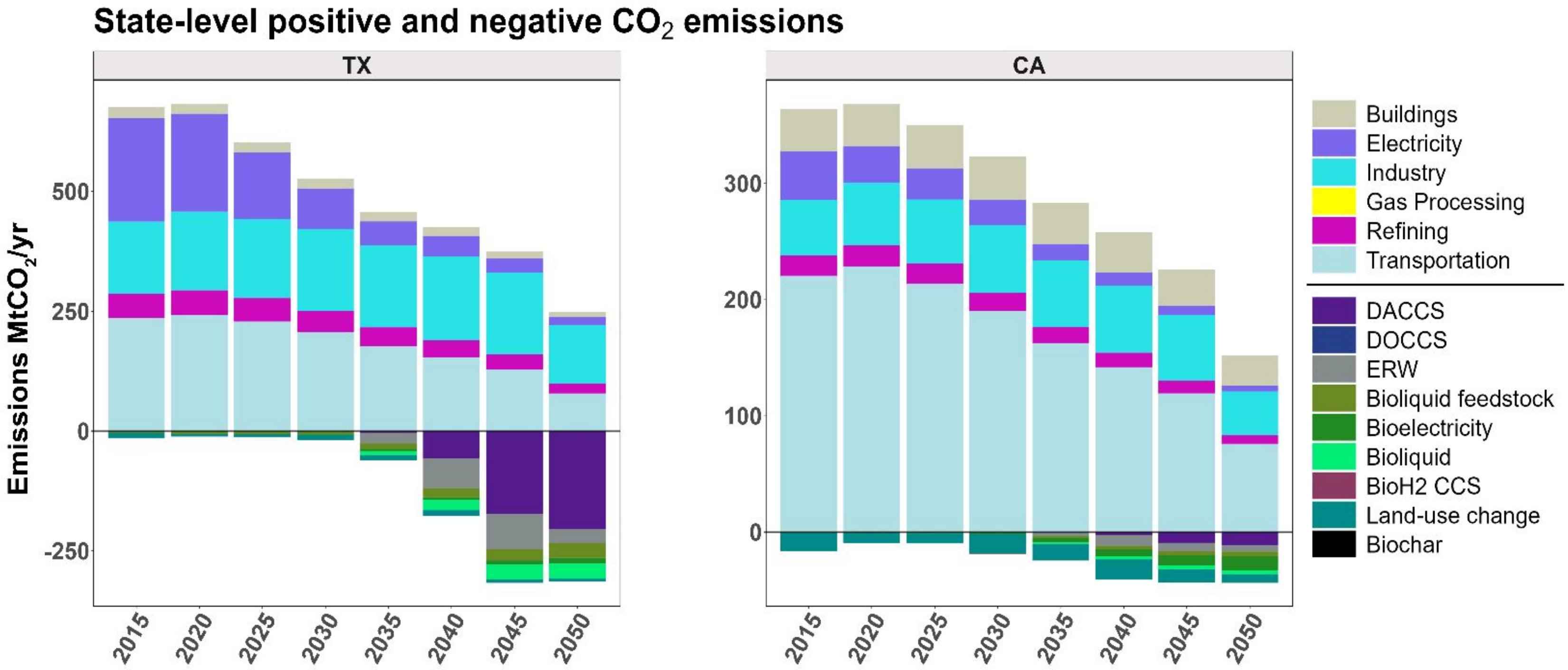
GCAM documentation: http://jgcri.github.io/gcam-doc/

U.S. Net-Zero 2050



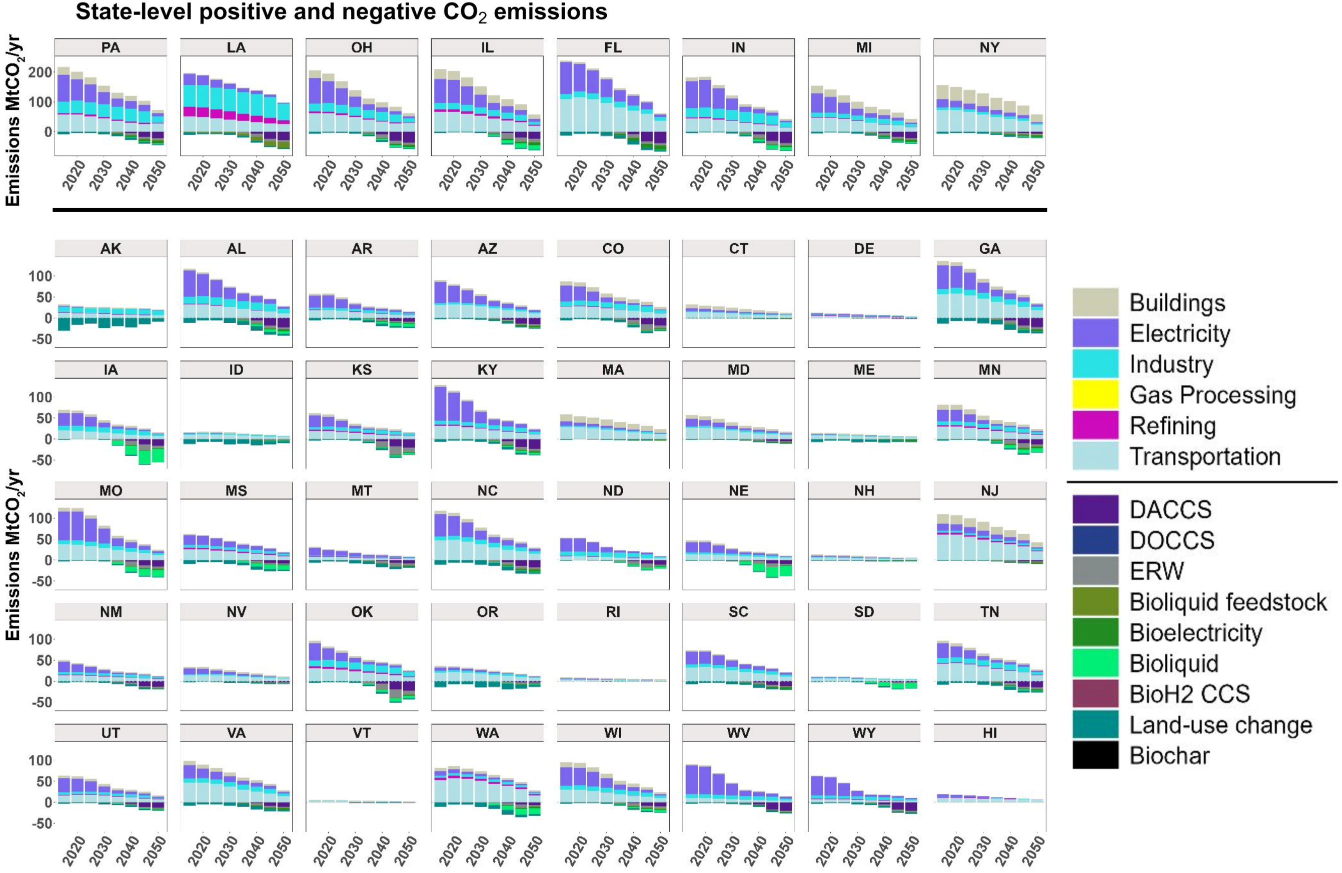
U.S. Net-Zero 2050

Full Portfolio Scenario



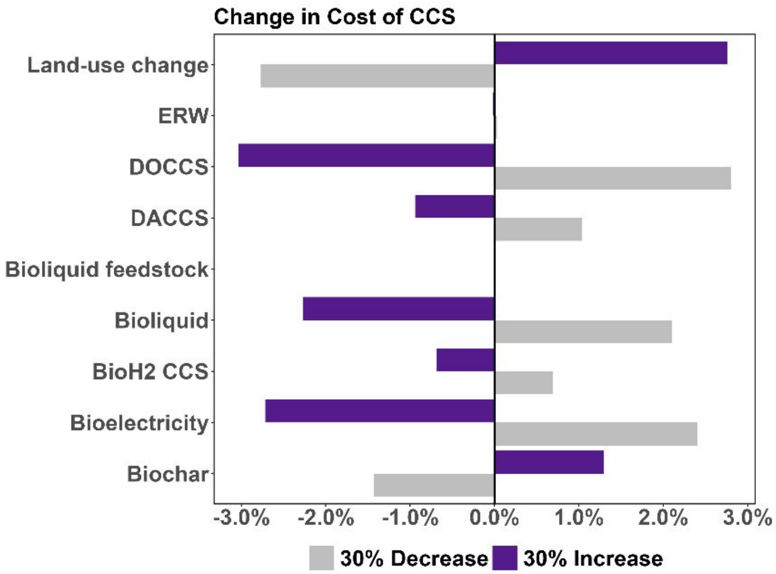
U.S. Net-Zero 2050

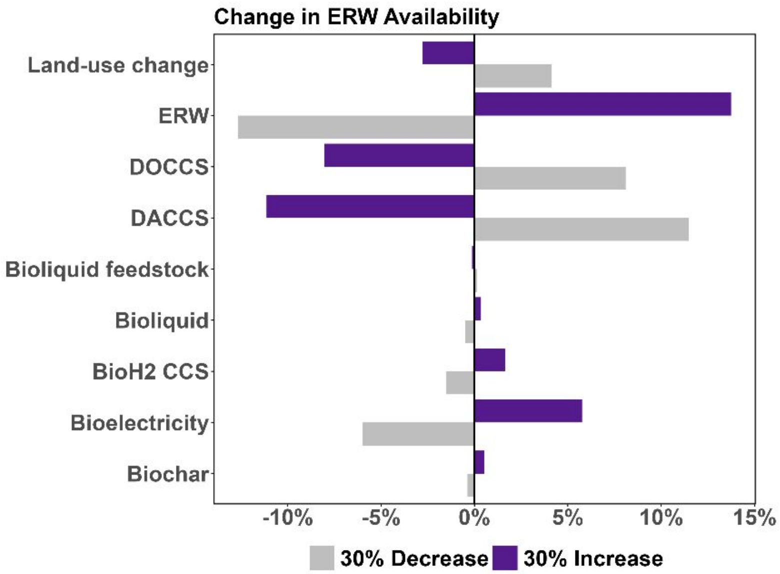
Full Portfolio Scenario



Sensitivity Analysis

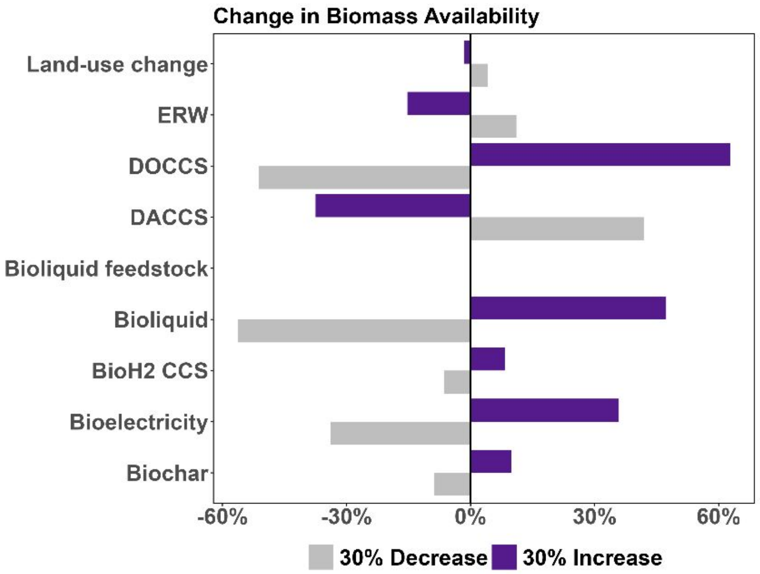
Sensitivity of CDR deployment in the Full Portfolio Scenario in 2050

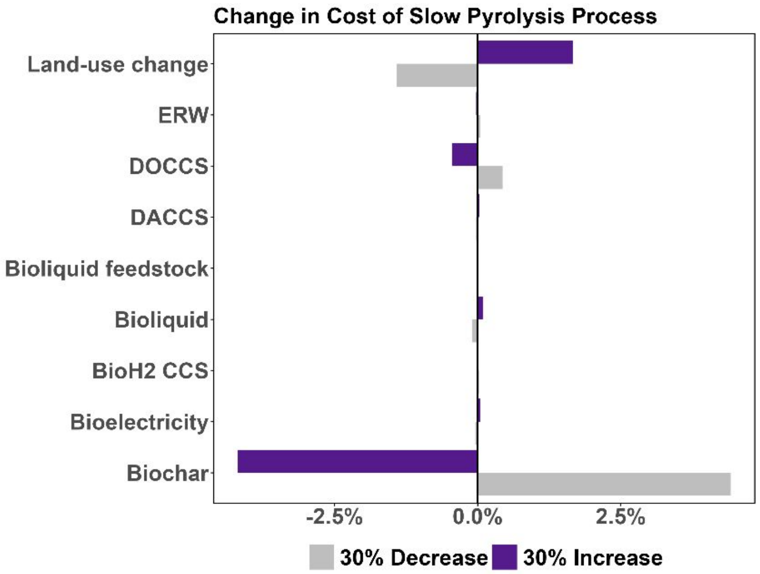




Sensitivity Analysis

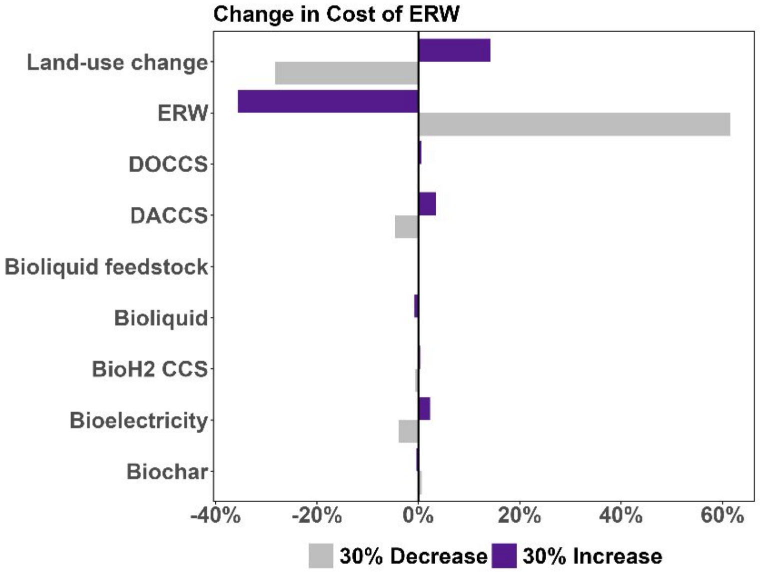
Sensitivity of CDR deployment in the Full Portfolio Scenario in 2050

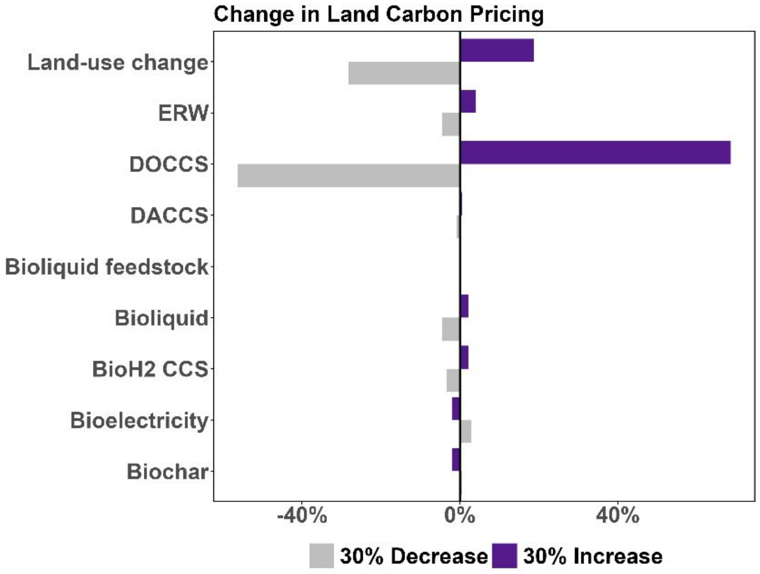




Sensitivity Analysis

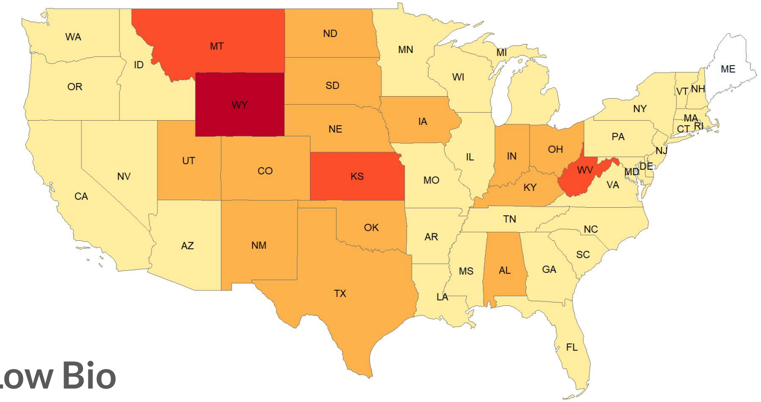
Sensitivity of CDR deployment in the Full Portfolio Scenario in 2050



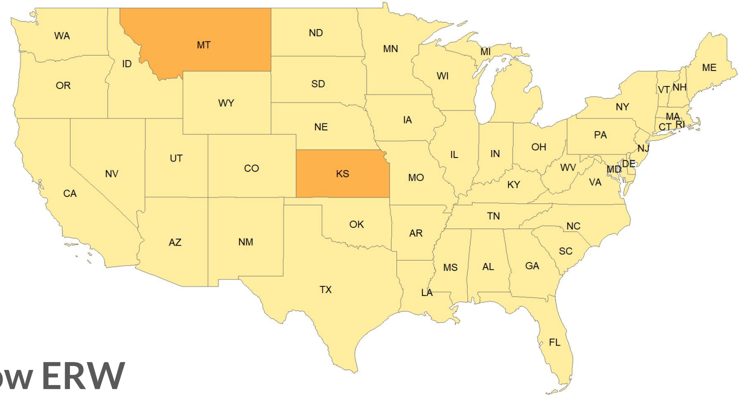


Fraction of Final Energy Consumed by CDR in 2050 (%)

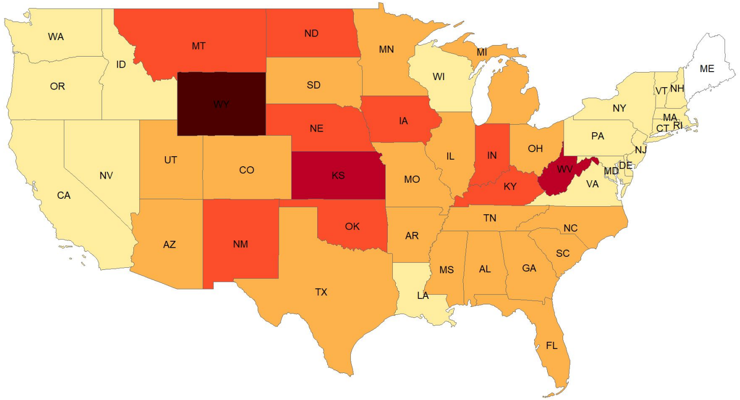
Full Portfolio



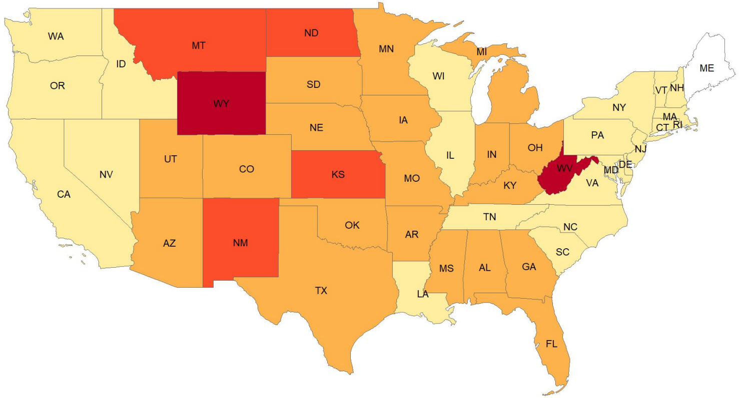
Low CCS

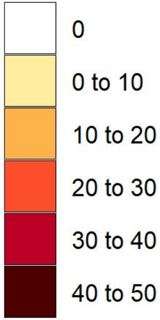


Low Bio



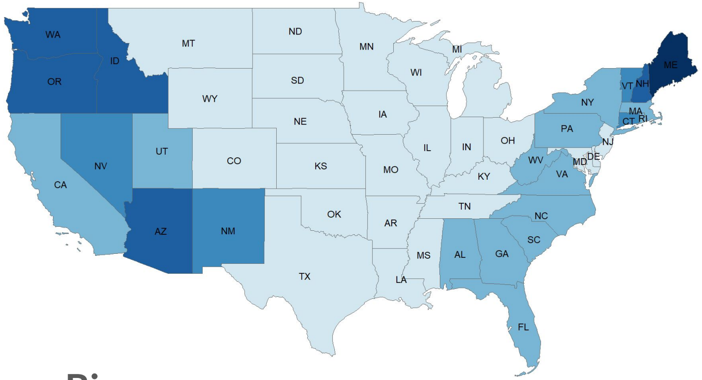
Low ERW



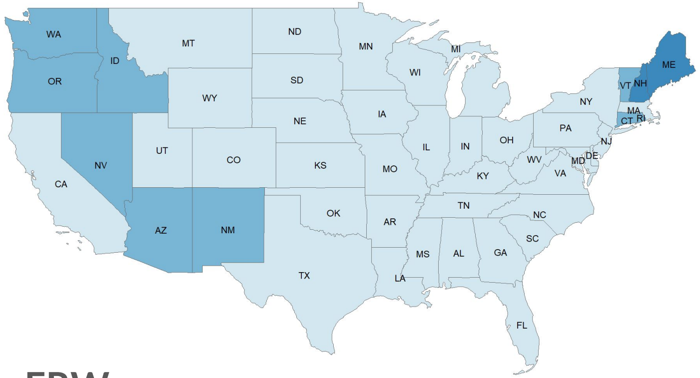


Fraction of Water Consumed by CDR in 2050 (%)

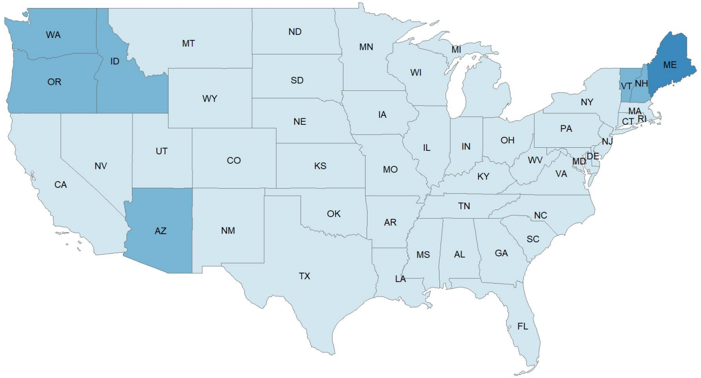
Full Portfolio



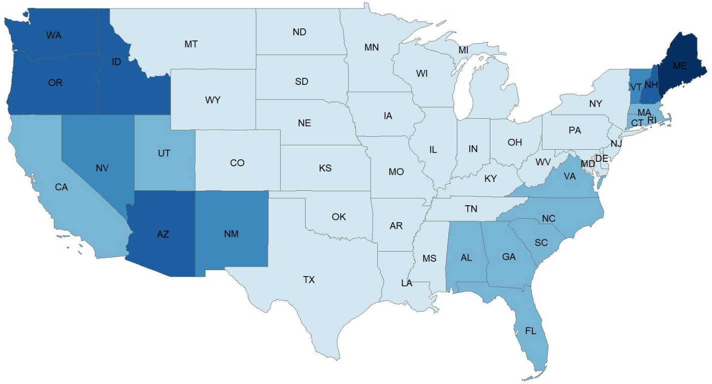
Low CCS

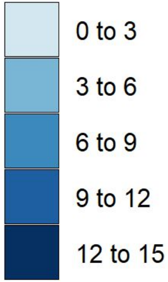


Low Bio



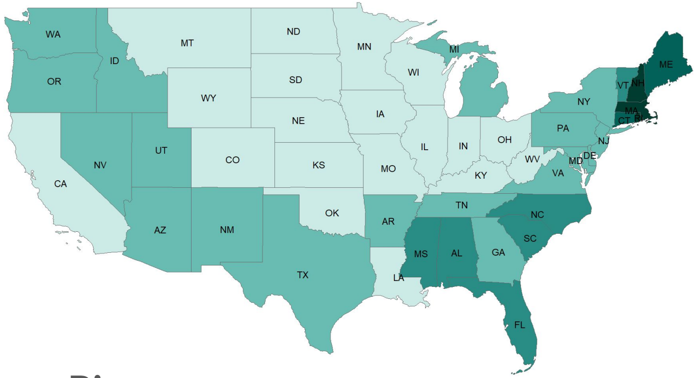
Low ERW



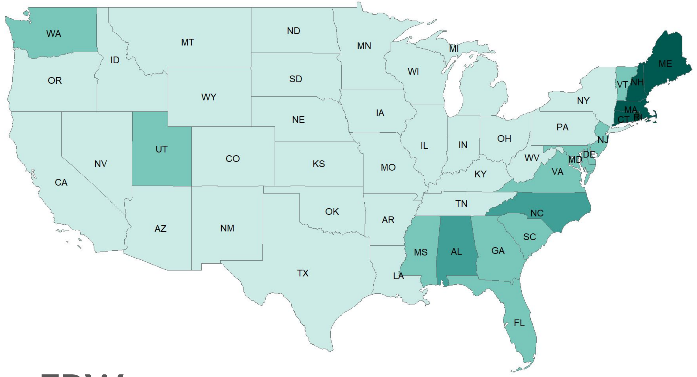


Fraction of Biomass Croplands in 2050 (%)

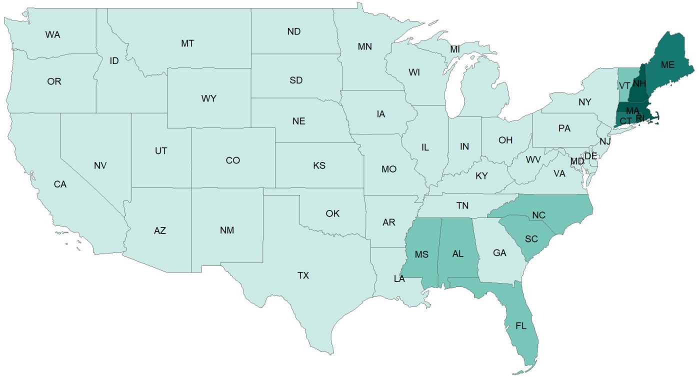
Full Portfolio



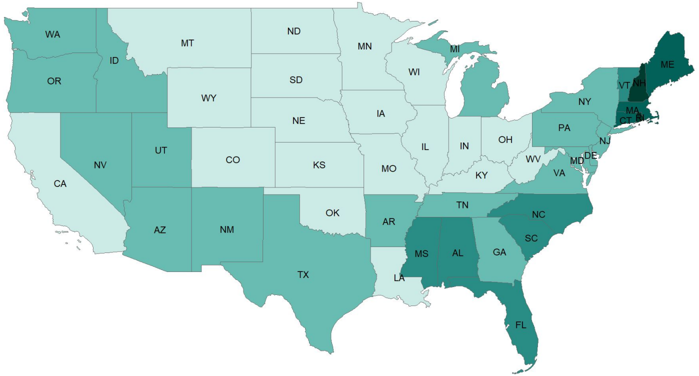
Low CCS

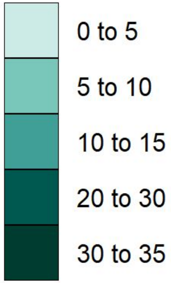


Low Bio



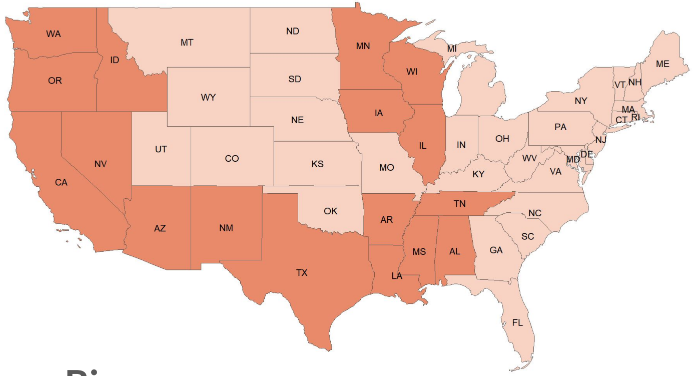
Low ERW



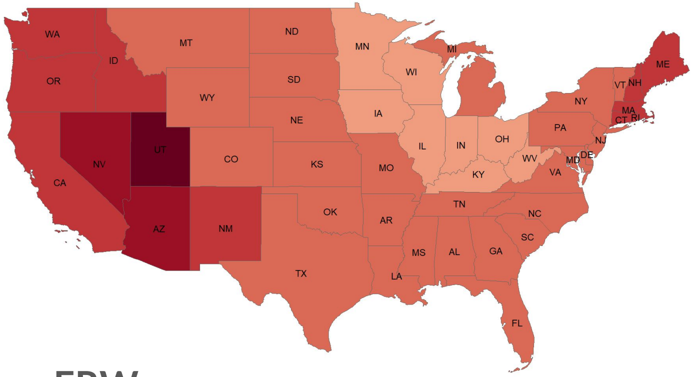


Fraction of Biochar Croplands in 2050 (%)

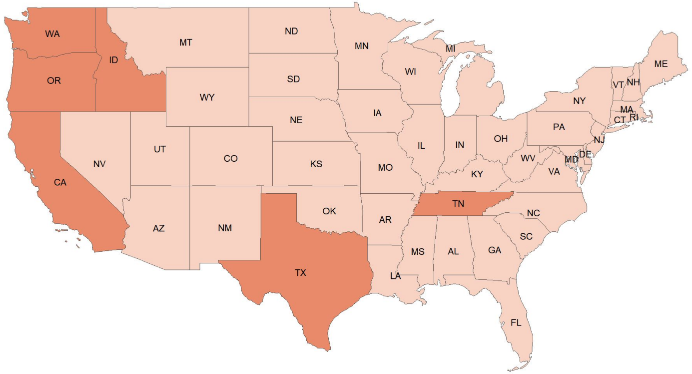
Full Portfolio



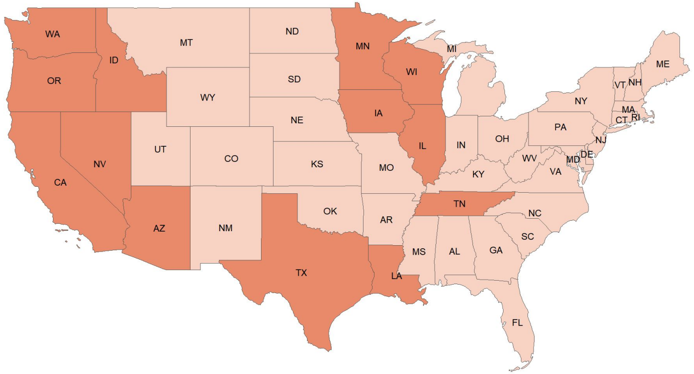
Low CCS

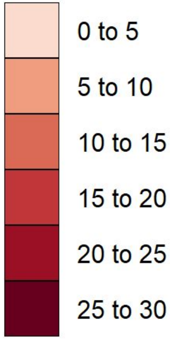


Low Bio



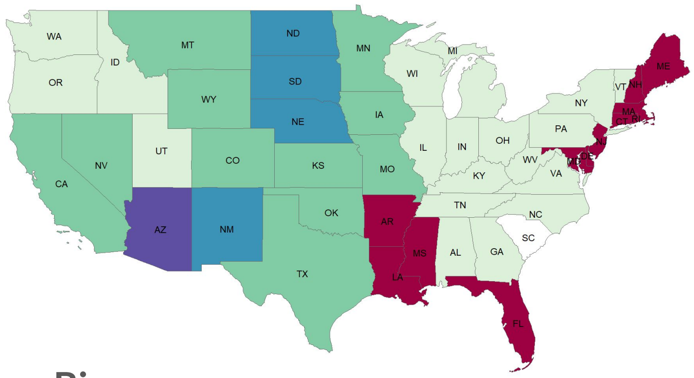
Low ERW



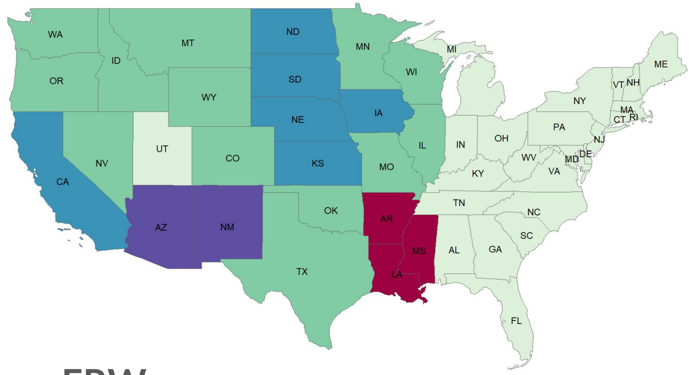


Forestland Growth, 2015 to 2050 (%)

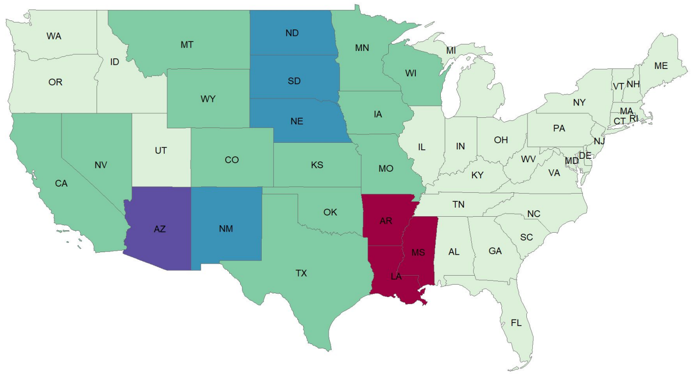
Full Portfolio



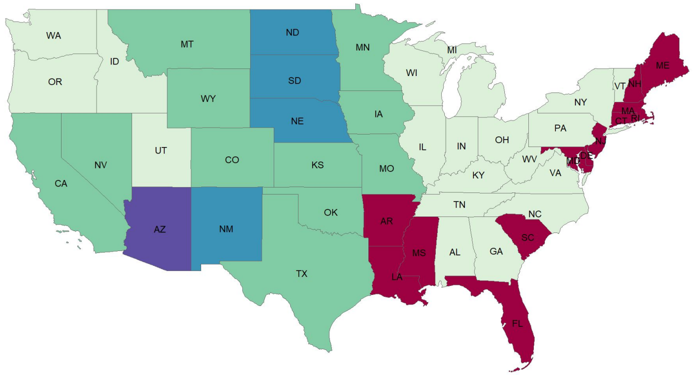
Low CCS

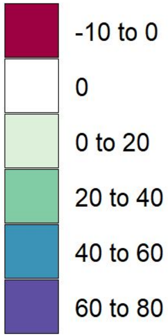


Low Bio

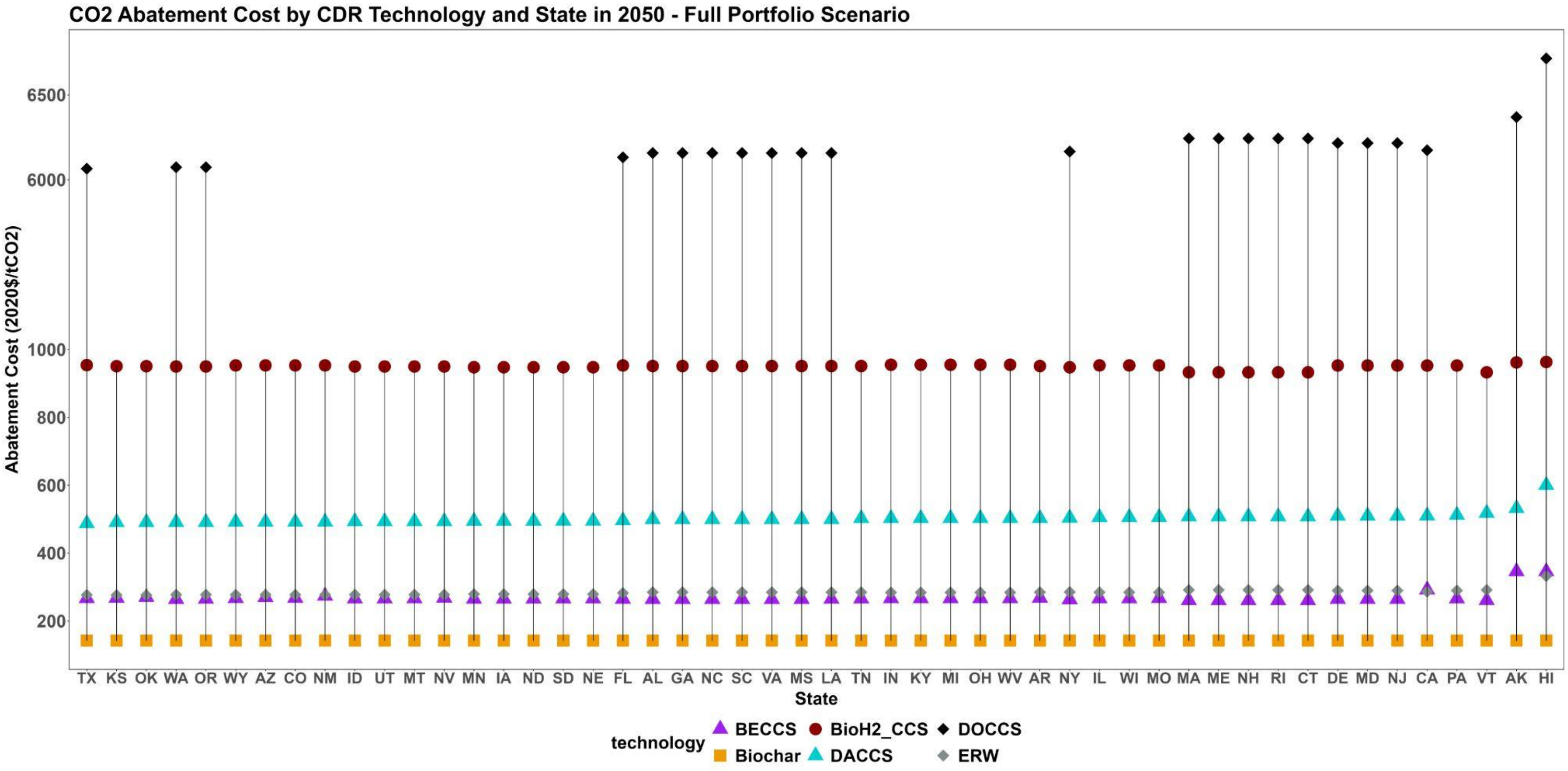


Low ERW

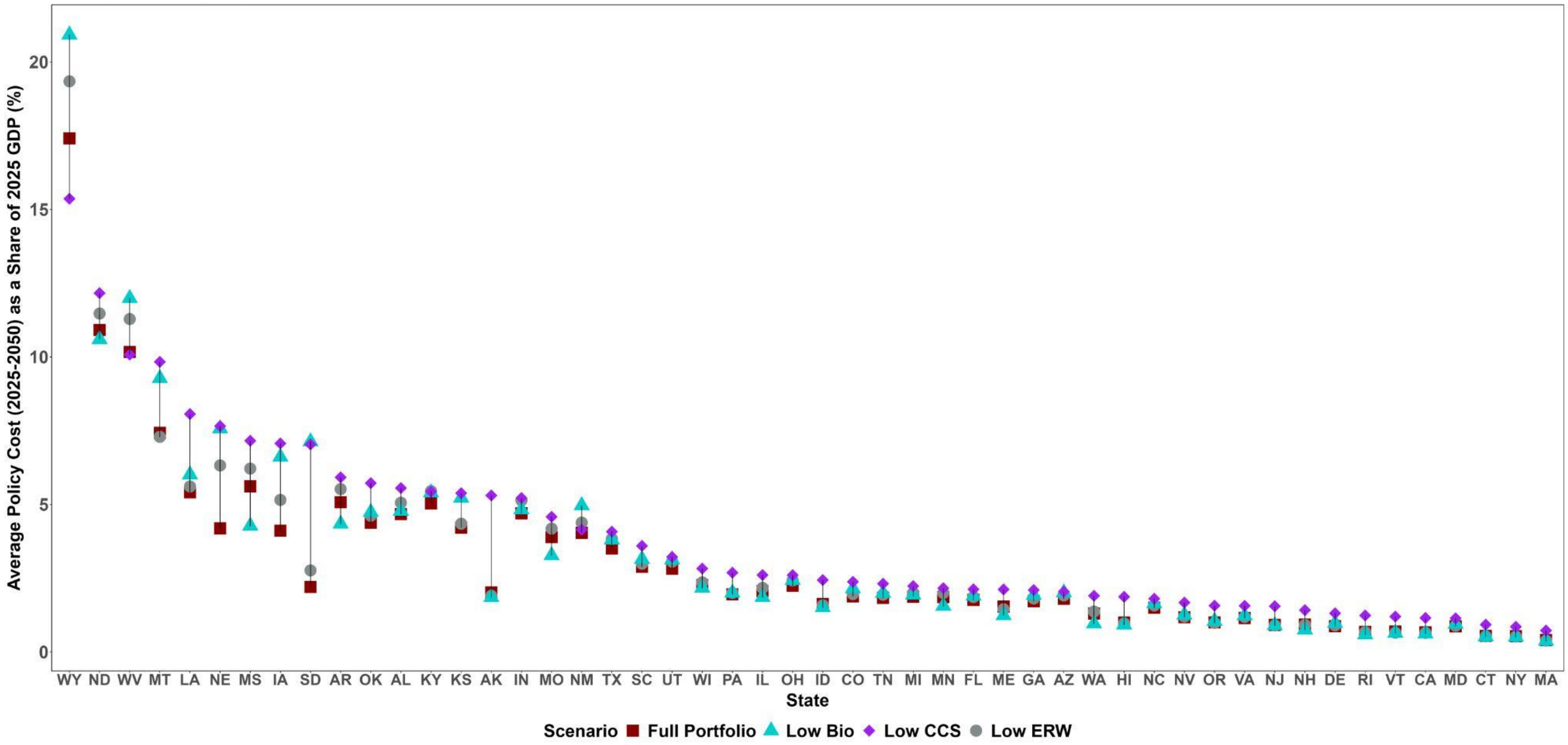




CO2 Abatement Cost in 2050



Cost of Policy



Conclusion

- **1-1.9 GtCO_2/yr** removal is required to meet U.S. national net-zero goal by mid-century
- ERW may provide up to **683 MtCO_2** removal by 2050 at a lower cost without relying on geological storage
- Relying only on **technology-intensive CDRs** results in higher final energy consumption
- The disparity in **regional concentration** of CDR approaches highlights the need for policies that consider regional advantages and constraints, ensuring that decarbonization efforts are both **effective** and **economically viable**

Acknowledgements

Collaborators

Pacific Northwest National Laboratory

Jay Fuhrman

Patrick O'Rourke

KAIST Graduate School of Green Growth & Sustainability

Haewon McJeon

Research Grants

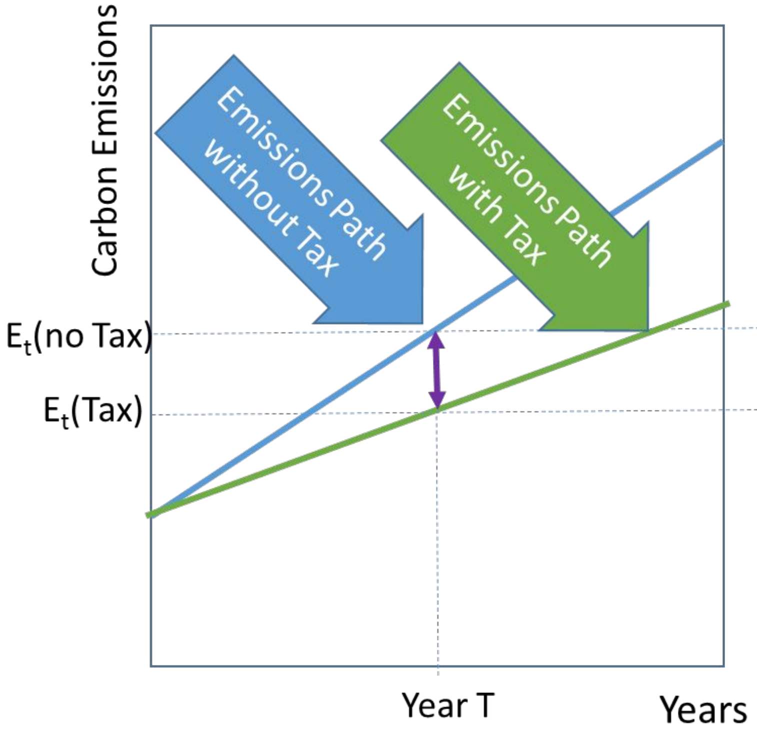
NSF U.S. National Science Foundation

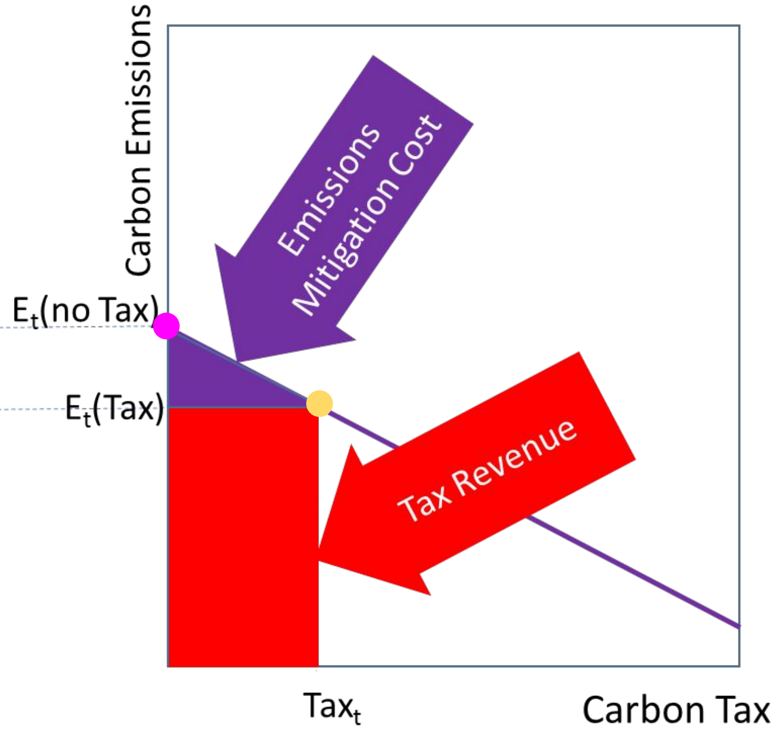
ALFRED P. SLOAN FOUNDATION

Thank You!

kcw8qq@virginia.edu

Cost of Policy





Reference: GCAM v7.1 Documentation: GCAM Policies
(https://jgcri.github.io/gcam-doc/policies.html)