

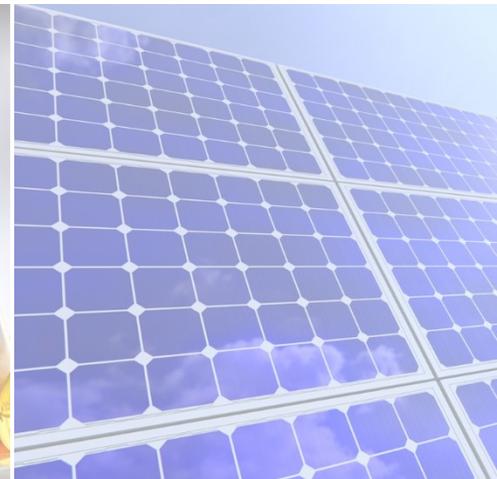


# CO<sub>2</sub> Capture & Storage Software

## CARBON SOLUTIONS

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# CARBON SOLUTIONS



## Vision: Solutions for a net-zero carbon economy

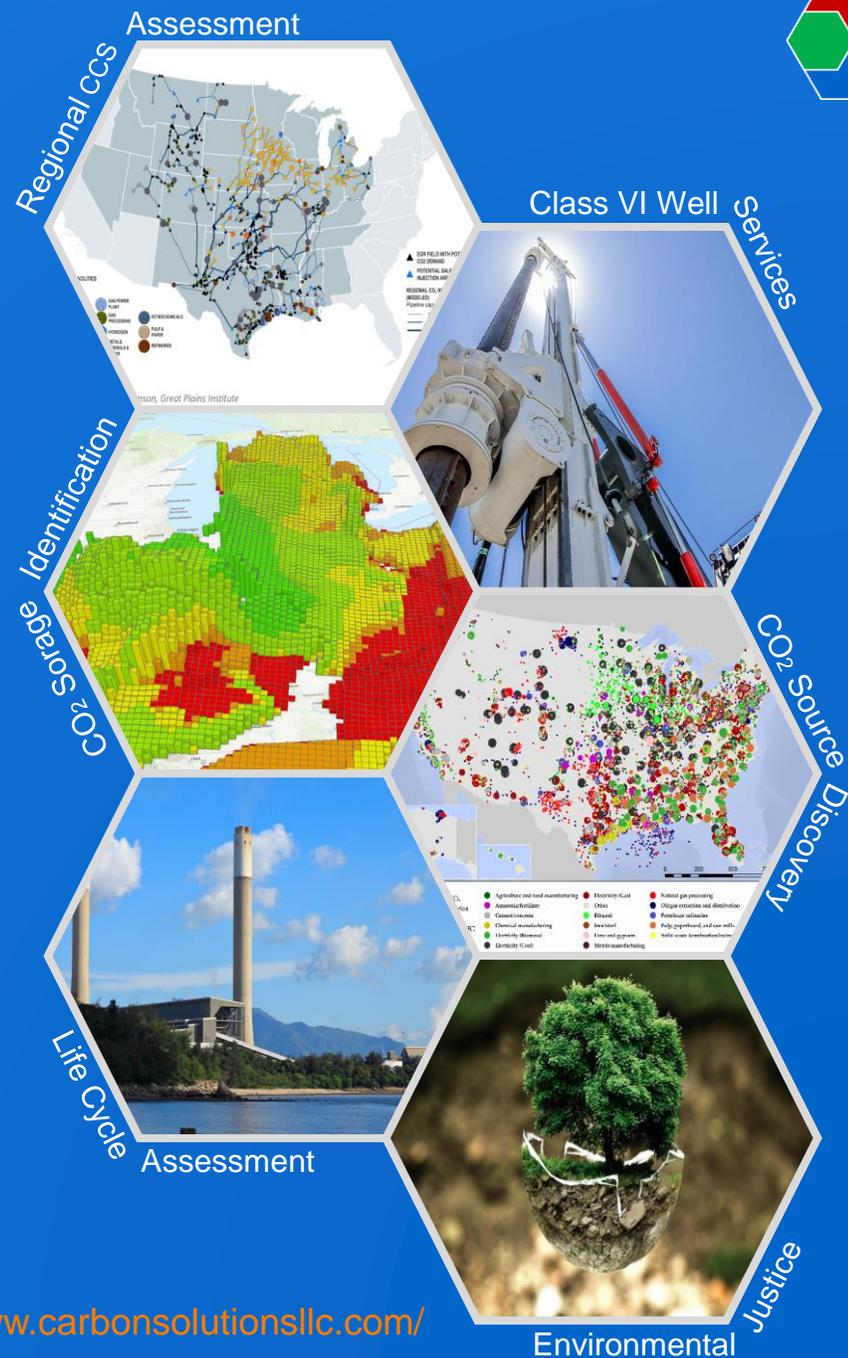
- *CARBON SOLUTIONS works with industry, government, non-profits, researchers, & other stakeholders to identify & implement real-world solutions for low-carbon energy challenges.*
- **HISTORY:** Launched 2021 | 30+ employees (15 PhD's) | 75+ projects.
- **FUNDING:** 65% Government | 20% NGOs | 15% Industry.
- **FOUNDATION:** Development of *SimCCS*.

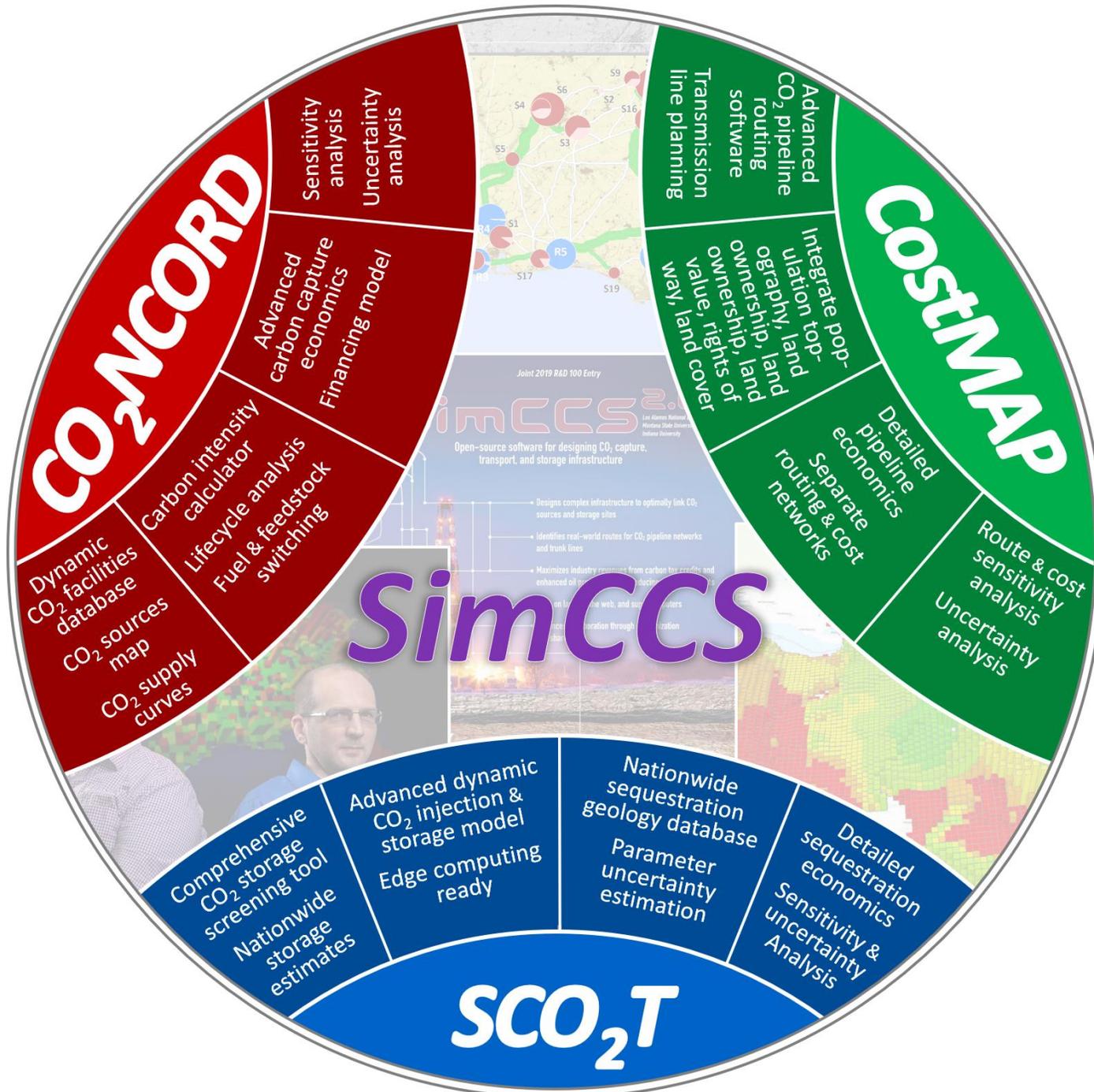
## Energy applications

- CO<sub>2</sub> capture-transport-utilization-storage, hydrogen, direct air capture, geothermal, wind, energy storage, grid modeling, electric vehicles, energy equity...

## Data analytics

- Optimization, reservoir simulation, ML/AI, LCA, TEA, econometrics, GIScience...





*SIMCCS<sup>PRO</sup>*  
**SimCCS Software**

**SimCCS<sup>PRO</sup> (system analysis)**

- Decision support across the CCS value chain.
- Leading sub-models for CO<sub>2</sub> capture, transport, & storage.

**CO<sub>2</sub>NCORD (capture)**

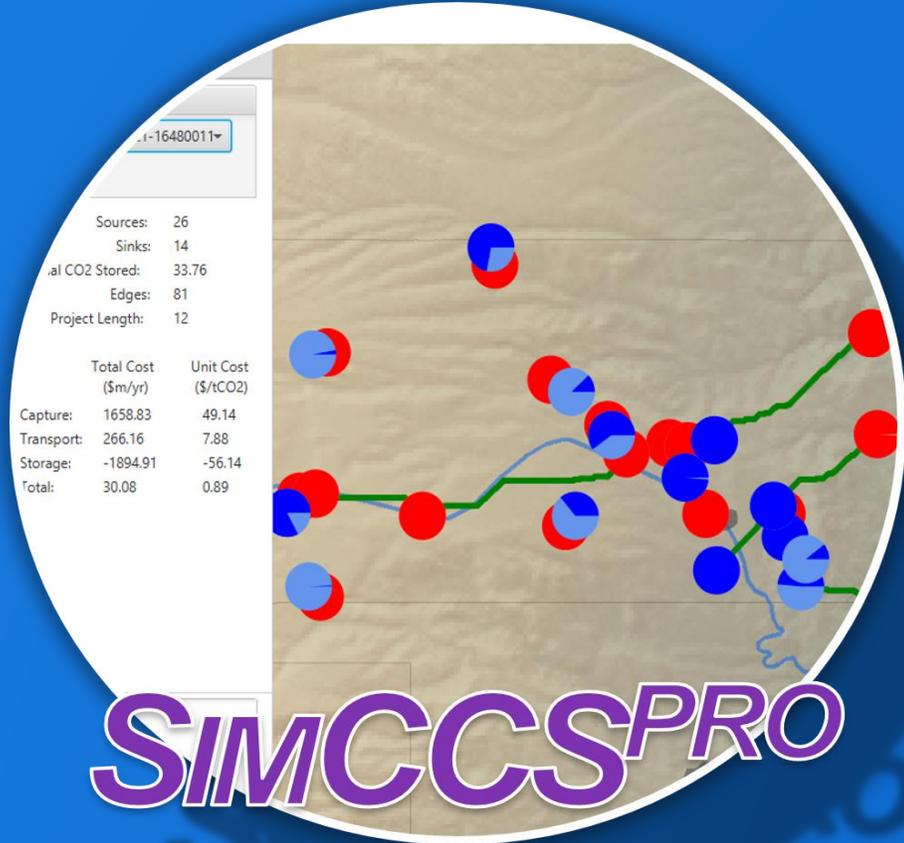
- Dynamic, customizable CO<sub>2</sub> capture database.
- 10,000+ sources.

**CostMAP<sup>PRO</sup> (transport)**

- Advanced, multiscale, multi-attribute pipeline routing.

**SCO<sub>2</sub>T<sup>PRO</sup> (storage)**

- World's most advanced & accurate tool for dynamic CO<sub>2</sub> storage & costs.



# SIMCCSPRO

# Disruptive Science

## Foundation

- Award-winning CCS science & software.

## SimCCS<sup>PRO</sup>

- Decision-support framework for designing CO<sub>2</sub> capture, transportation, & storage (CCS) infrastructure.
- Industry- & research-leading CCS infrastructure tool.
- Dozens of scientific papers, thousands of citations.
- Two R&D 100 Awards (2019).

## Decision discovery & support

- Integrated capture, transport, & storage economics.
- End-to-end techno-economic assessment (TEA).
- Policy analysis.
- System-wide life cycle assessment (LCA).

## CARBON SOLUTIONS

- Leveraging decades of carbon *research* to help industry, stake-holders, and the Nation develop carbon *solutions*.

Joint 2019 R&D 100 Entry

# SimCCS<sup>2.0</sup>

Los Alamos National Laboratory,  
Montana State University, and  
Indiana University

Open-source software for designing CO<sub>2</sub> capture,  
transport, and storage infrastructure

- Designs complex infrastructure to optimally link CO<sub>2</sub> sources and storage sites
- Identifies real-world routes for CO<sub>2</sub> pipeline networks and trunk lines
- Maximizes industry revenues from carbon tax credits and enhanced oil production while reducing carbon footprints
- Runs on laptops, the web, and supercomputers
- Enhances collaboration through customization and shareability

SPECIAL RECOGNITION

2019

R&D 100

SILVER

2019

R&D 100

WINNER

Los Alamos NATIONAL LABORATORY EST. 1943

MONTANA STATE UNIVERSITY

INDIANA UNIVERSITY

# CCS Decision Support

## Integrated CCS assessment

- Simultaneously understand capture, transport, & storage of CO<sub>2</sub>.

## Capture

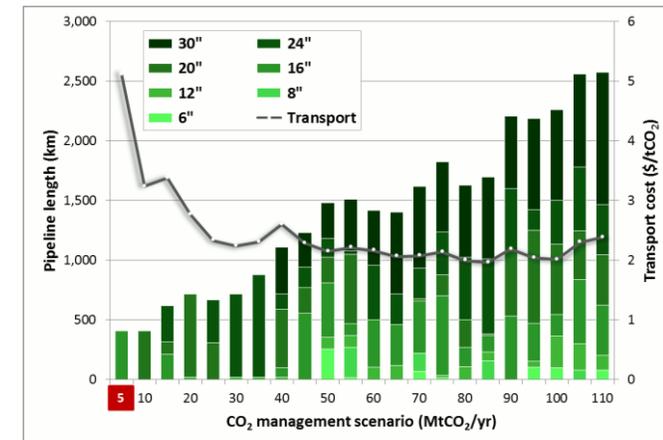
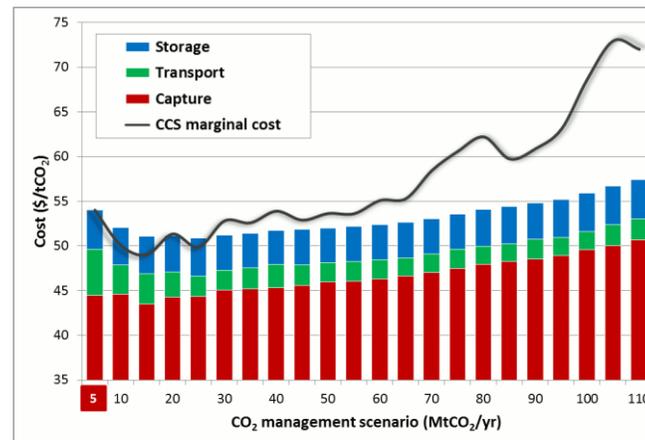
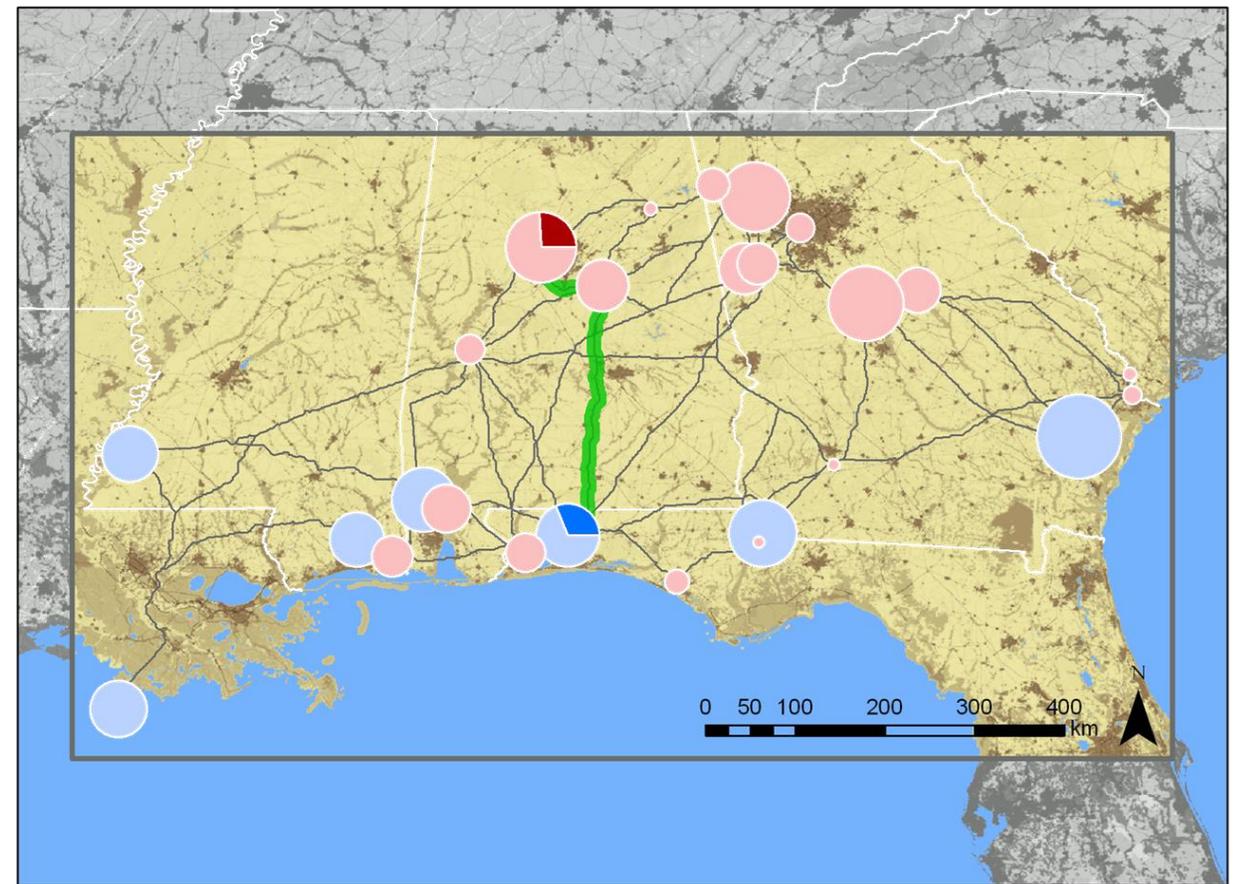
- CO<sub>2</sub> emissions, capturable CO<sub>2</sub>, CO<sub>2</sub> purity by multiple streams, economics over space & time.

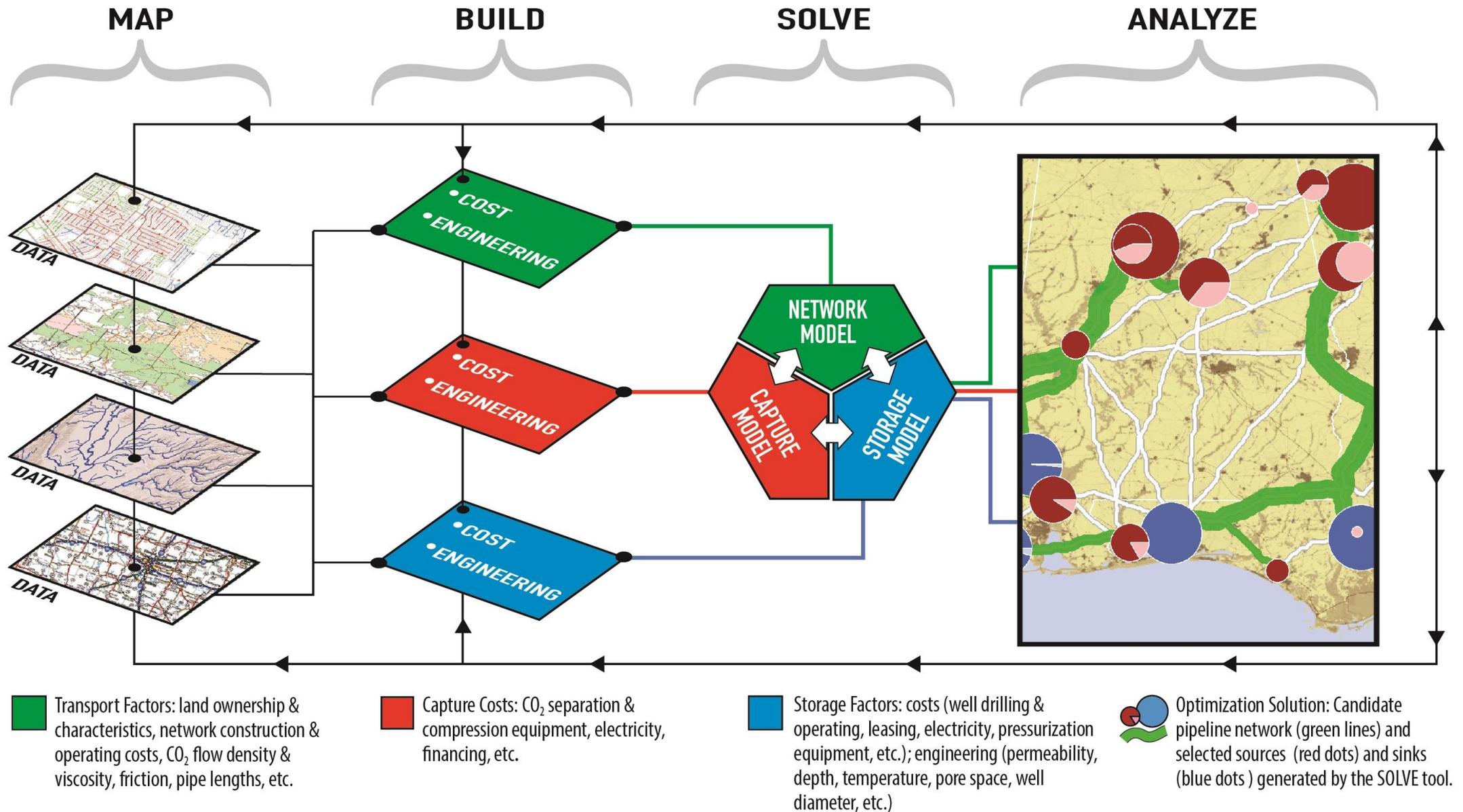
## Transport

- **ROUTES:** Potential routes considering multi-dimensional geographies.
- **PIPELINES:** Capacities, trunklines to aggregate CO<sub>2</sub>, economics (capital, fixed & variable O&M).

## Storage:

- **STORAGE:** Identify ideal sites, dynamic CO<sub>2</sub> injection & storage, life-time reservoir costs (injection, storage, & PISC).
- **UTILIZATION:** Oil, shale gas, geothermal, & materials.





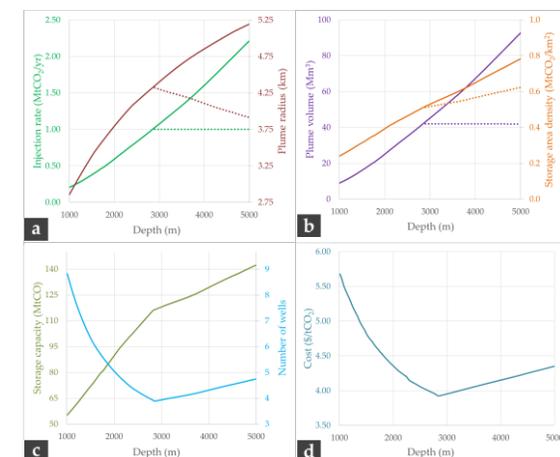
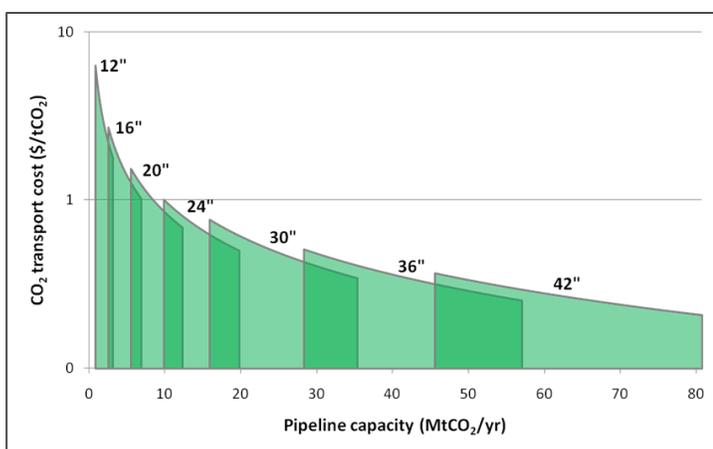
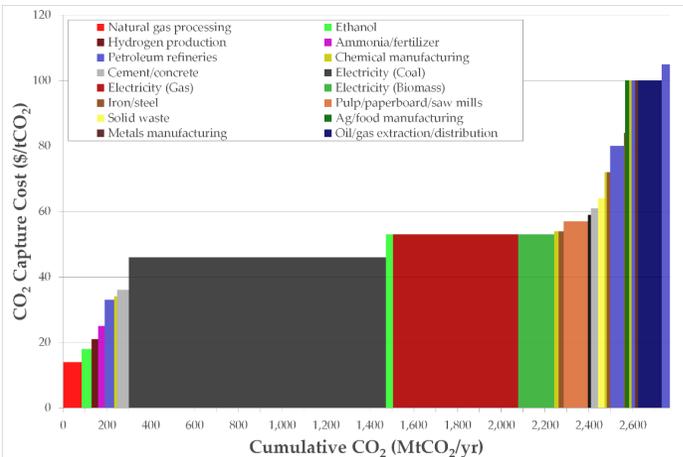


## CAPTURE

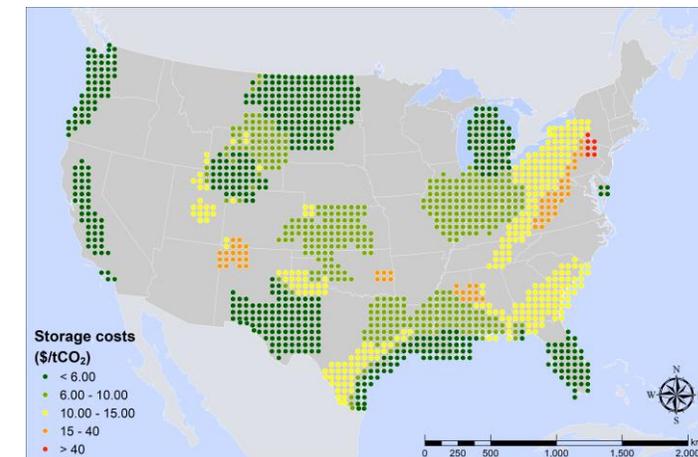
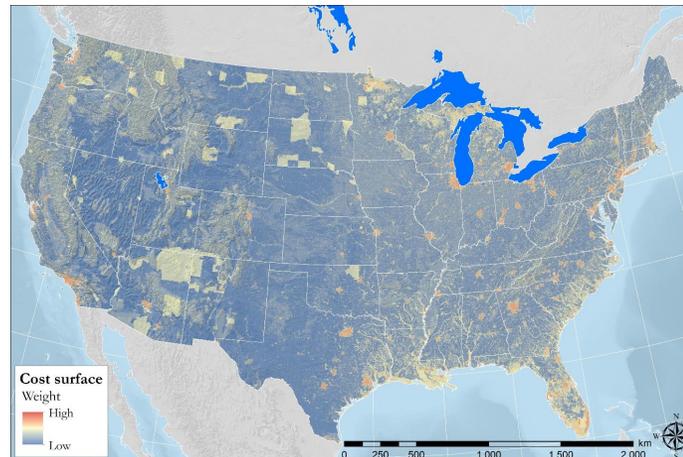
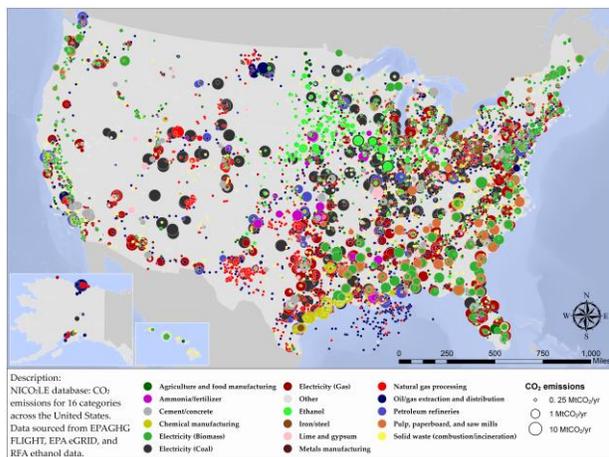
## TRANSPORT

## STORAGE

SCIENCE



DATA





# Why? (MOTIVATION)

## Description

- **SOFTWARE:** Most advanced screening-level **CO<sub>2</sub> capture** database.

## Motivation

- Rapidly characterize individual CO<sub>2</sub> sources.
- Directory of CO<sub>2</sub> opportunities.

## Customer discovery

- Capture technologies.
- Investment banks.
- Technology companies.
- CO<sub>2</sub> storage.
- Government/NGOs.

## CO<sub>2</sub>NCORD

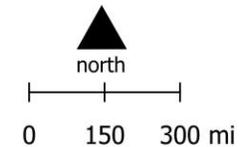
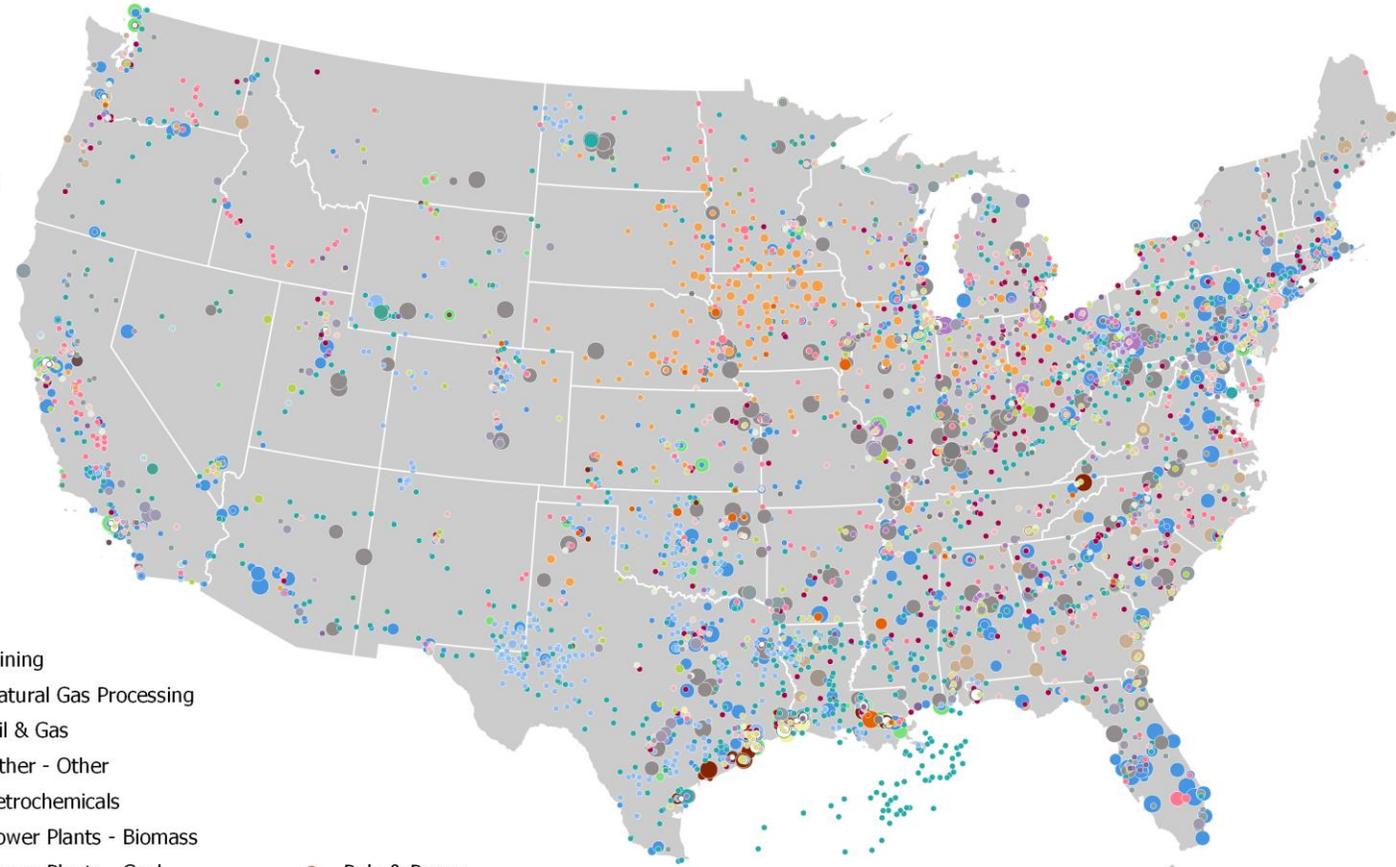
The CO<sub>2</sub> National Capture Opportunities and Readiness Database

### Capturable Emissions (MtCO<sub>2</sub>)

- 0.00 - 0.50
- 0.50 - 0.85
- 0.85 - 1.50
- 1.50 - 3.00
- 3.00+

### Industry Category

- |                     |                               |                    |
|---------------------|-------------------------------|--------------------|
| ○ Aluminum          | ● Mining                      |                    |
| ● Ammonia           | ● Natural Gas Processing      |                    |
| ● Cement            | ● Oil & Gas                   |                    |
| ● Chemicals         | ● Other - Other               |                    |
| ● Chemicals - Other | ● Petrochemicals              |                    |
| ● Ethanol           | ● Power Plants - Biomass      | ● Pulp & Paper     |
| ● Facilities        | ● Power Plants - Coal         | ● Refineries       |
| ● Food & Ag         | ● Power Plants - Gas          | ● Solid Waste      |
| ● Glass             | ● Power Plants - Other        | ● Waste - Landfill |
| ● Hydrogen          | ● Power Plants - Other Fossil | ● Waste - Other    |
| ● Iron & Steel      | ● Power Plants - Pet Coke     |                    |
| ● Lime & Gypsum     |                               |                    |
| ● Manufacturing     |                               |                    |
| ● Metals - Other    |                               |                    |
| ● Minerals - Other  |                               |                    |





## Product

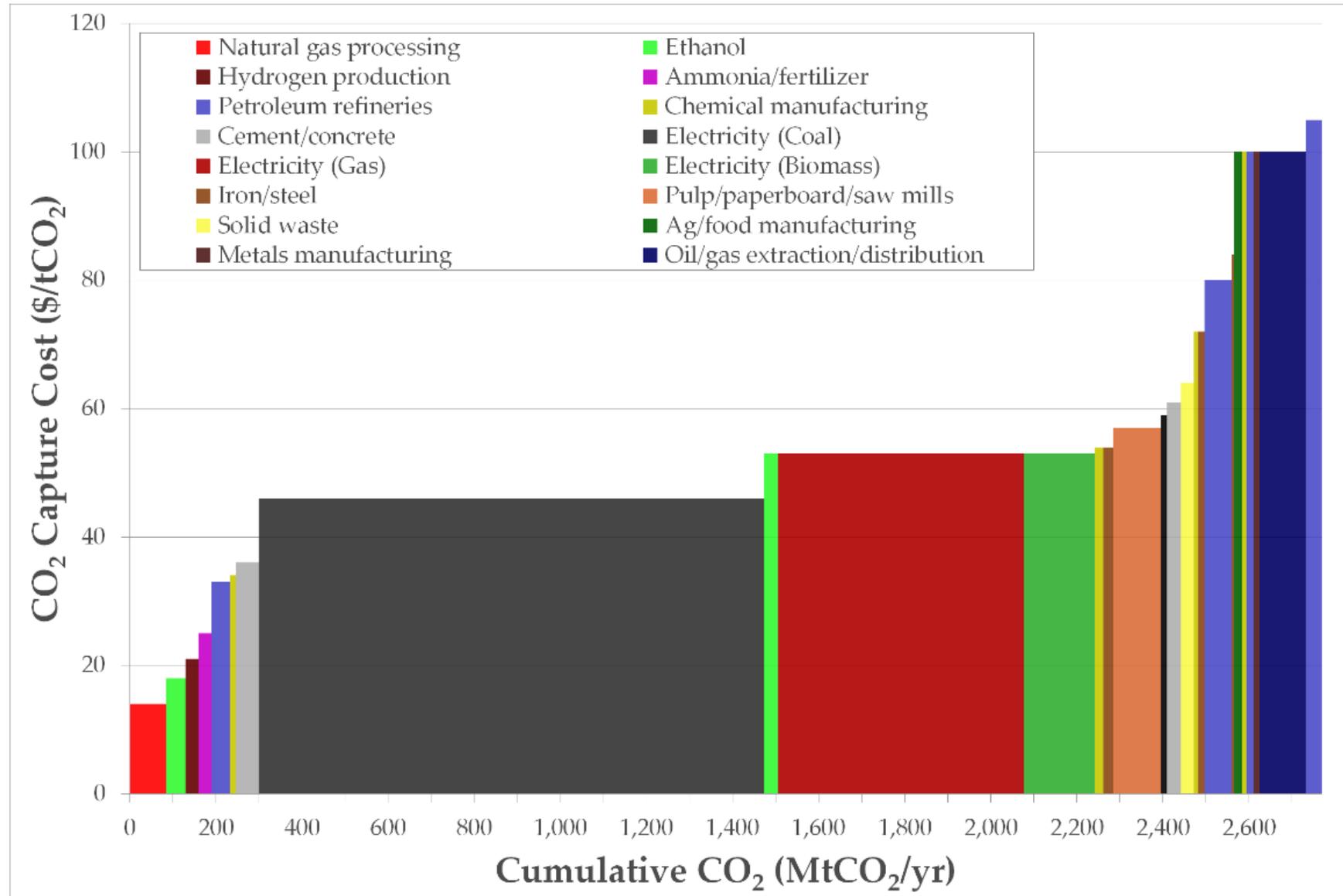
- **DATABASE:** Locations, CO<sub>2</sub> streams (quantity, purity), fuels, carbon intensity, capture costs.
- **SUPPLY CURVES:** Identify economic opportunities.

## Deliverables

- Market assessment.
- Identify investments.
- Hub analysis.

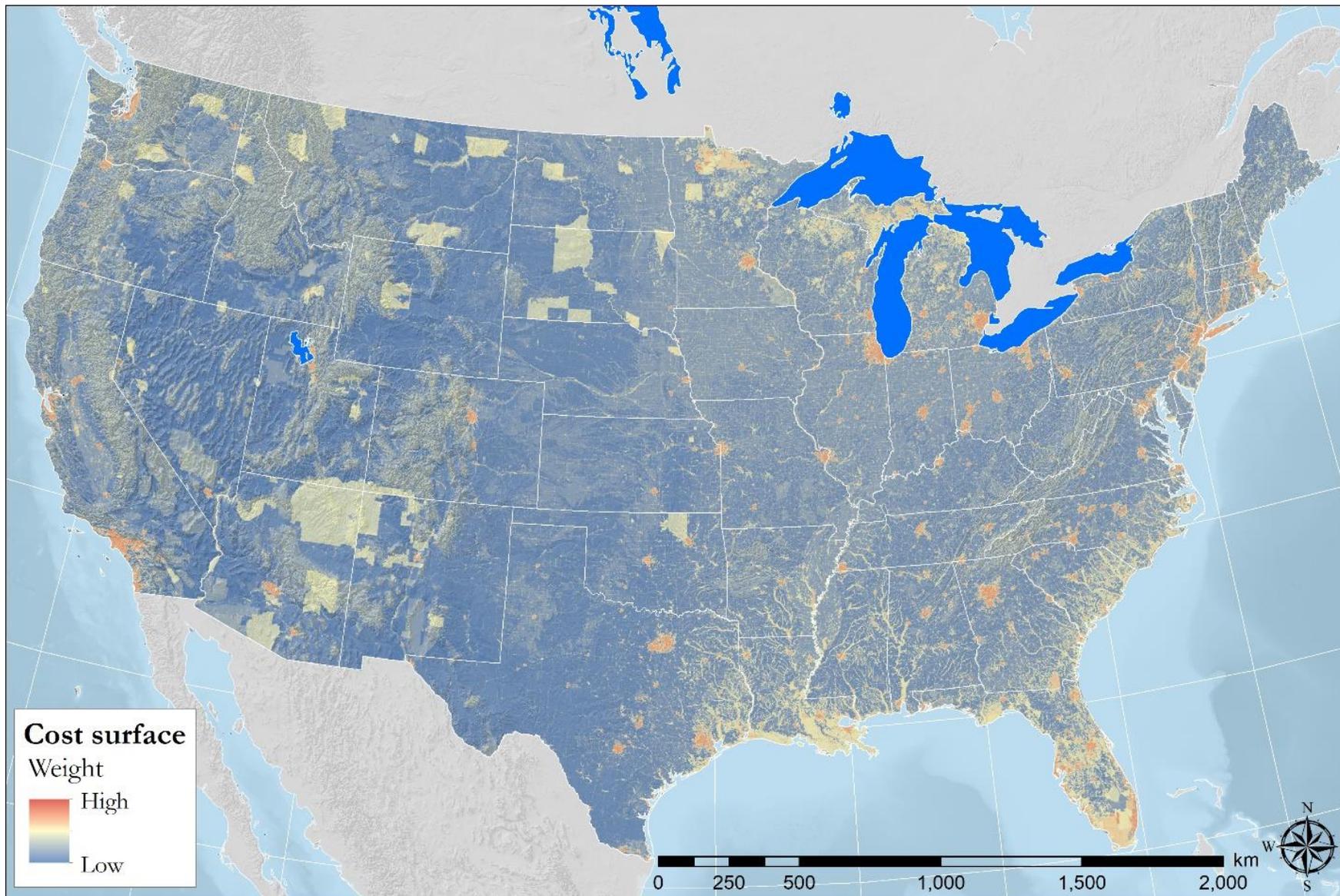
## Status

- **CURRENT:** Consulting version with data served online.
- **FUTURE:** Software as a Service (SaaS).





**COSTMAPPRO**



## Description

- **SOFTWARE:** Most advanced screening-level **CO<sub>2</sub> transportation** & routing model (or any pipelines, transmission lines).

## Motivation

- Identify corridors that balance connectivity, cost, environmental impact, community engagement.
- Customer interaction.
- Identify multiple routes.

## Customer discovery

- Utilities.
- CCS projects.
- Oil & gas.
- Government/NGOs.

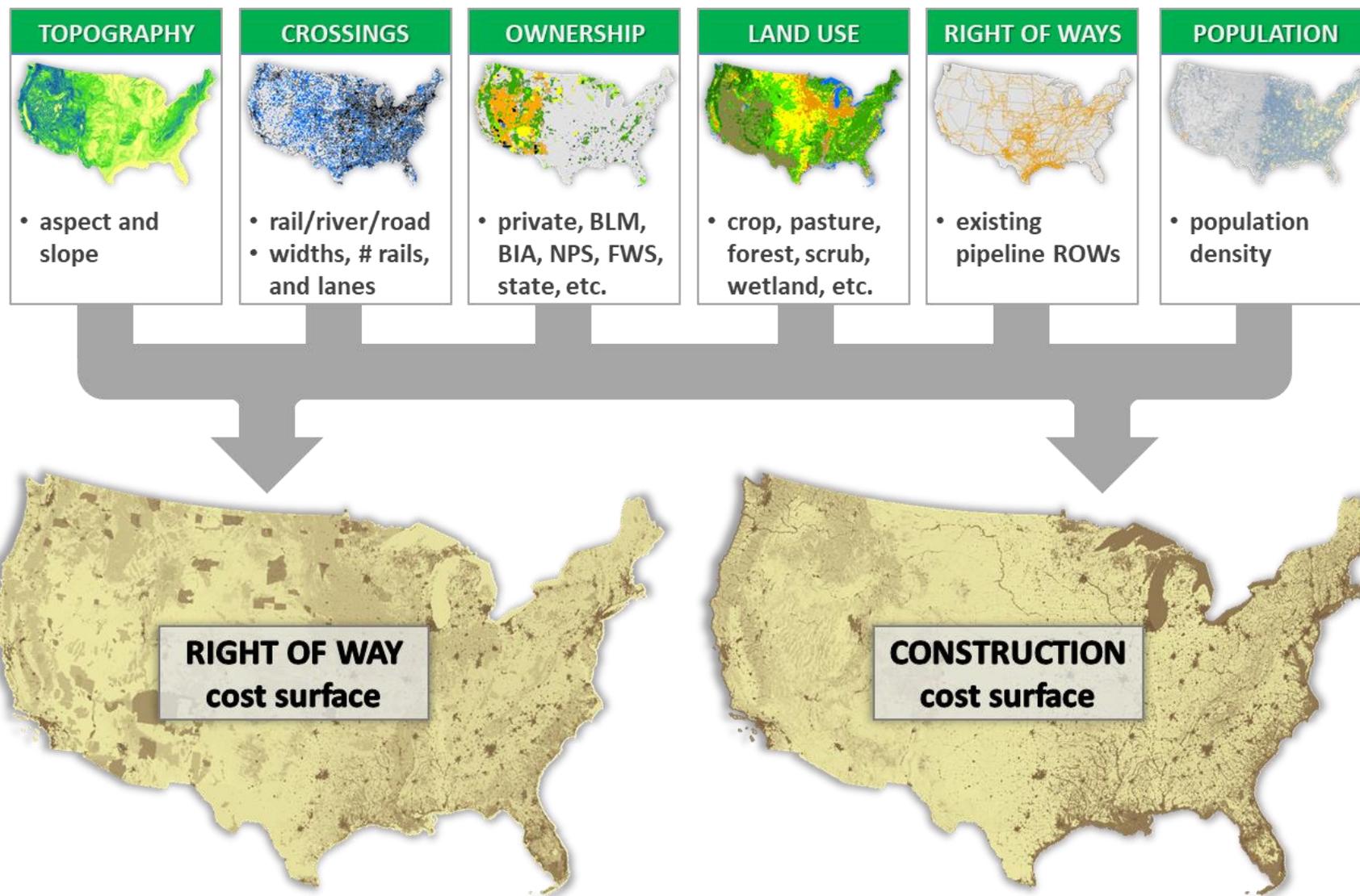


## Geospatial data fusion

- **PEOPLE:** Population, demographics, community, environmental justice, property values.
- **LAND:** Land cover, land use, fed/state/private, ownership.
- **CORRIDORS:** Pipelines, roads, transmission.
- **BARRIERS:** Roads, rivers, rail.
- **CUSTOM:** Any GIS layer.

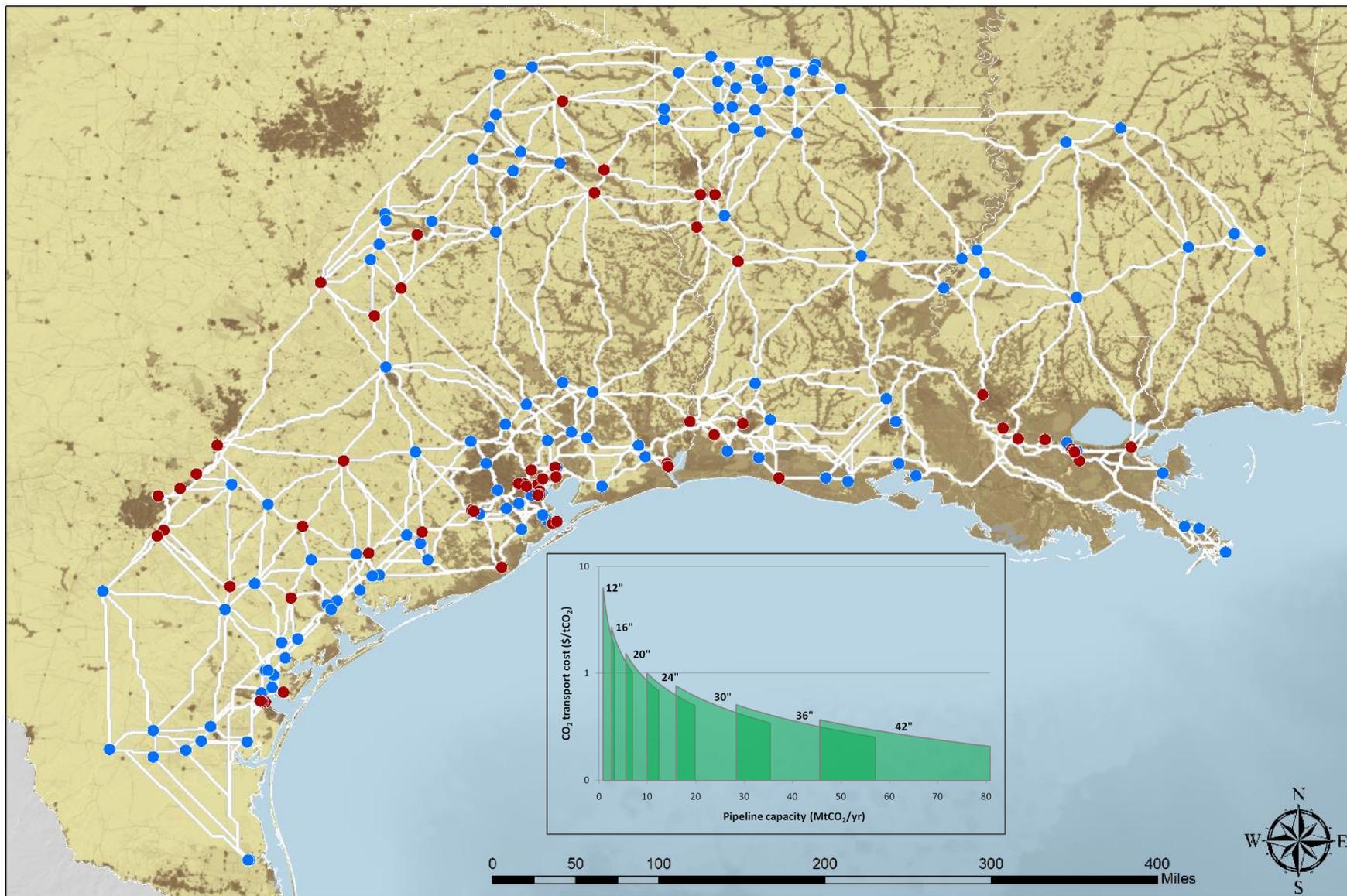
## Workflow

- Nonlinear weight calculations for routing & for cost.
- Develop interactive weights.
- Extract shortest (lowest-weight) paths.
- Vary weights, uncertainty.



Middleton et al. (2012) Generating candidate networks for optimization: The CO<sub>2</sub> capture and storage optimization problem, *Computers, Environment and Urban Systems*.

Hoover et al. (2020) CostMAP: an open-source software package for developing cost surfaces using a multi-scale search kernel, *International Journal of Geographical Information Science*.



## Product

- Optimized pipeline routes.
- Pipeline economics (construction, operation).

## Deliverables

- Low-cost, low-impact pipeline routes.
- Robustness analysis.
- Multi-resolution analysis: 10–720 m.

## Status

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**SCO<sub>2</sub>TPRO**



# Why? (MOTIVATION)

## Description

- **SOFTWARE:** Most advanced screening-level **CO<sub>2</sub> storage** model & database.

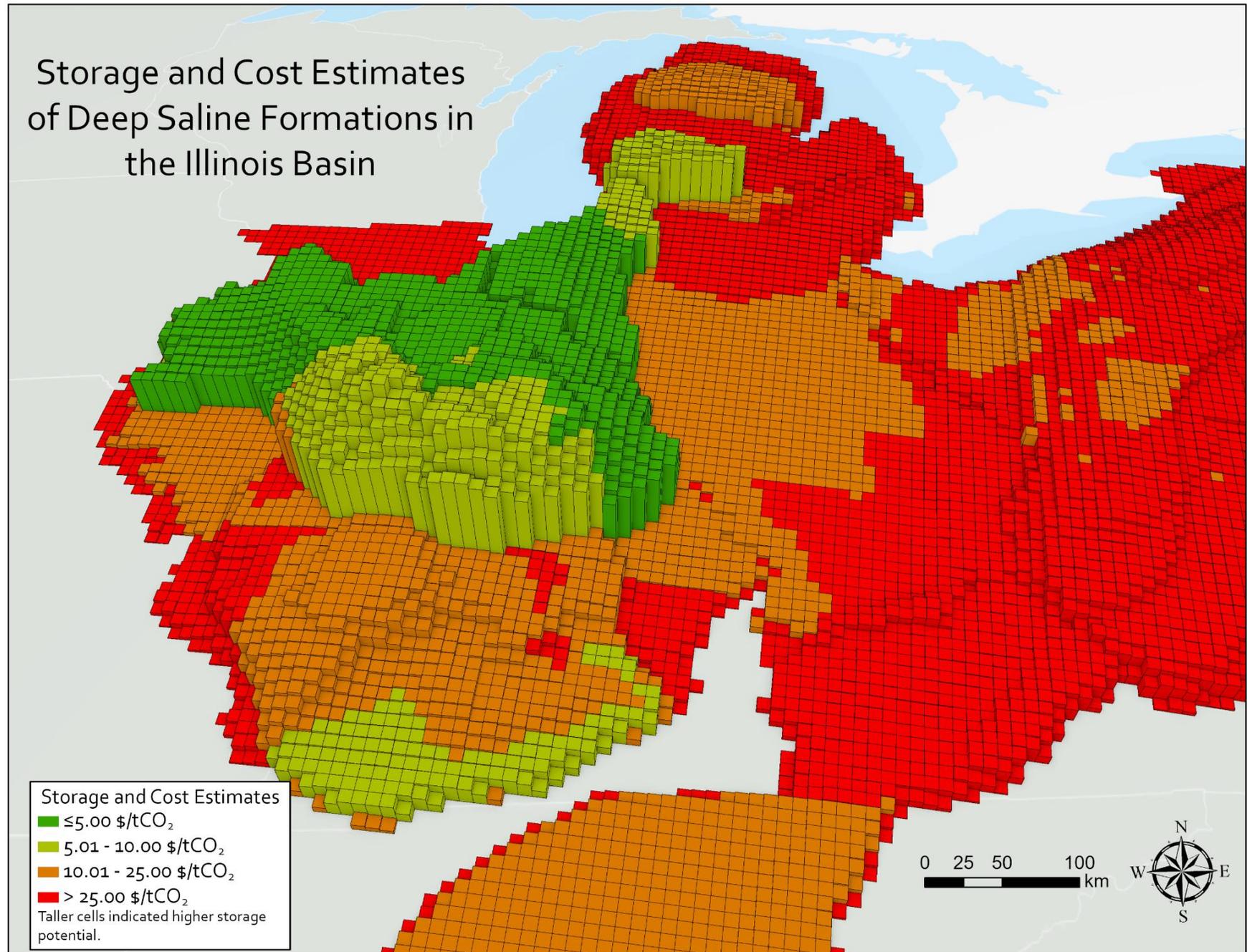
## Motivation

- Capture complex CO<sub>2</sub> storage with fast-running models.
- Rapidly characterize individual storage reservoirs.
- Regional/national assessment of CO<sub>2</sub> storage potential.

## Customer discovery

- CCS projects.
- CO<sub>2</sub> facilities.
- Investment banks.
- Government/NGOs.

## Storage and Cost Estimates of Deep Saline Formations in the Illinois Basin



# How? (SCIENCE)

## Machine learning/AI

- Use ML/AI to develop reduced-order models (ROMs) from 10,000s of full-physics simulations.

## Advanced geology

- Develop nation's leading sequestration geology inputs.

## Sequestration economics

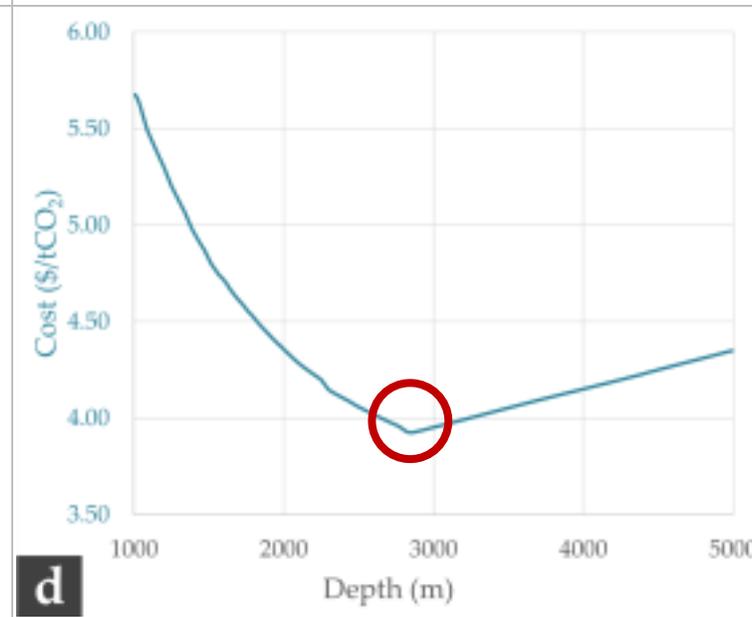
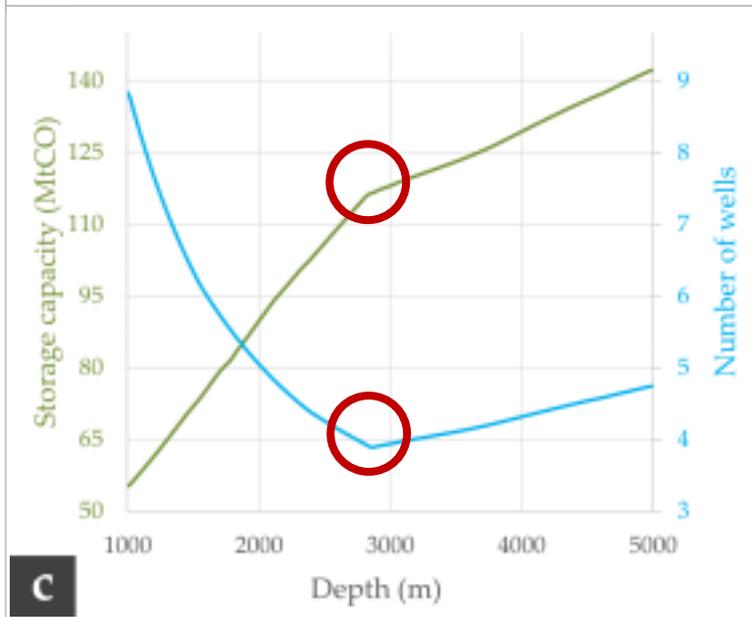
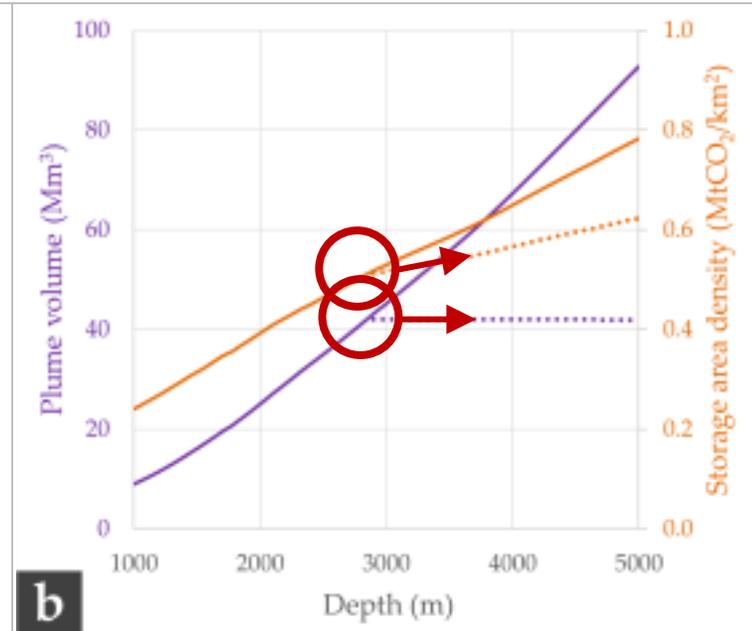
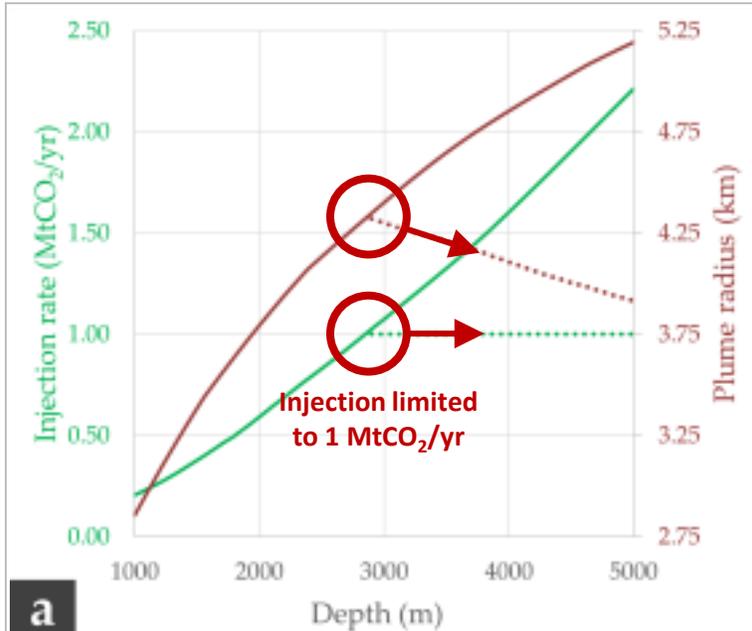
- Comprehensive sequestration costs, including injection, monitoring, & post-injection & site care (PISC).

## Software

- Integrate ROMs, geology, & economics.
- Uncertainty analysis.

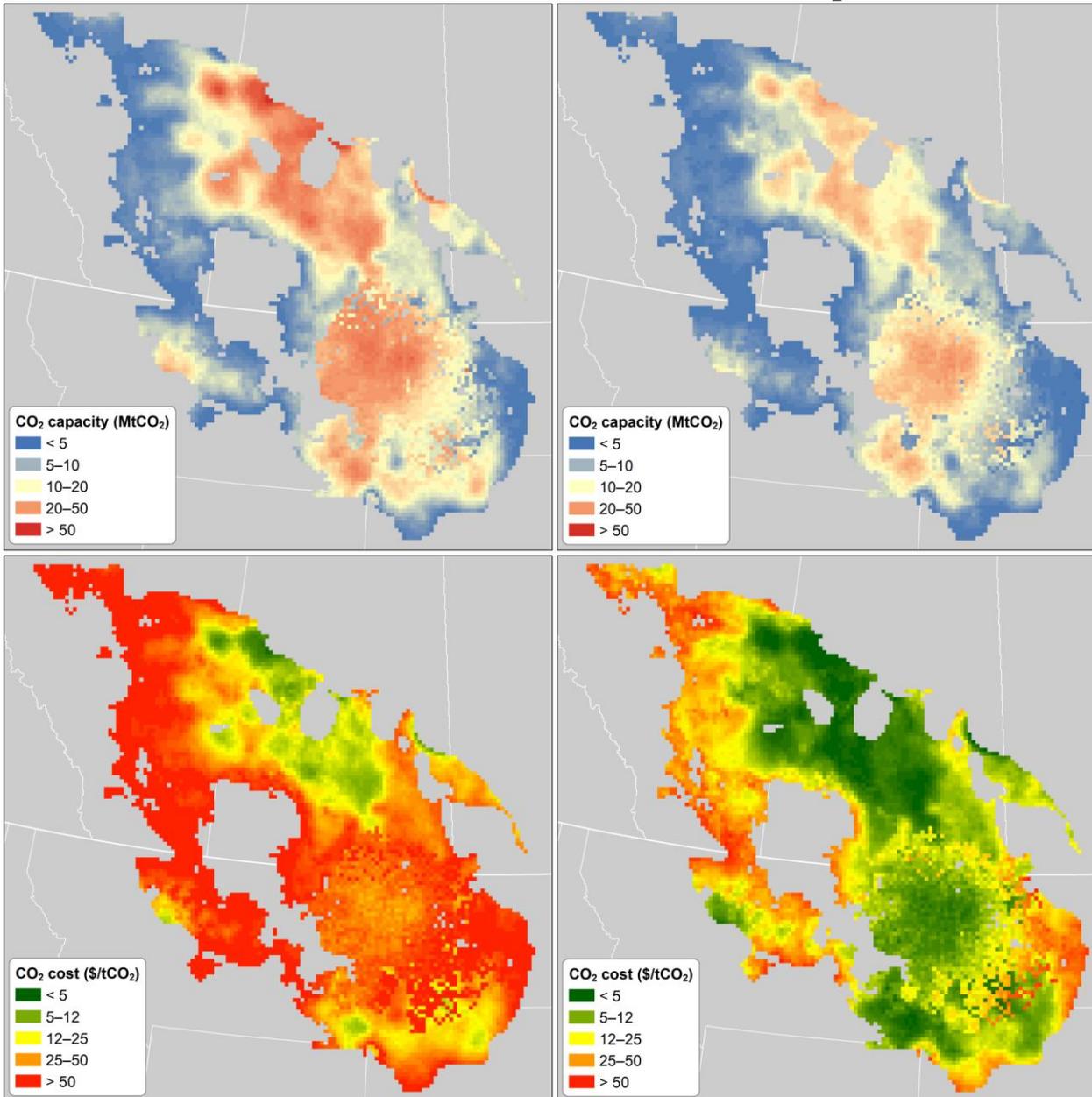
## Visibility

- Six SCO<sub>2</sub>T peer-reviewed publications.



CSSC

SCO<sub>2</sub>T<sup>PRO</sup>



SCO<sub>2</sub>T<sup>PRO</sup>

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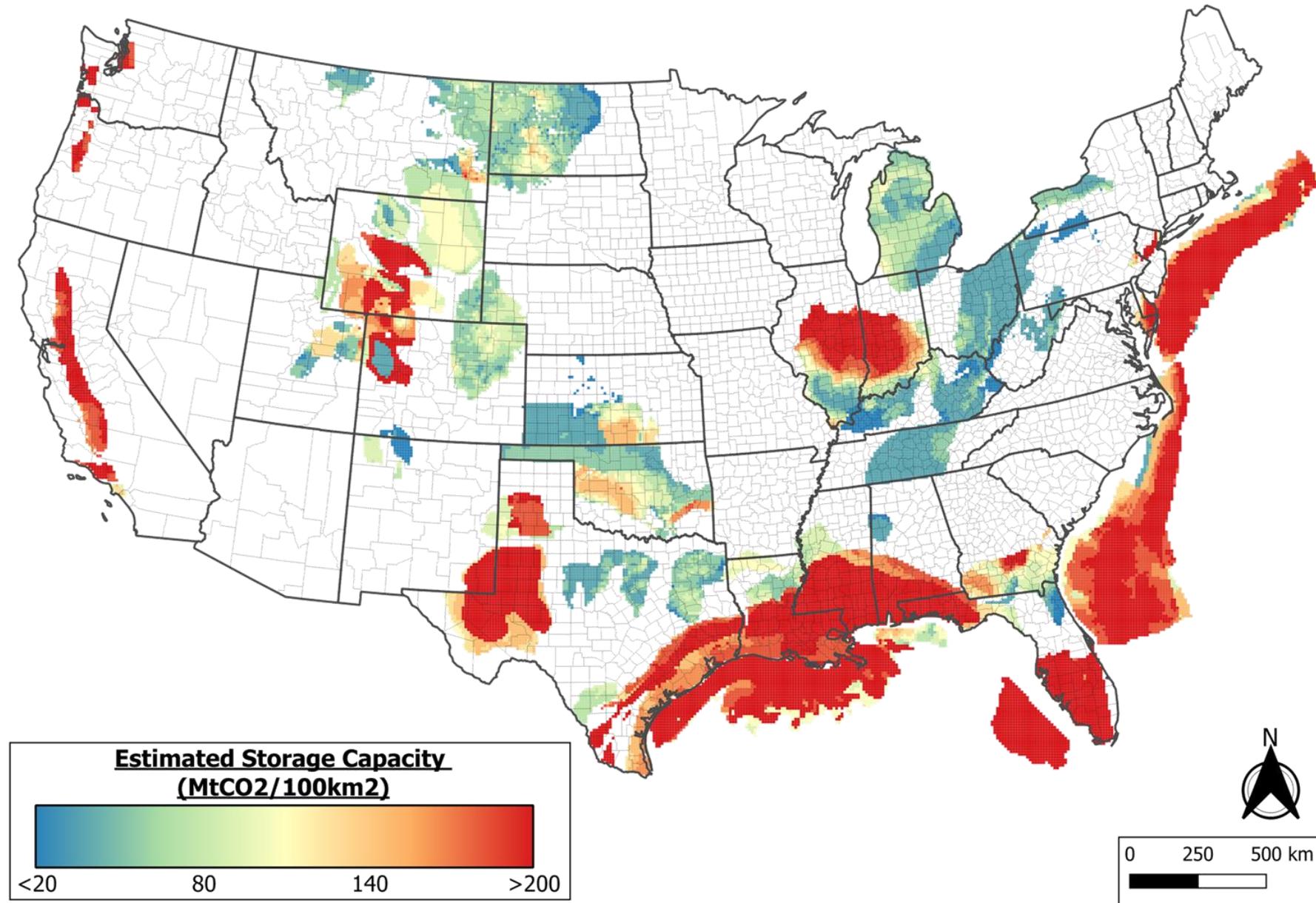
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- **MODEL:** Standalone tool for individual reservoir analysis.

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## Product

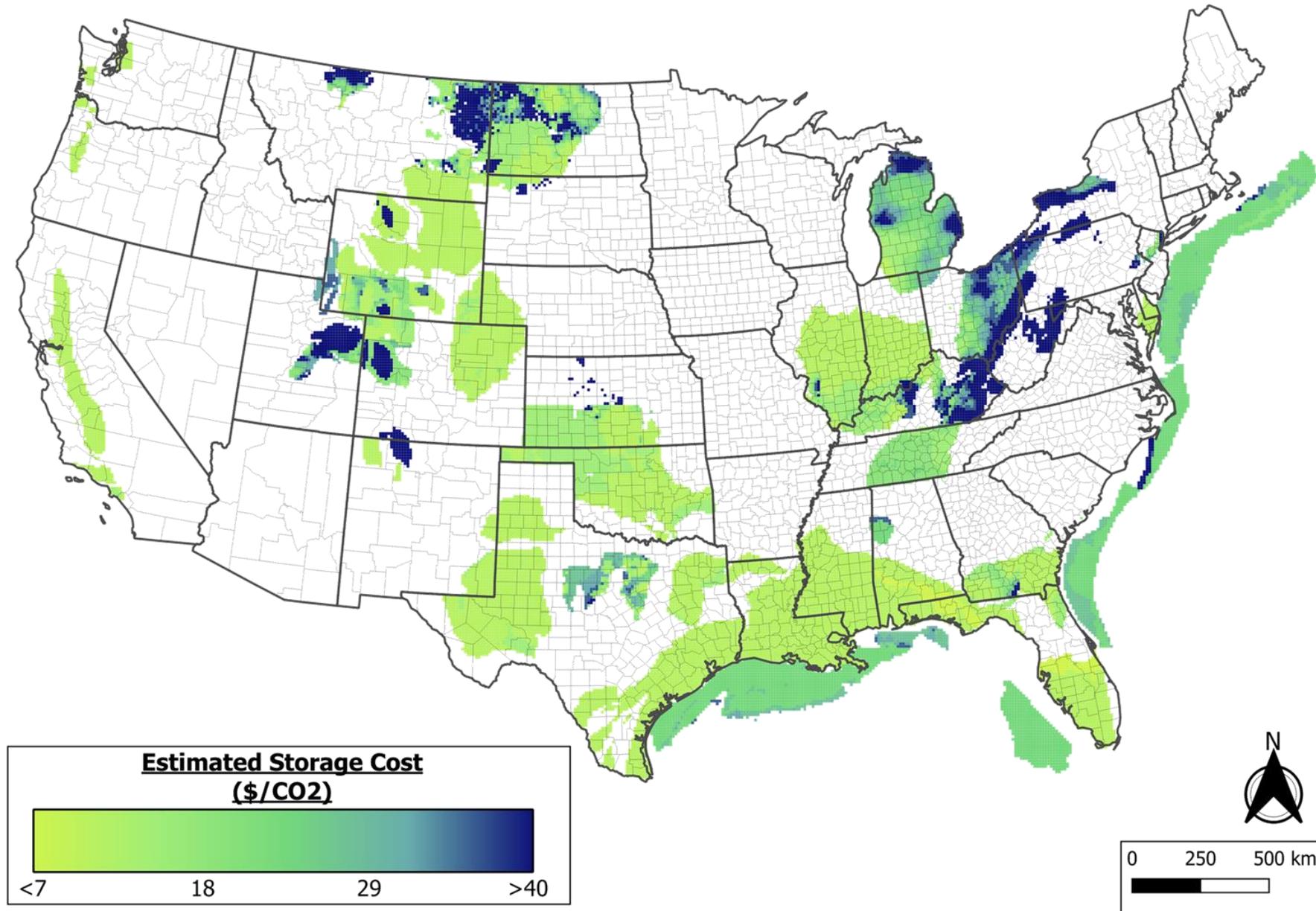
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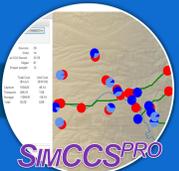
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# GIS Database to Serve SimCCS<sup>PRO</sup> Data

## SimCCS<sup>PRO</sup> frontend

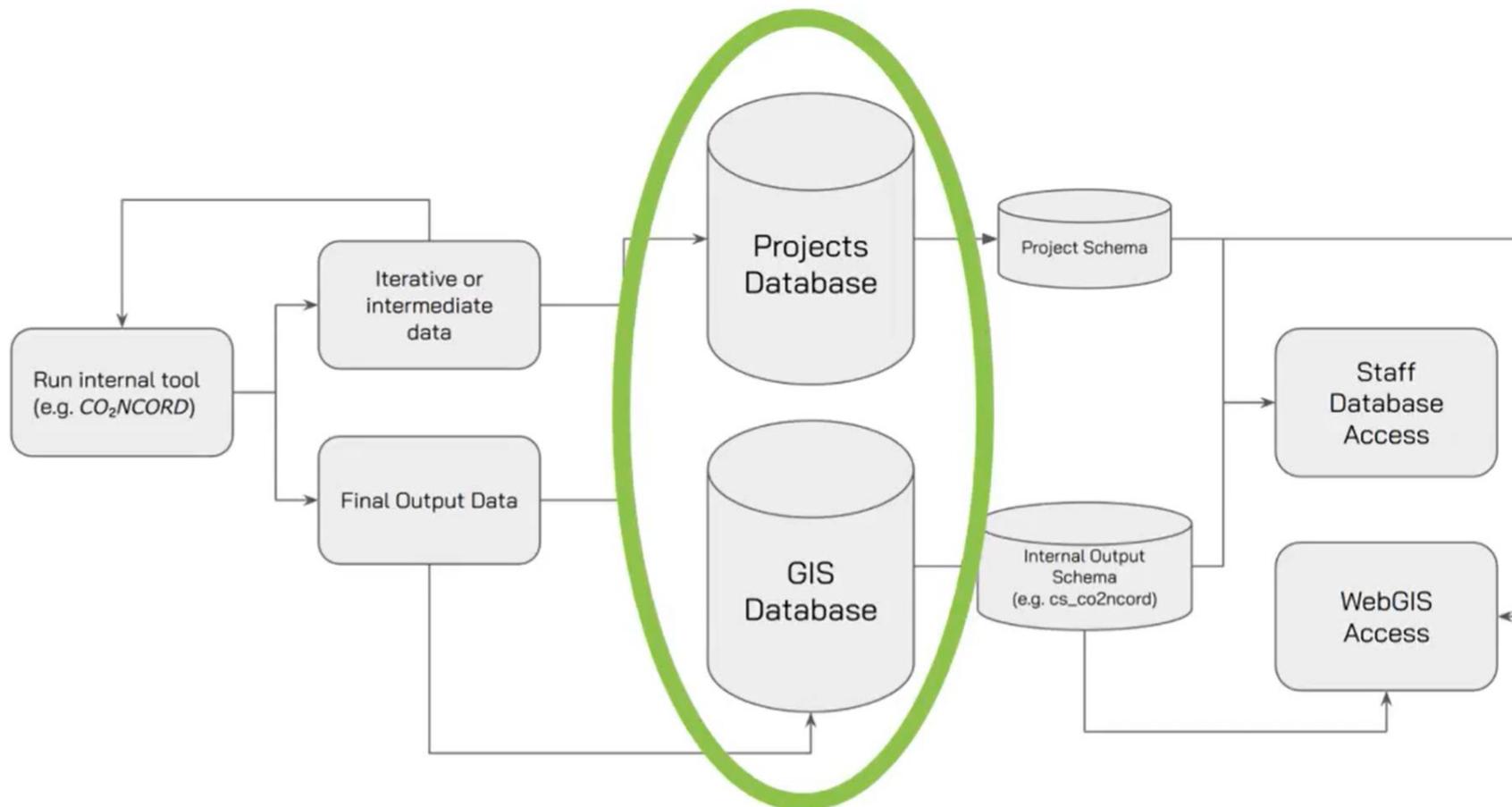
- Deliver GIS & non-GIS on a dedicated server.
- Public “free” data.
- Clients securely access their private data/results.
- Push updated data.
- Archive old data.

## Current capabilities

- Query data.
- Download data.

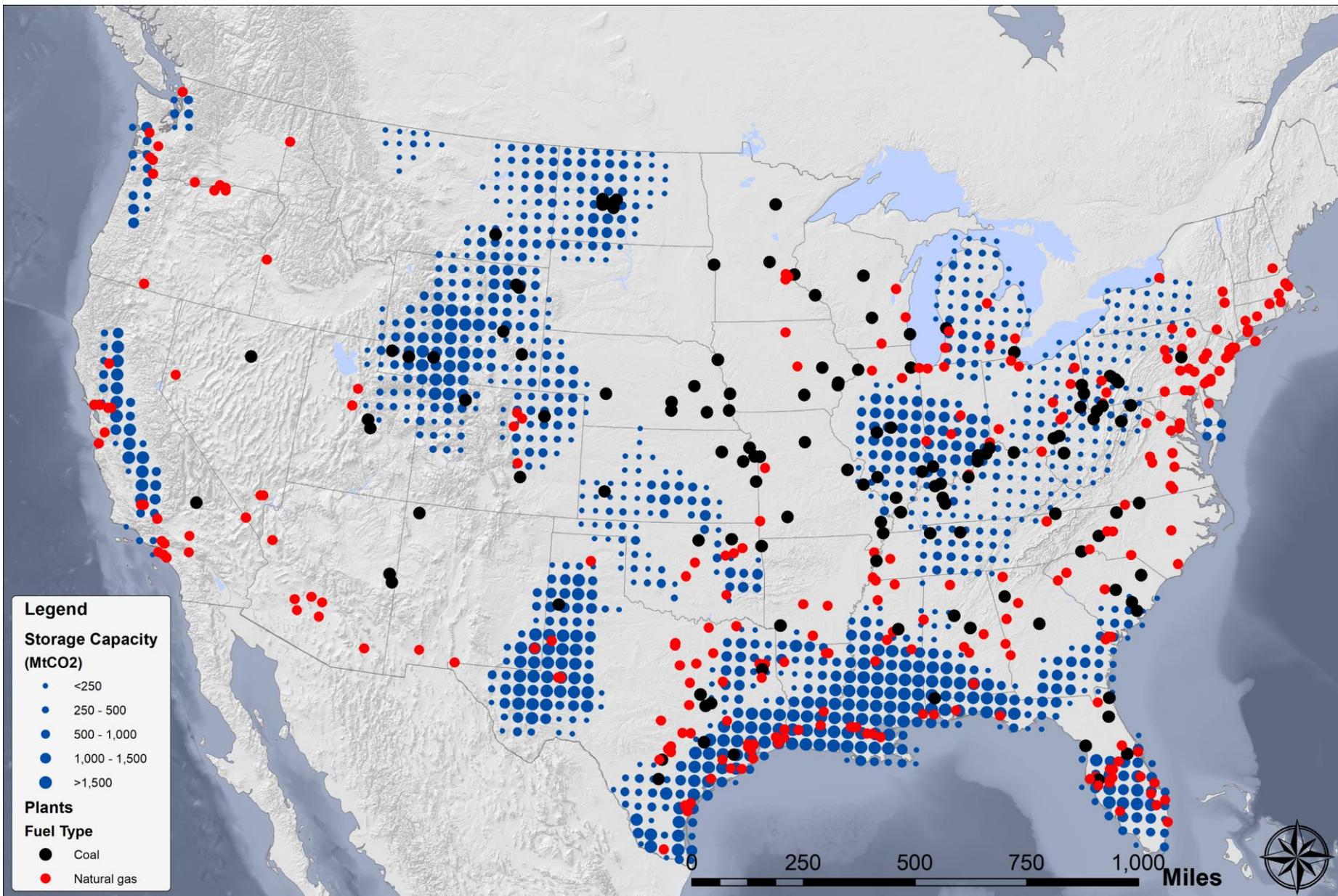
## Future capabilities

- Recreate data.
- SaaS.





# Decarbonization of Fossil Electricity



## Scenario

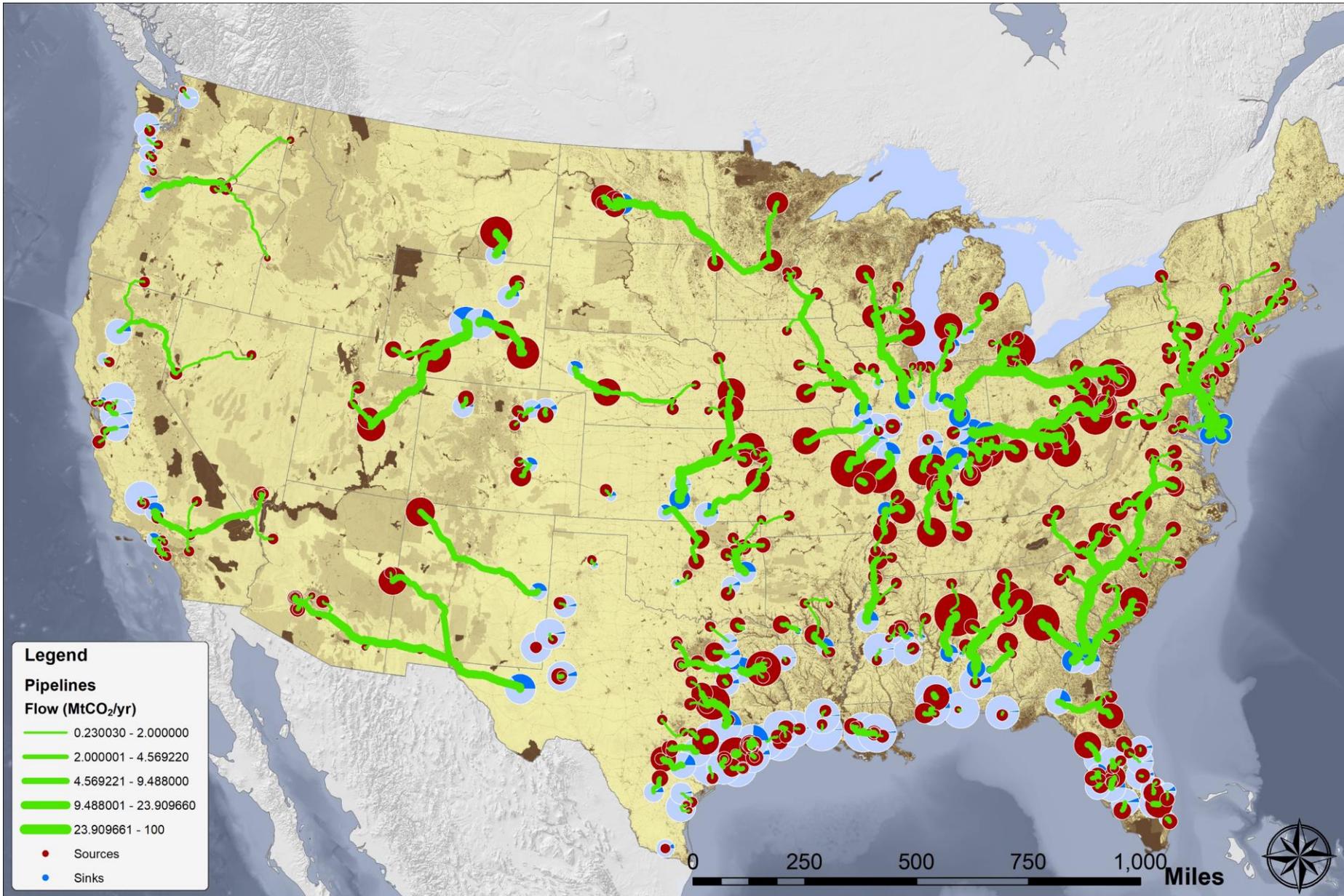
- Help guide policymaker plans for emissions rules for coal and gas plants.

## Scenario

- Sources:
  - 429 plants | 1,044 MtCO<sub>2</sub>/yr.
  - 137 coal | 603 MtCO<sub>2</sub>/yr.
  - 293 NGCC | 444 MtCO<sub>2</sub>/yr.
- Storage:
  - Saline-only, Medium-cost estimates from *SCO<sub>2</sub> TPRO*.
- Scenario:
  - *SimCCS<sup>CAP</sup>* mode.
  - Increasing CO<sub>2</sub> capture (100–1,1044 MtCO<sub>2</sub>/yr).

## Analysis

- Distributed storage vs. major hubs?



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## Analysis

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# Supporting the Energy Transition with Novel Science

## Disruptive R&D

- Novel energy science for CCS, energy storage, hydrogen, geothermal, wind...

## Award-winning software

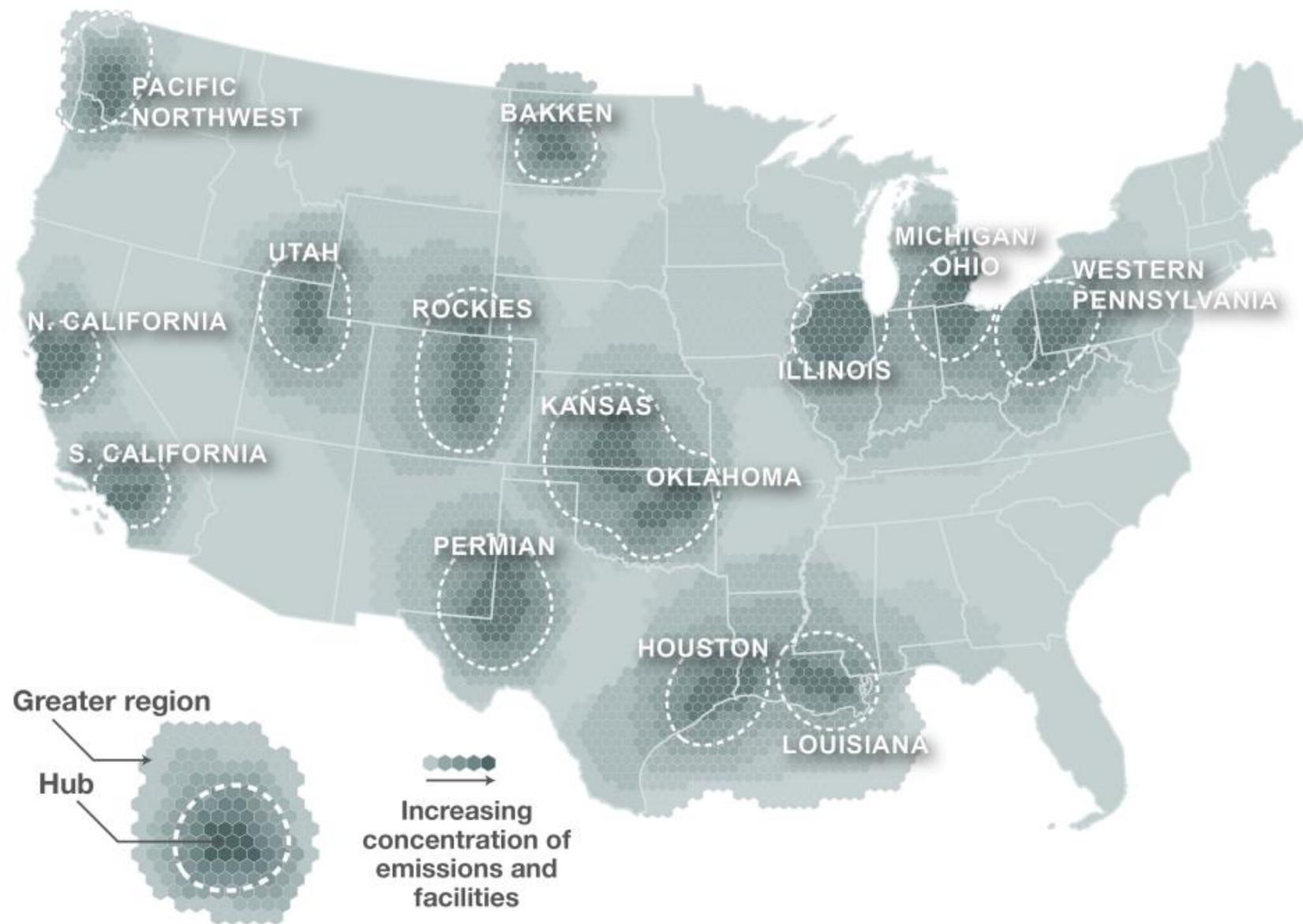
- Energy planning from individual projects to nationwide impacts.

## Information

- Unique data to support energy transition decisions.

## Services

- Supporting energy projects with agile science & software.



An Atlas of Carbon and Hydrogen Hubs for United States Decarbonization

[https://scripts.betterenergy.org/CarbonCaptureReady/GPI\\_Carbon\\_and\\_Hydrogen\\_Hubs\\_Atlas.pdf](https://scripts.betterenergy.org/CarbonCaptureReady/GPI_Carbon_and_Hydrogen_Hubs_Atlas.pdf)



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