Meeting the Global CCUS Challenge: Infrastructure Design and Roadmaps

Richard Middleton | CEO | CARBON SOLUTIONS

CCUS Latin America 2025

Cartagena, Colombia: May 28–29, 2025

carbonsolutionsllc.com

CARBON SOLUTIONS

Acknowledgment: “Some of this material is based upon work supported by the Department of Energy under Award Numbers DE-FE0032347 and DEFE0032360."

R&D Background


Carbon
Solutions

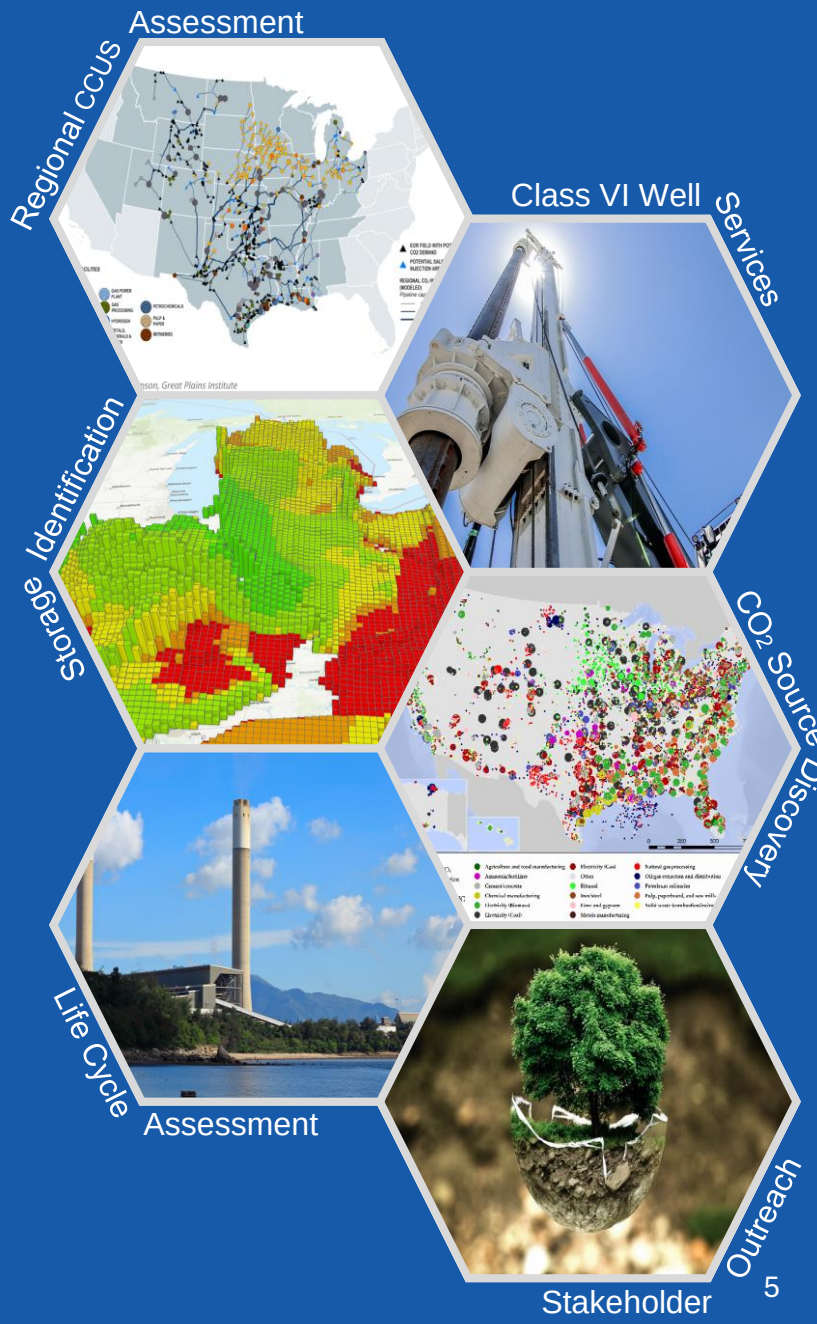
Carbon Solutions

Overview

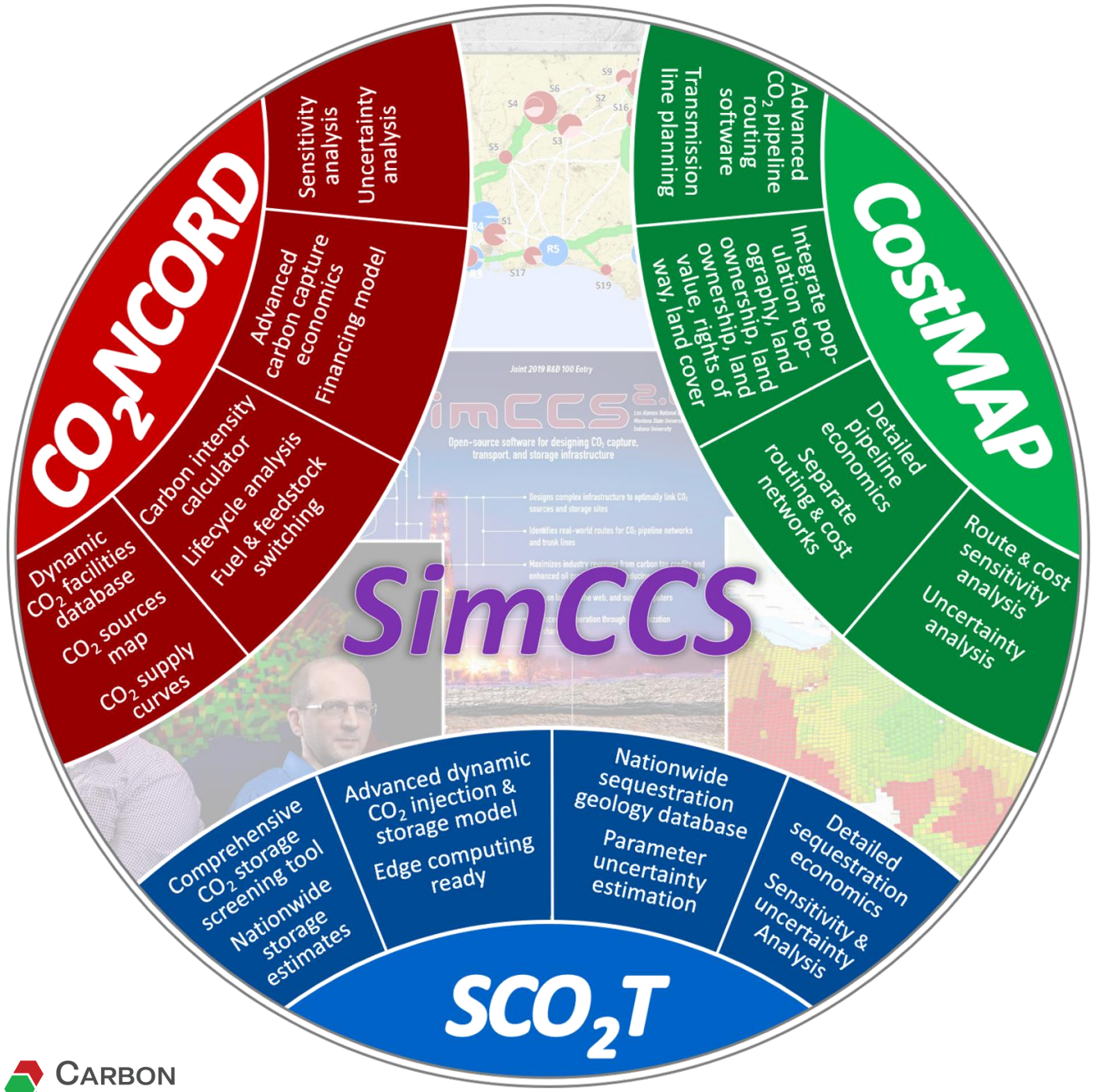
- R&D company launched in 2021, 25 staff.
- Launched on research developed at the Los Alamos National Laboratory (LANL).
- Led/supported 40+ Department of Energy (DOE) projects.
- Total: 100+ projects from government (70%), non-profit (20%), & industry (10%).

Energy applications

- CO_2 capture, utilization, & storage (CCUS), transmission/pipelines, hydrogen, geothermal, unconventional fossil fuels, nuclear, energy storage, grid modeling…



Tools for CCUS Infrastructure Modeling



CCUS Software

SimCCS^{PRO} (infrastructure)

- Decision support across the CCUS value chain.

CO_2NCORD (capture)

- Dynamic, customizable facility software & database, ~10,000 US sources.

CostMAP^{PRO} (transport)

- Advanced, multiscale, multi-attribute pipeline & transmission routing.

SCO_2T^{PRO} (storage)

- Advanced tool for dynamic CO_2 injection, storage, & costs.

CARBON SOLUTIONS

SimCCS^{PRO}

Description

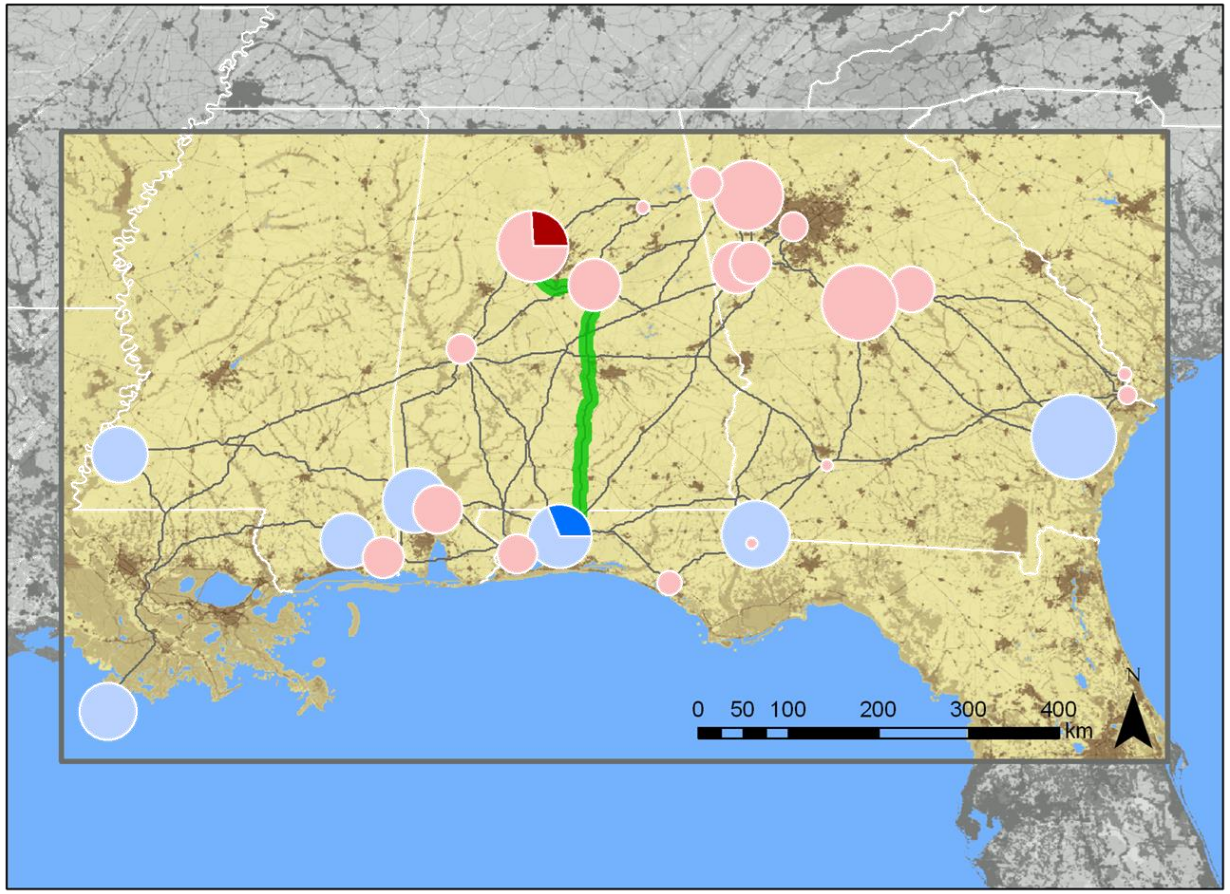
- Where, when, & how to build infrastructure (CO_2, H_2, wind/transmission).

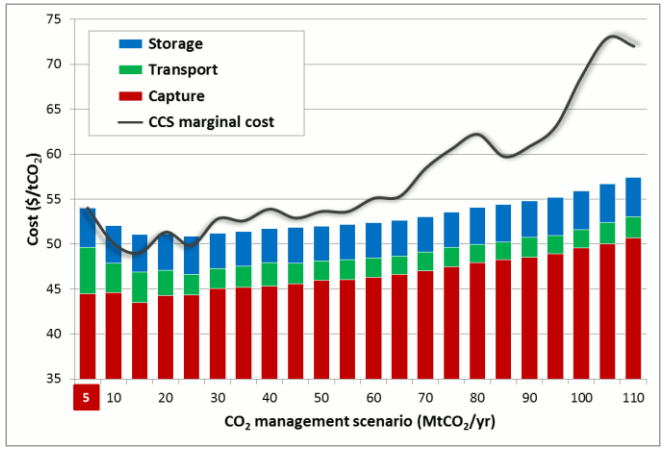
Motivation

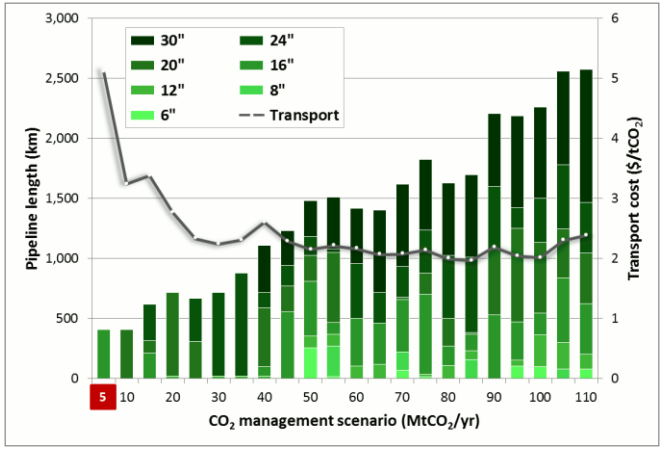
- Design small-to-large scale CCUS systems.
- Feasibility and pre-FEED studies (Class 4/5 costs).

Users

- R&D (e.g., DOE).
- Non-profits (e.g., policy).
- Industry: Utilities, oil & gas, investors.







Middleton et al. (2012) The cross-scale science of CO_2 capture and storage: from pore scale to regional scale, *Energy & Environmental Science*

CARBON SOLUTIONS

CO_2NCORD

Description

- Industry facility software/ database for processes, fuels, & emissions.

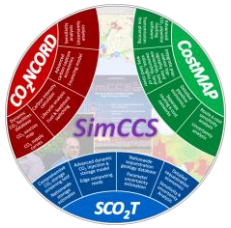
Motivation

- Rapidly characterize individual CO_2 sources.
- Directory of CO_2 opportunities.

Users

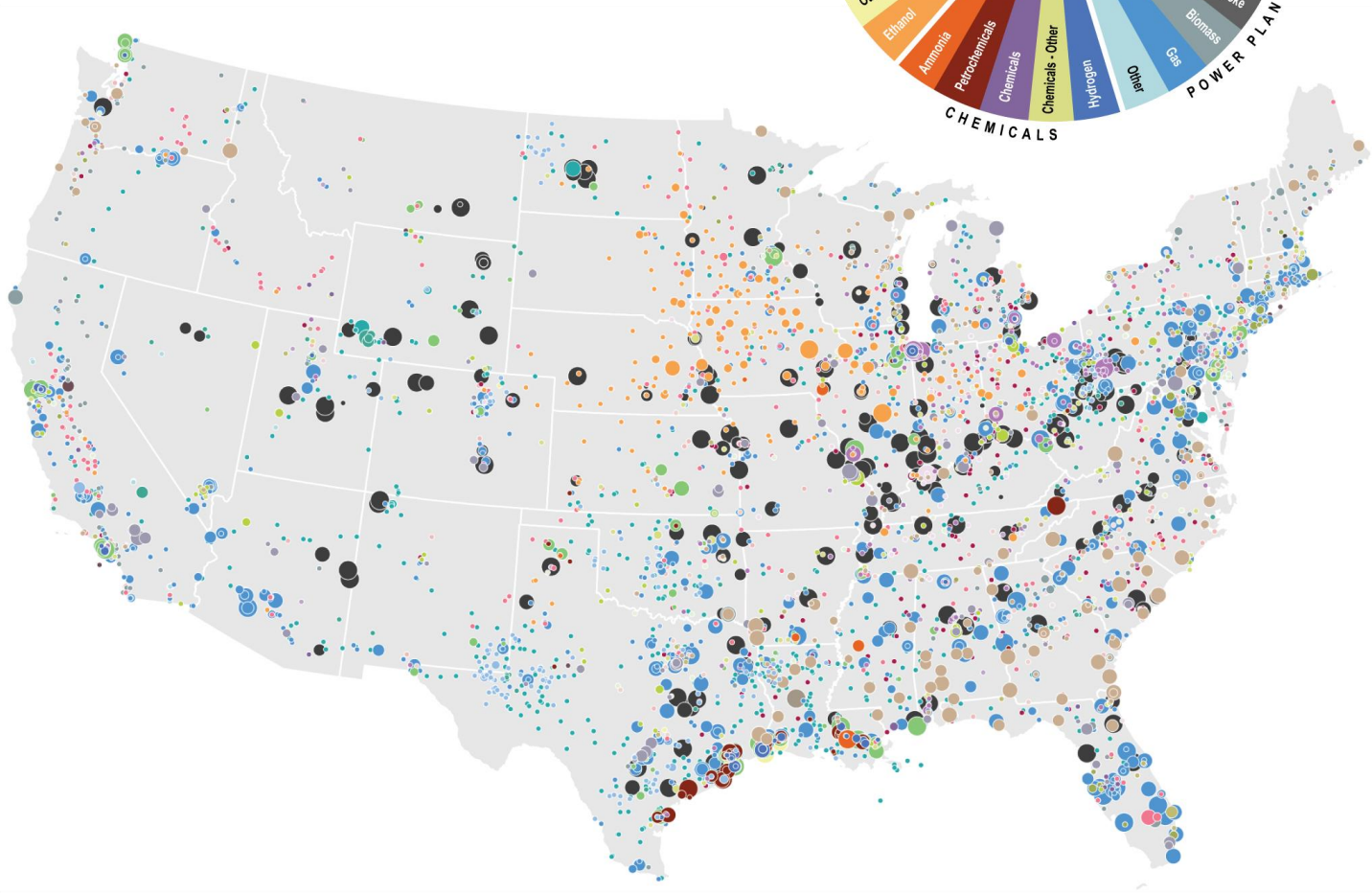
- R&D (e.g., DOE).
- Non-profits (e.g., policy).
- Industry: Capture technologies, utilities, investors.

CARBON SOLUTIONS



CO_2NCORD

The CO_2 National Capture Opportunities and Readiness Database



Sale et al. (2024) Finding New Opportunities for Carbon Capture with *CO_2NCORD*, *Engineering Archive*
Bennett et al. (2012) Identifying Opportunities and Cost for CO_2 Capture at Power and Industrial Facilities in the United States, *CCUS 2025*

CostMAP^{PRO}

Description

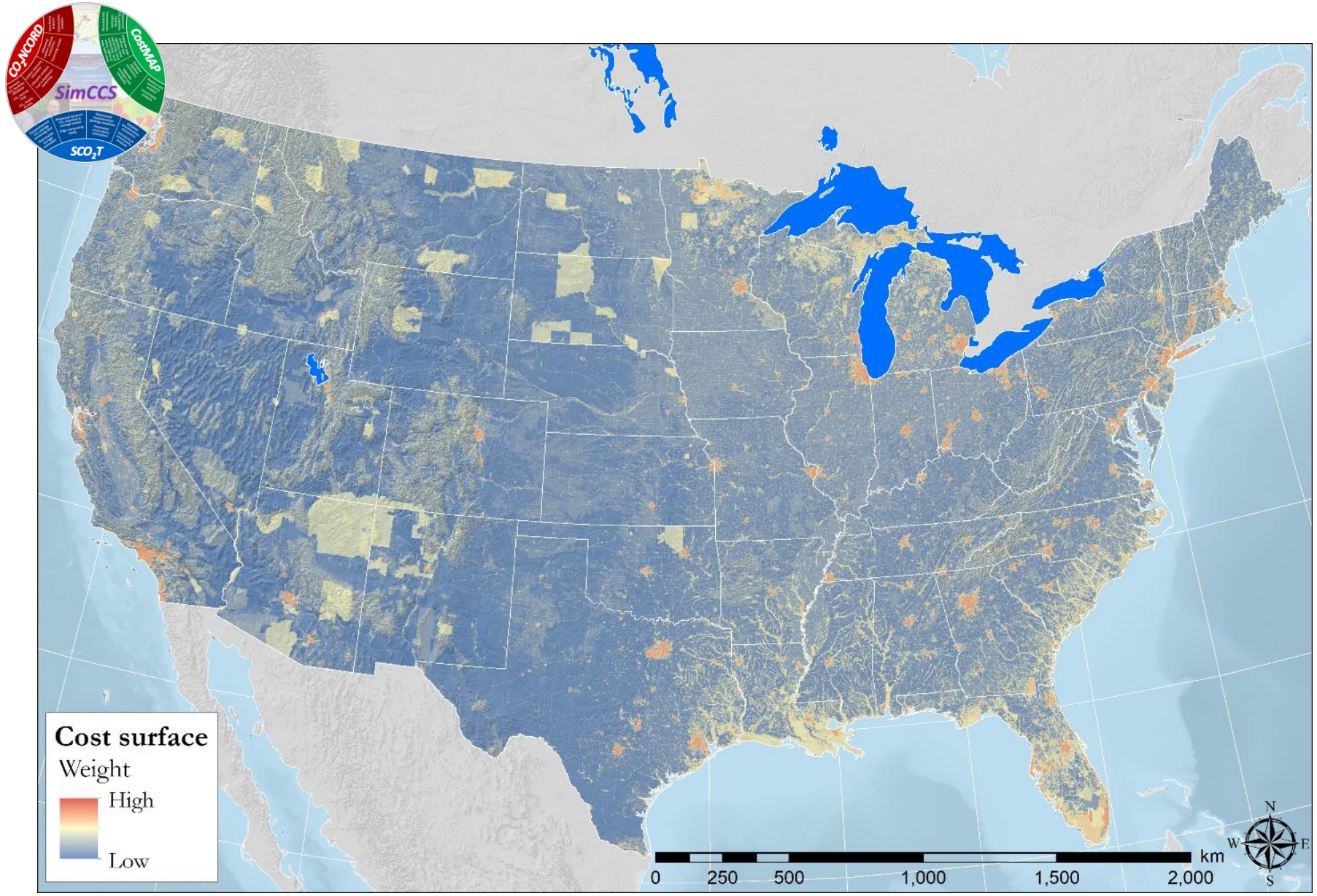
- Infrastructure routing & costing software including pipelines.

Motivation

- Rapidly identify pipeline & transmission line route.
- Estimate infrastructure costs.

Users

- R&D (e.g., DOE).
- Non-profits (e.g., policy).
- Industry: Midstreams/oil & gas, CCUS technologies, utilities, investors.



CARBON SOLUTIONS

Hoover et al. (2020) *CostMAP*: an open-source software package for developing cost surfaces using a multi-scale search kernel, *Int. Journal of GIS*
Middleton et al. (2012) Generating candidate networks for optimization: The CO_2 capture and storage optimization problem, *Computers, Env. & Urban Systems*

SCO_2T^{PRO}

Description

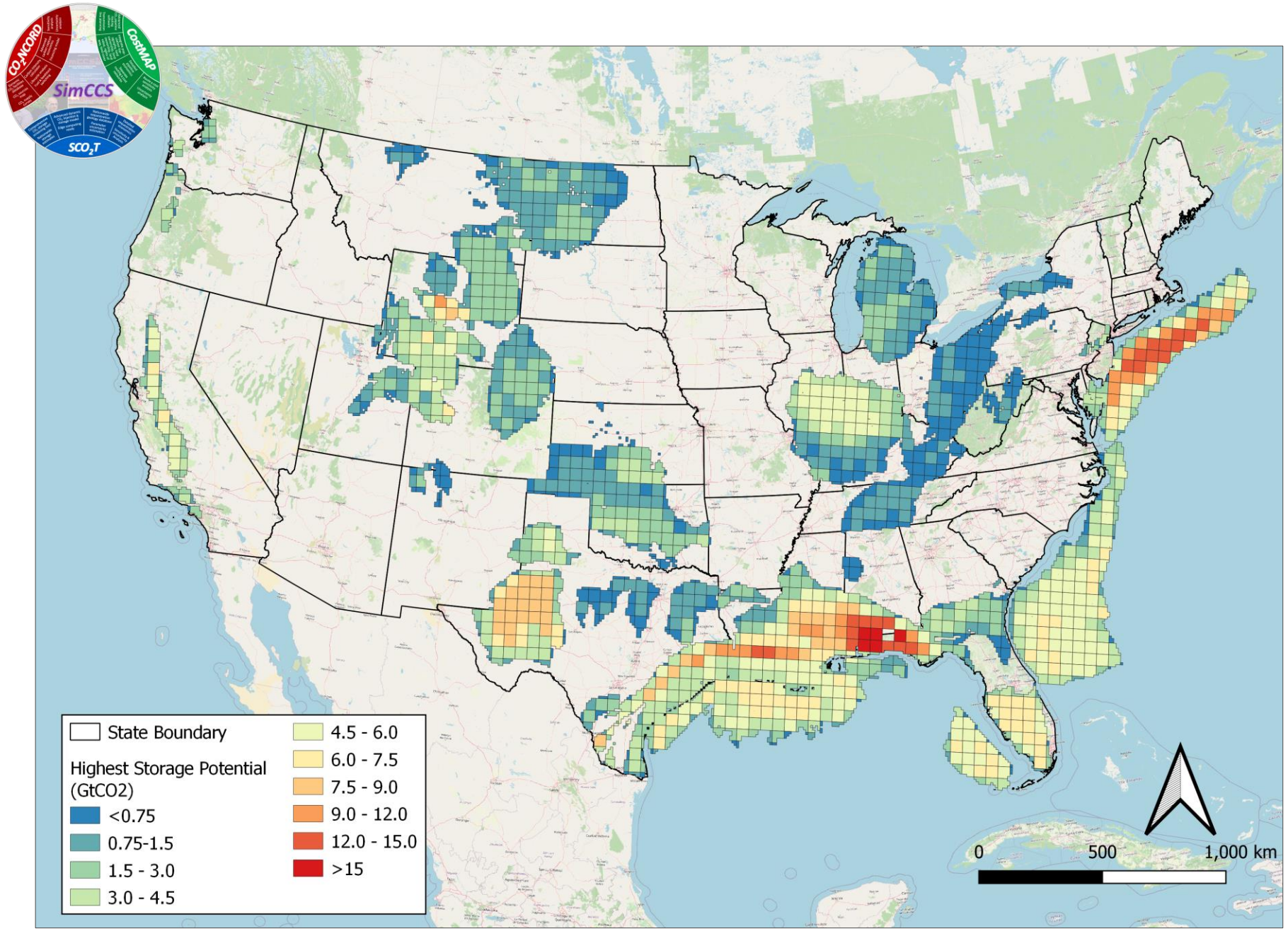
- Most-advanced screening-level storage potential.

Motivation

- Capture complex storage with fast-running models.
- Rapidly characterize individual reservoirs.

Users

- R&D (e.g., DOE).
- Non-profits (e.g., policy).
- Industry: Storage operators, oil & gas, utilities, investors.



Middleton et al. (2020) Great SCO_2T! Rapid tool for carbon sequestration science, engineering, and economics, *App. Computing and Geosciences*
Ogland-Hand et al. (2012) Screening for Geologic Sequestration of CO_2, *International Journal of Greenhouse gas Control*

CARBON SOLUTIONS

CCUS Projects: Government, Non-Profits, & Academia

DOE CO_2 Pipeline Projects: *WyoTCH*

Time's Ticking: Embarking on the Wyoming Trails Carbon Hub ("WyoTCH")

Goal

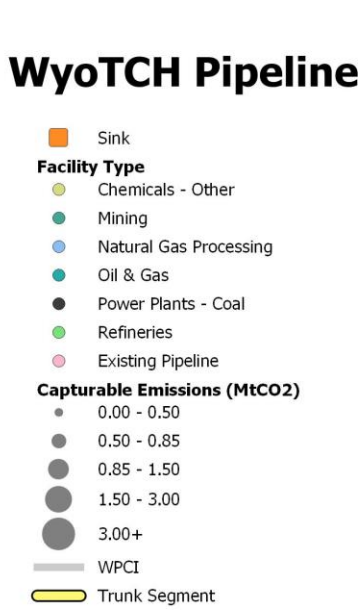
- Front-end engineering & design (FEED) study.
- Pipeline design for carbon management in Wyoming.

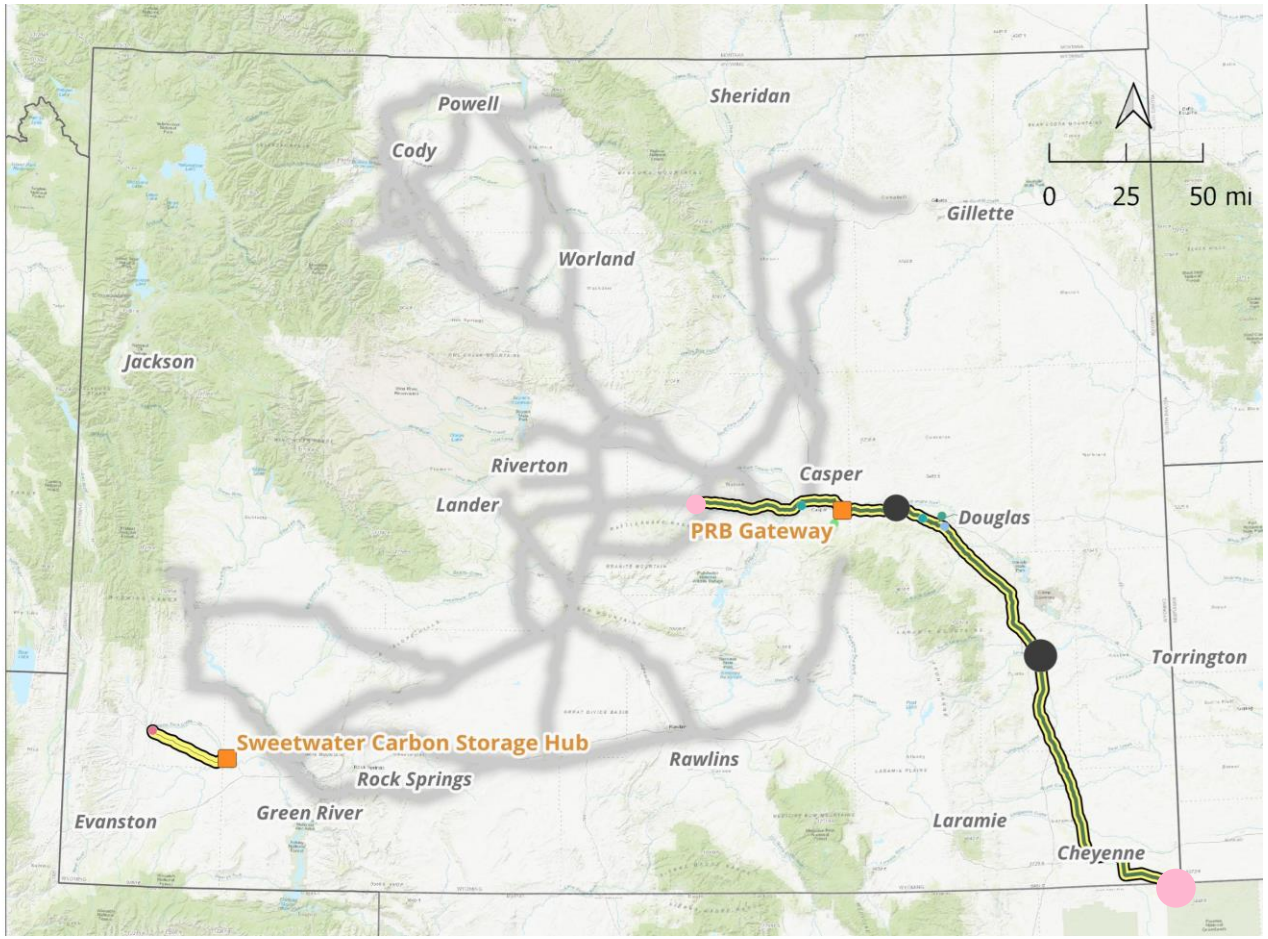
CO_2 demand

- Saline aquifers, CO_2-enhanced oil recovery (CO_2-EOR), sustainable aviation fuel.

CO_2 supply

- Ethanol, coal power…





CARBON SOLUTIONS

DOE CO_2 Pipeline Projects: *TOTC*

Trail of the Chiefs ("TOTC")

Goal

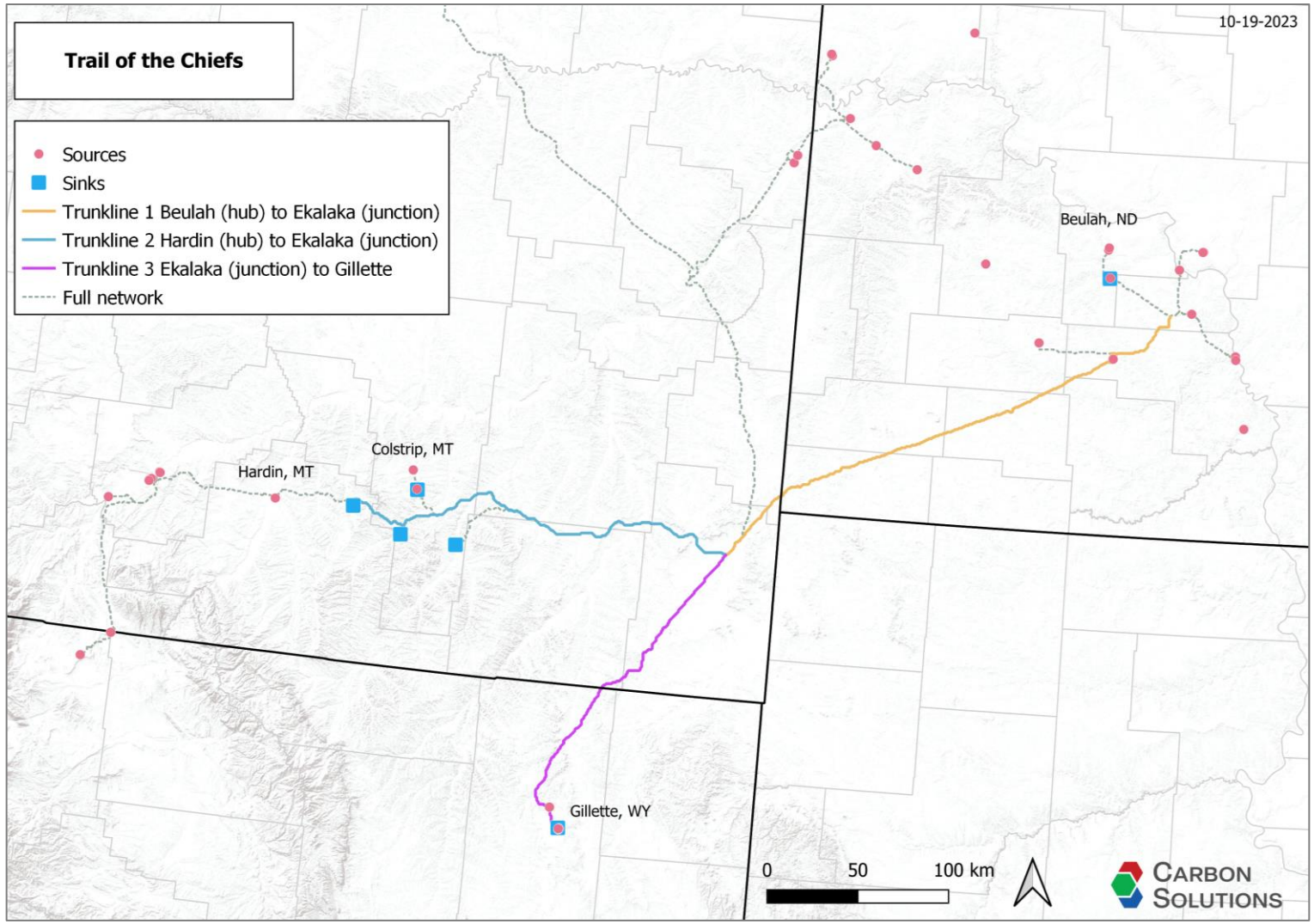
- Pipeline FEED study linking Montana, North Dakota, & Wyoming.

Engagement

- Work with tribal nations.

Key partners

- **Kanata America:** Business development.
- **CarbonEx:** Engagement.
- **Crescent Midstream:** Pipeline design & operation.



Carbon Solutions

Non-profit Projects: *Fossil Power & CCUS*

Goal

- Nationwide CCUS for coal & gas plants in 2030 & beyond.

Sources

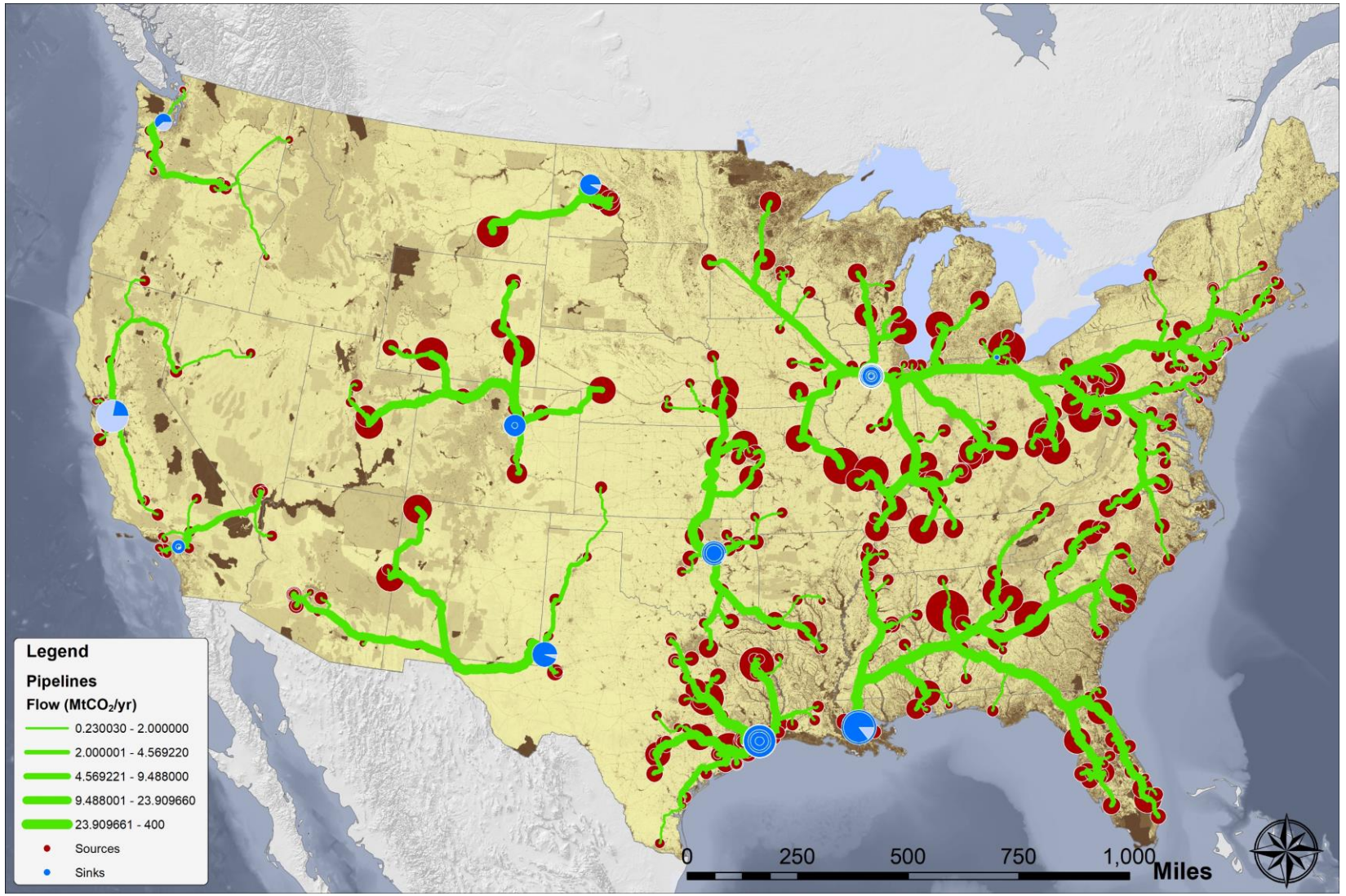
- 429 plants | 1,044 $MtCO_2$/yr.
- 136 coal | 600 $MtCO_2$/yr.
- 293 NGCC | 444 $MtCO_2$/yr.

Storage

- Saline, onshore only.
- 14 hubs, 371 *SCO$_2$T* sites.

Scenario

- Capture 200|400|600|800|1,000|1,044 $MtCO_2$/yr.



CARBON SOLUTIONS

Non-Profit Projects: *Industrial & CCUS*

Goal

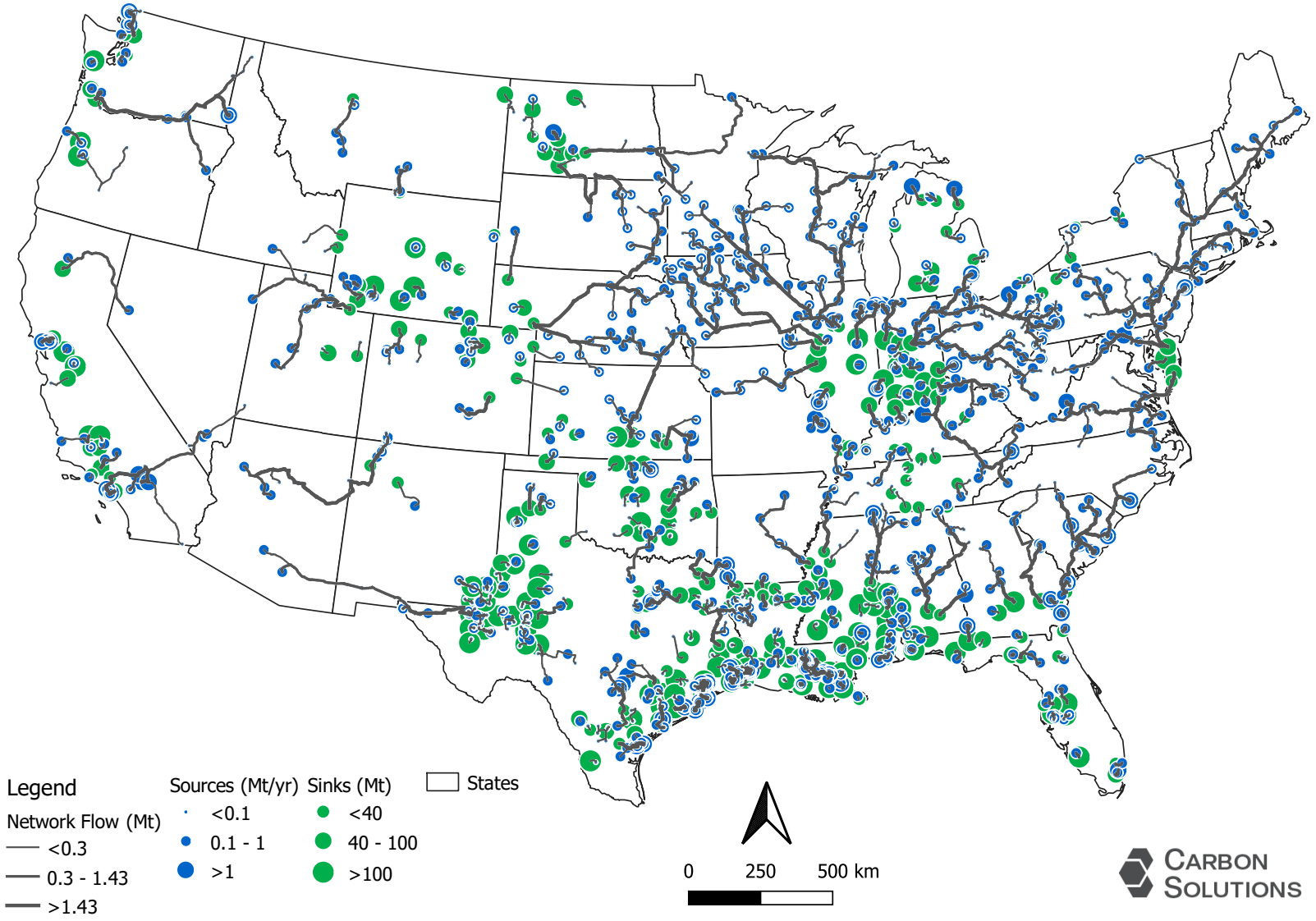
- Identify what national decarbonization via CCUS could look like.

Study

- **Capture:** ~1900 sources and 618 $MtCO_2/yr$.
- **Storage:** >300 sinks.
- **Network:** ~55,000 km.

Costs

- **Total:** $\$81.46/tCO_2$.
- **Capture:** $\$58.98/tCO_2$.
- **Transport:** $\$15.63/tCO_2$.
- **Storage:** $\$6.84/tCO_2$.



CARBON SOLUTIONS

CARBON SOLUTIONS

Middleton E. et al. (2024) National Industrial Sector Decarbonization: Extent of Carbon Capture Opportunities and Network Optimization Across the United States (LINK)

Non-Profit Projects: *Offshore Storage*

Source parameters

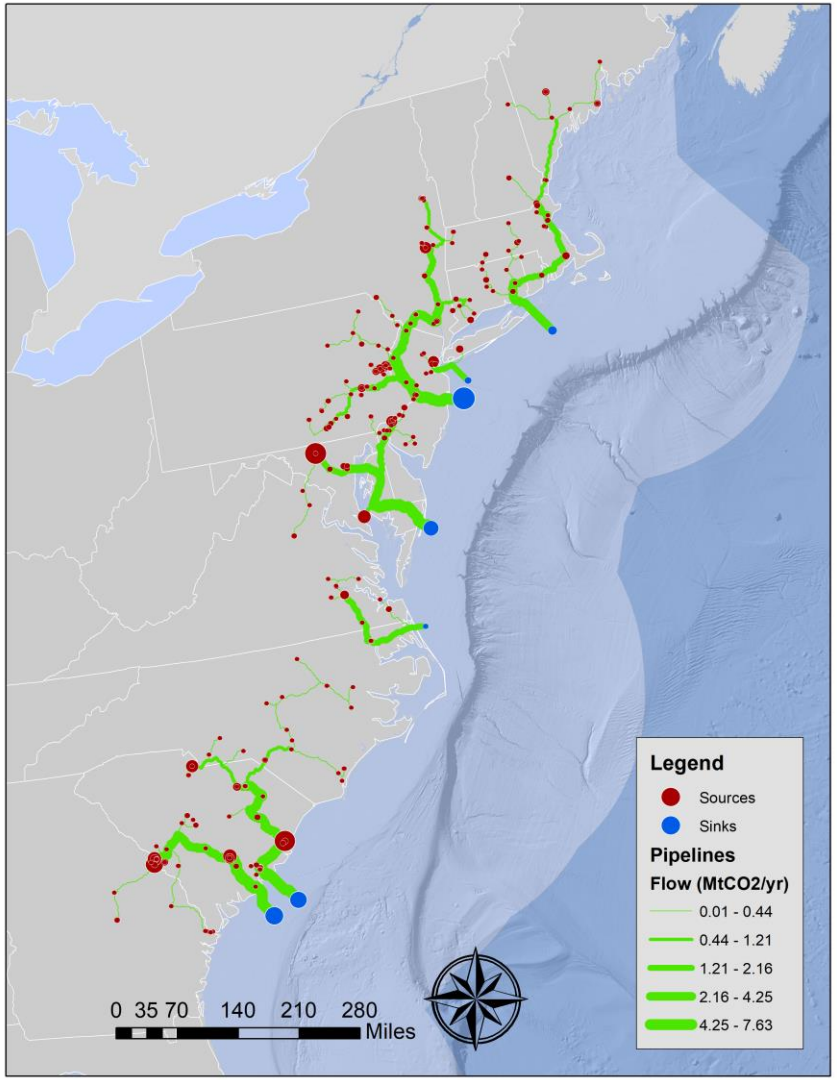
- Ammonia, hydrogen, ethanol, aluminium, iron & steel, cement, lime, natural gas processing, ethylene, petro-chemicals, pulp & paper.

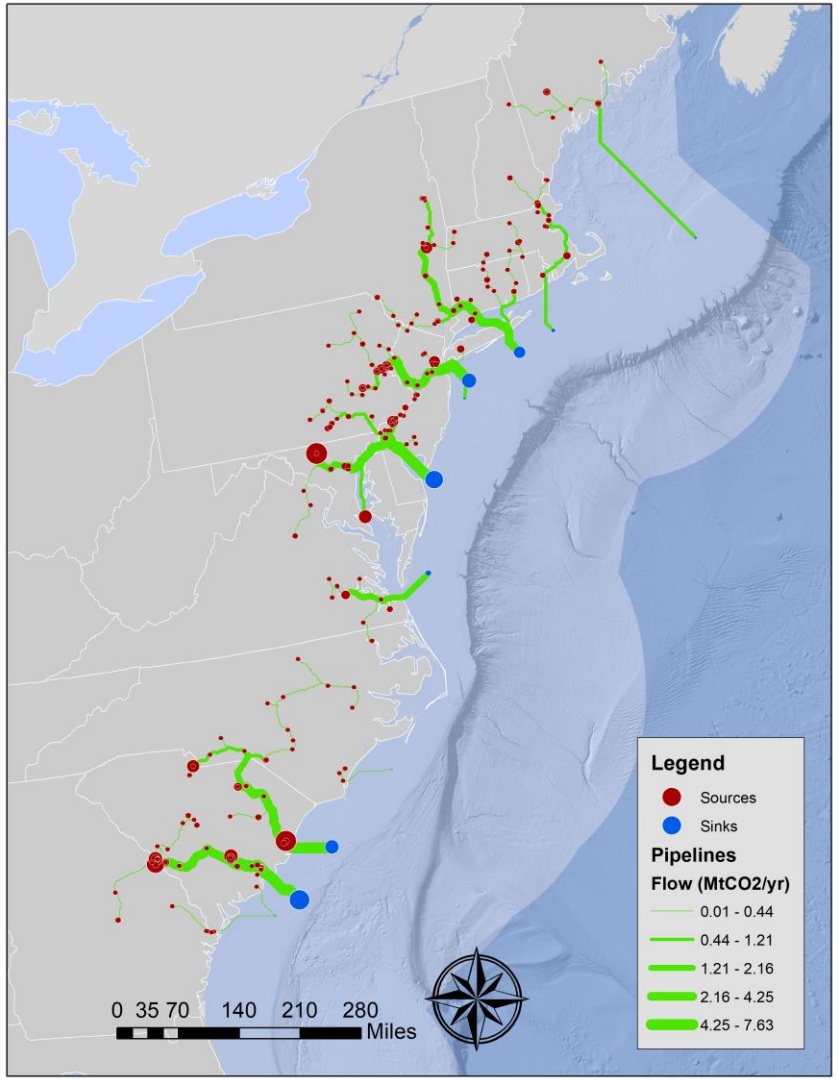
Sources

- **Sources:** 199
- **Streams:** 263.
- **Supply:** 31.5 $MtCO_2$/yr.

Scenario

- **Scenario A:** Let model choose best pipeline route.
- **Scenario B:** Prioritize offshore transport.



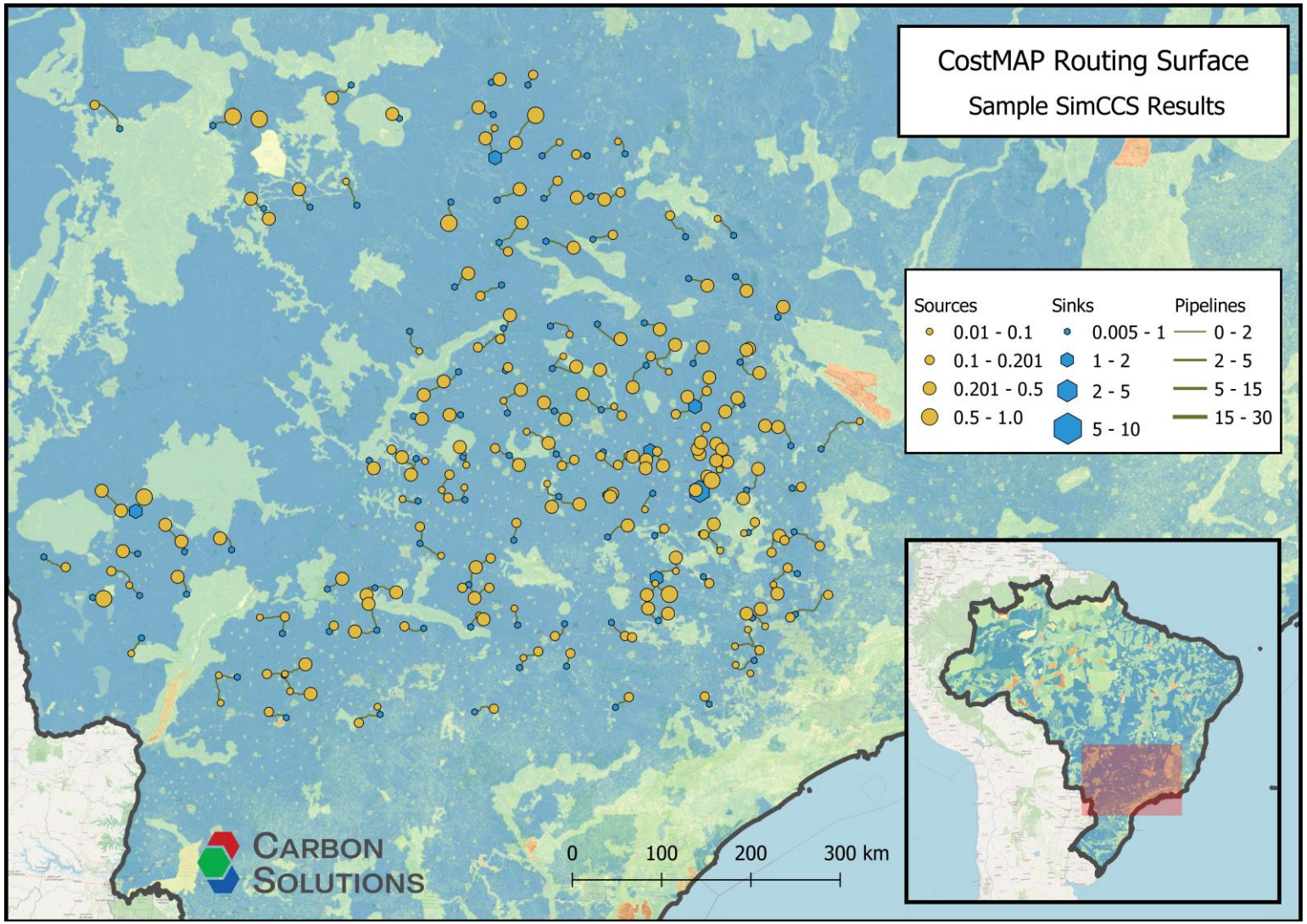


CARBON SOLUTIONS

Non-Profit Projects: *CCUS in Brazil*

Goal

- Develop CO_2 capture, pipeline, & storage data for Brazil using public data.
- Demonstrate *SimCCS*, *CO_2NCORD*, *CostMAP*, and *SCO_2T* for South America for the first time.



Academic Projects: *China & CCUS*

Description

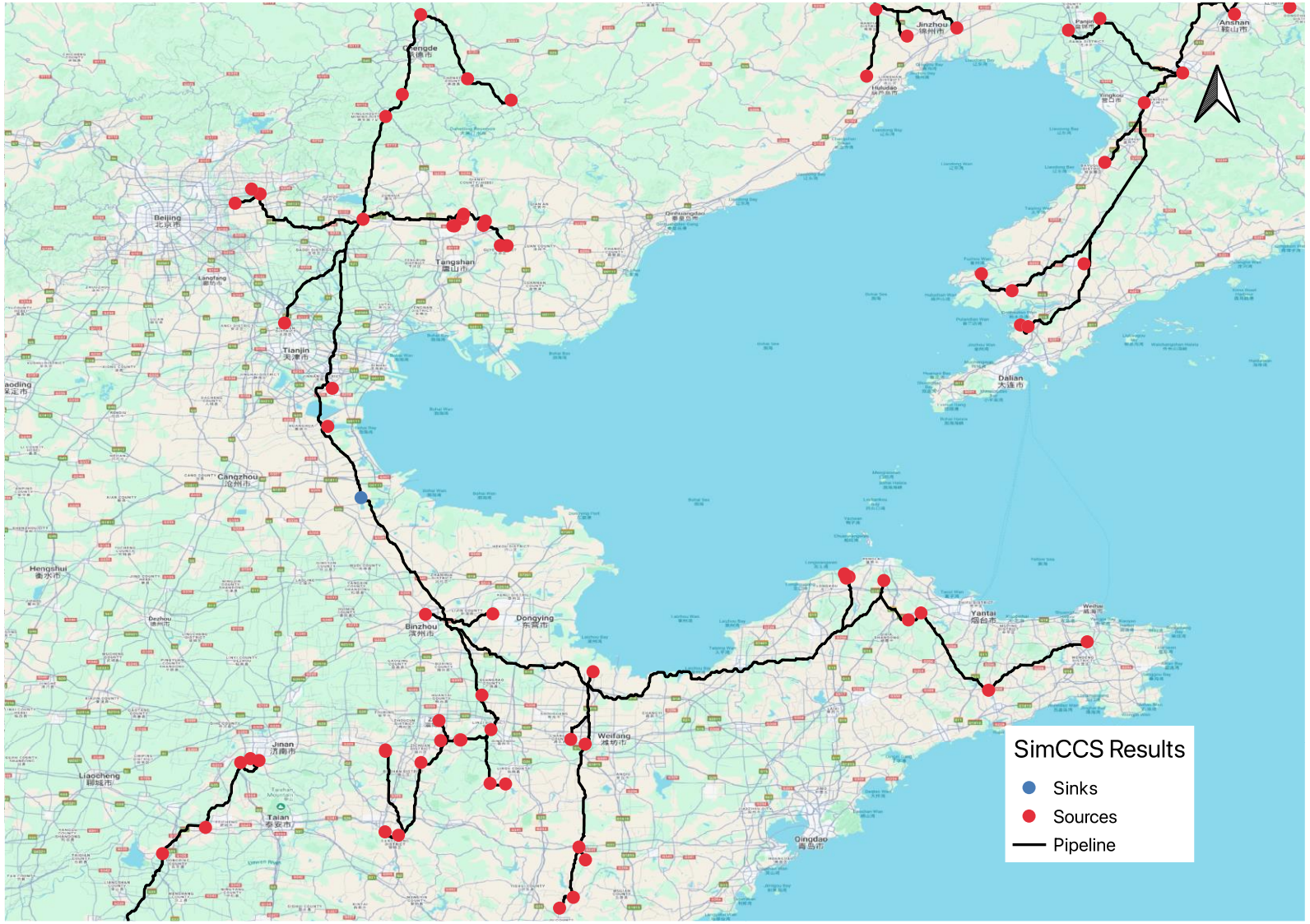
- Industrial CCUS in China.
- Focus on cement, methanol.
- Princeton University.

Data

- 300 sources, 359 $MtCO_2/yr.$
- 11 sinks, inc. utilization.
- 19,158 km of pipeline.

Preliminary Results

- **Total:** $275.90/$tCO_2$.
- **Capture:** $275.90/$tCO_2$.
- **Transport:** $16.27/$tCO_2$.
- **Storage:** $6.39/$tCO_2$.



CARBON SOLUTIONS

Take Home Message

Approach

- Developing R&D/software to advance CCUS infrastructure in the US & the world.
- Working with federal & state governments, non-profits, & industry.
- International projects include Canada, Mexico, Brazil, & China.
- Getting ready for CCUS in South America!

Richard Middleton | richard.middleton@carbonsolutionsllc.com