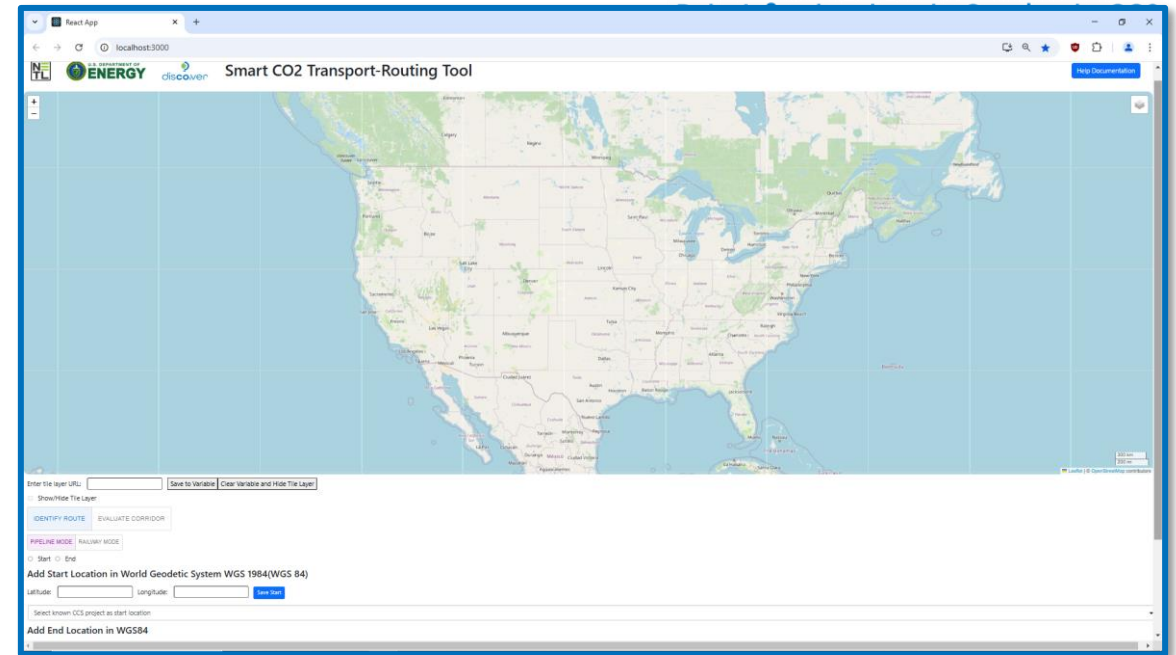
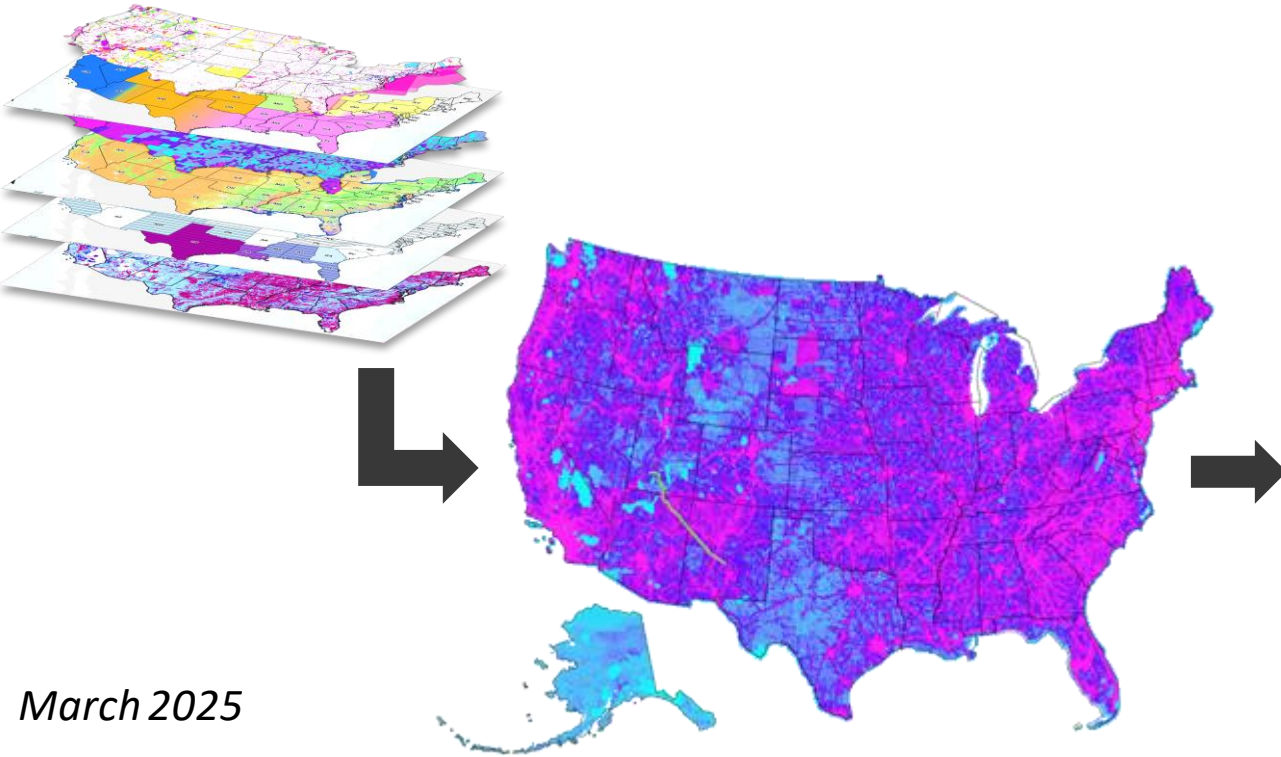
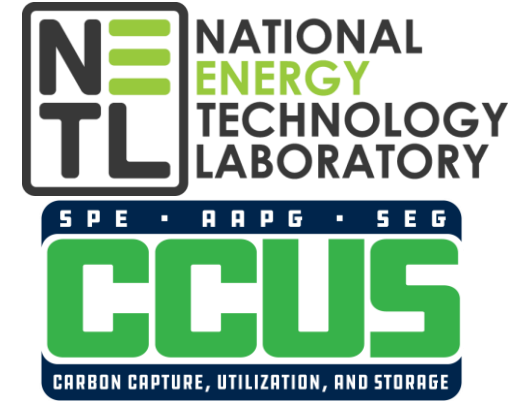


An Open-Source, ML-Informed, Geospatial-Driven Tool for Identifying & Evaluating CO₂ Transport Routes

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March 2025



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Meeting CTS Challenges with Smart and Spatial Solutions

Challenge

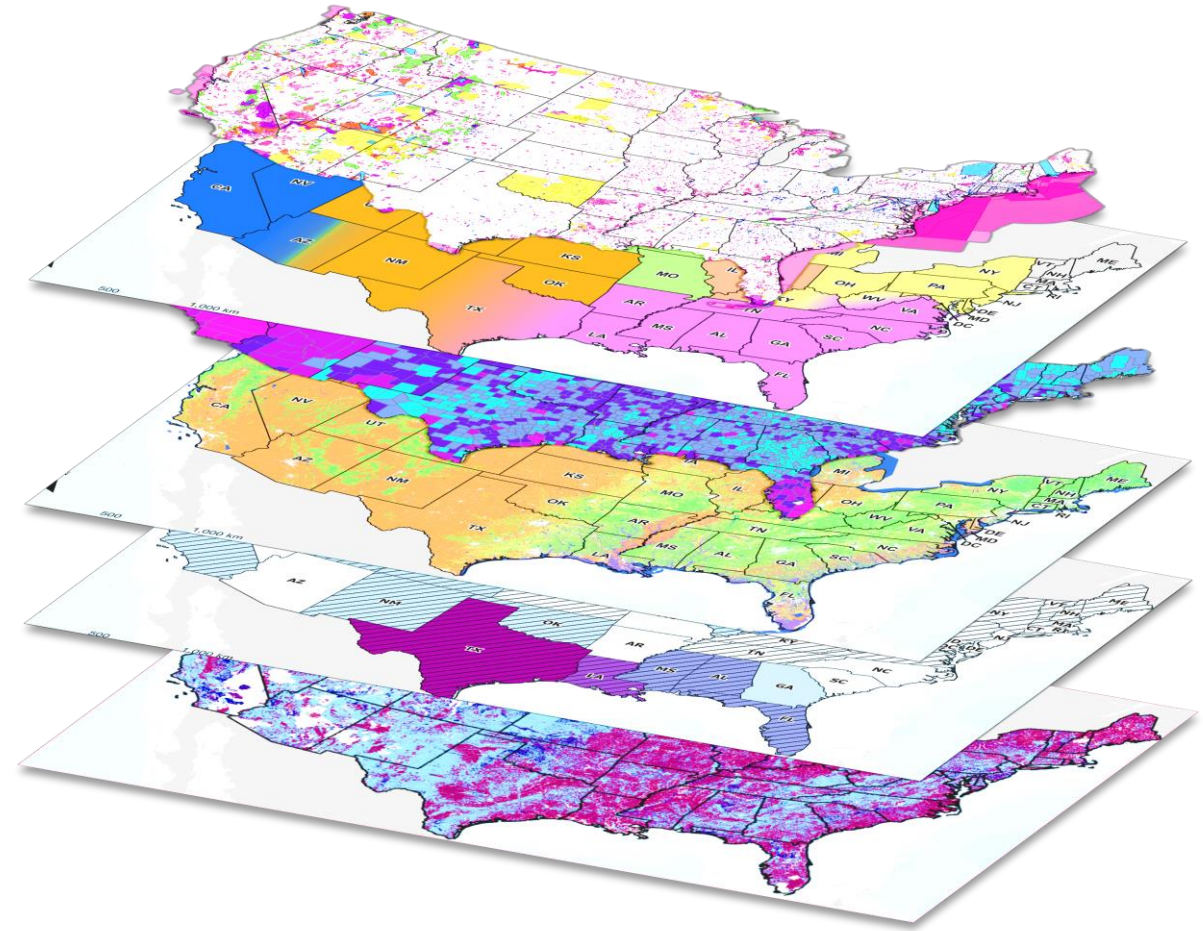
- The evolving energy transport landscape requires a **dynamic response**
- Many **complex and interconnected factors** can greatly affect the success of developing new transport and impact project costs
- Need for **evaluating existing transport corridors** for reuse

Solution



American
Petroleum
Institute

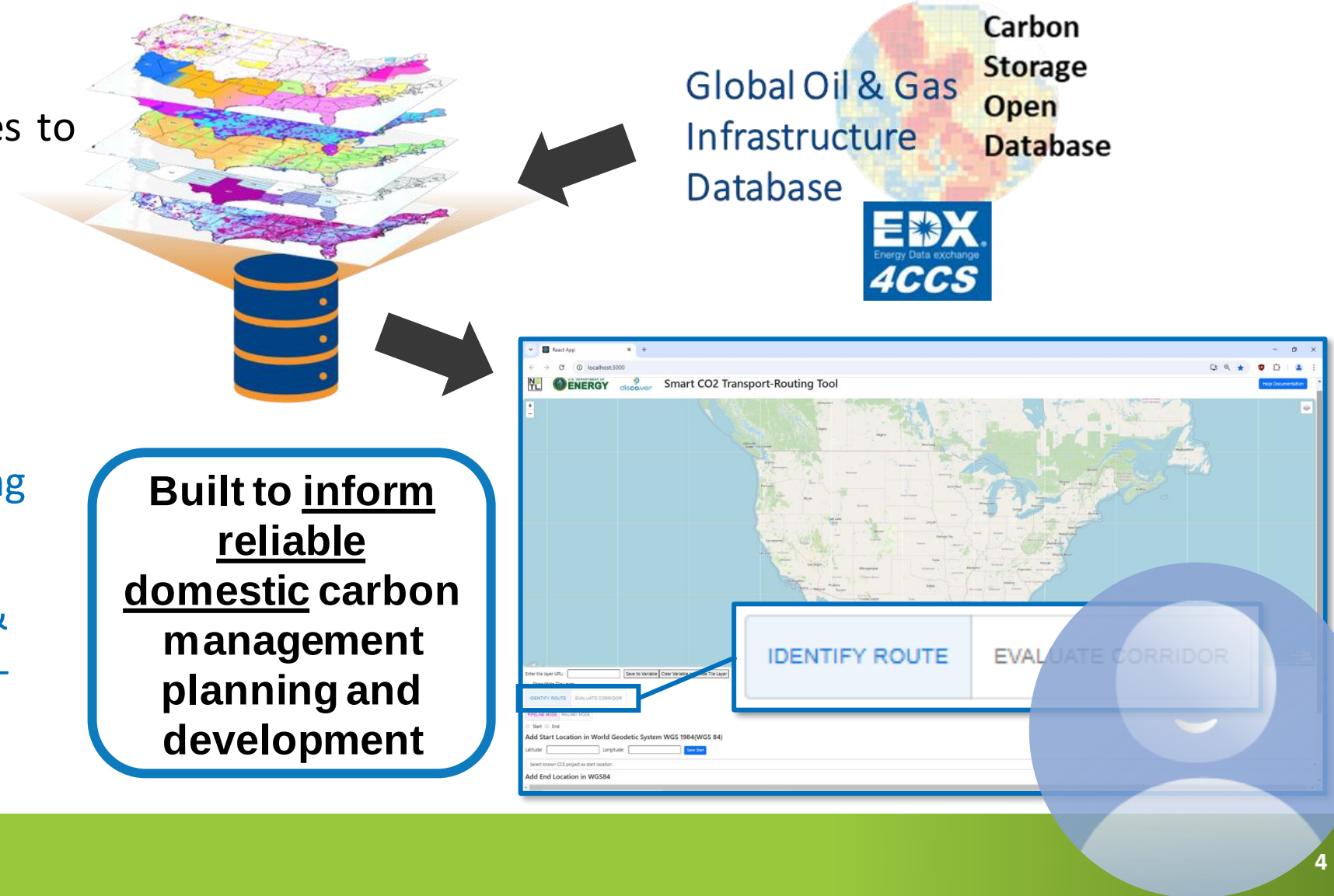
- **Interactive smart, geospatial tool** and database to assist route planning
- Accelerate carbon management development through a **multivariate, AI-informed algorithm**



Leveraging Data-Science, Geospatial Technologies & Competencies

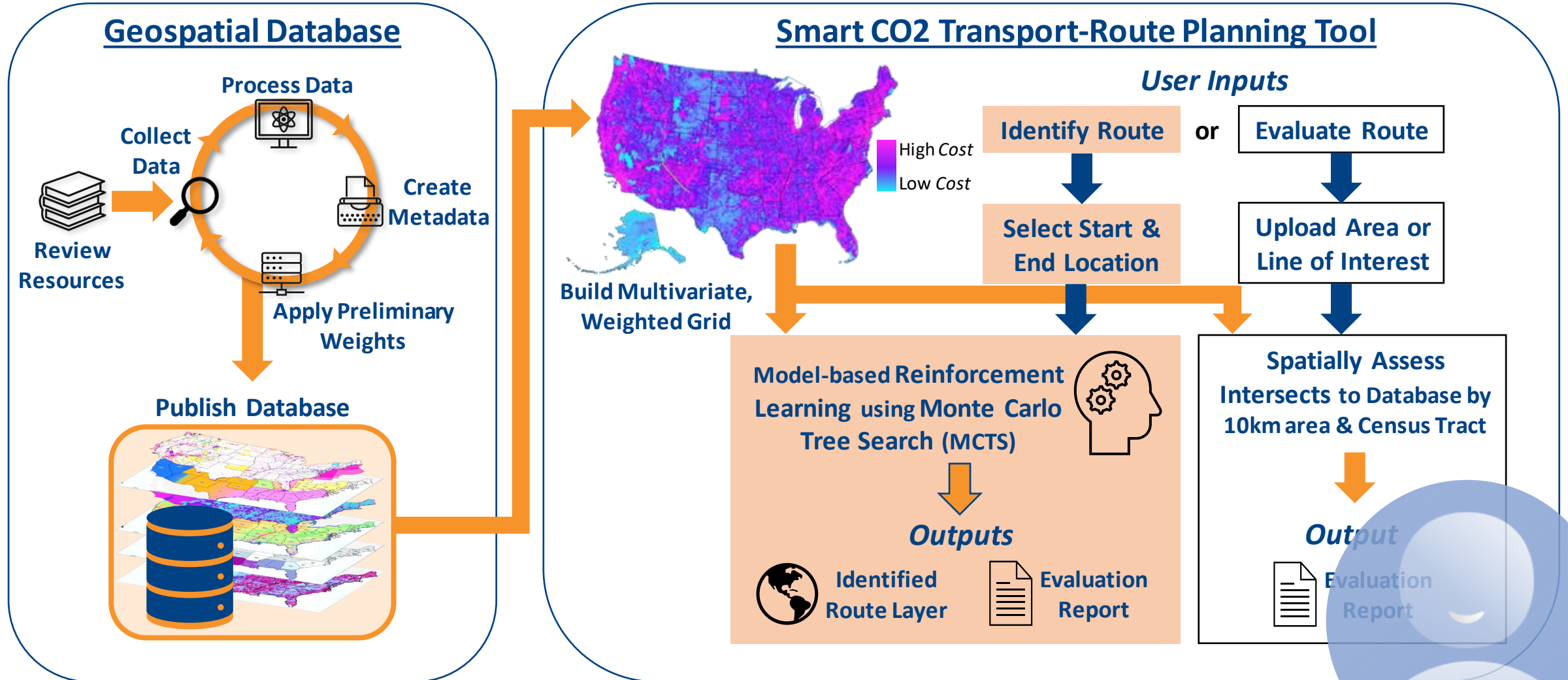
Objectives

1. Build-off existing resources to provide a **national comprehensive spatial database**
2. Integrate data and critical qualitative governance to **advance transport planning**
3. Enable stakeholders to **identify potential routes & evaluate existing rights-of-way**



Technical Workflow

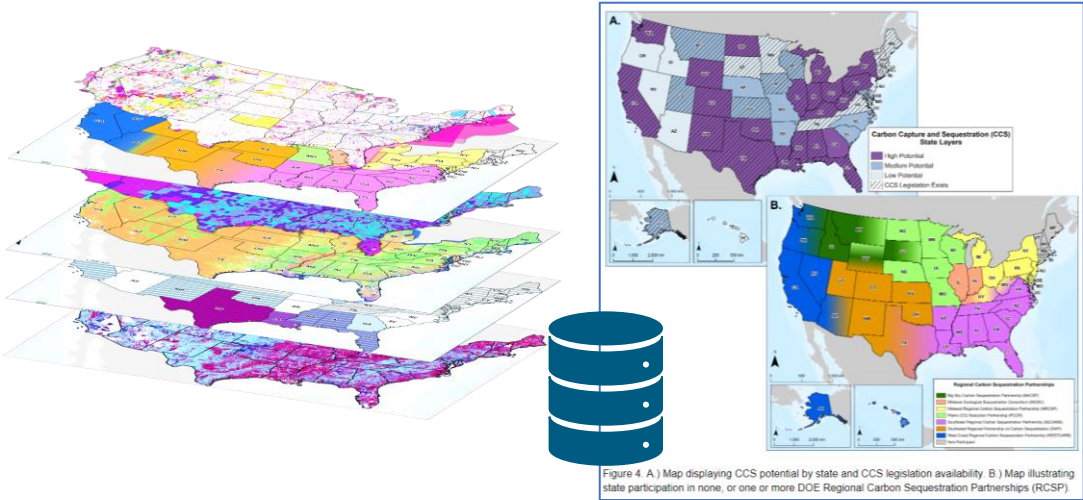
Built to Inform CTS Planning & Development



Carbon Transport Spatial Database



- Geospatial database
 - Version 1, 2023
 - Version 2, 2024
- 60+ weighted layers
- Metadata
 - Original sources
 - Weight definitions
- Publication available



Available on
EDX



Currently in Review – should be available soon!



Categories	Layer Examples
CCS by State	Restrictions & regulations
Boundaries	Protected areas, urban areas, buildings
Infrastructure	Pipelines, wells, roads
Natural Hazards	Floodplains, earthquake, wildfire, landslides
Hydrology	Lakes, rivers, aquifers, groundwater

Report of Spatial Insights from Database



Boundaries

Area Coverage by Land Type
(e.g., wetland, pasture, water)

Historic Sites Count and List

National Monument Area
Coverage

National Park Area
Coverage and List

Protected Area Coverage
and Local Designations

Counties

States

Tribally-Controlled Land
Area Coverage and List

Urban Area Coverage and
List

Wilderness Area Coverage

CCS by State

CO2 Emission in Million
Metric Tons by State

Count of CO2 Emission
Sources by State

Regulations Category by
State

Sum of Median Storage
Estimates by State

State CO2 Group
Involvement

**Easy to
adjust
variables!**

Hydrology

Area Coverage by Aquifer

Groundwater Monitoring
Count

National Hydrology Area
Coverage

National Hydrology
Waterbody Coverage

National Hydrology Well
Count

National Hydrology
Flowline Length

Active Sink Count

Active Source Count

Building Count

Infrastructure

High Consequence Area
Count

Hydrocarbon Pipeline
Length

Manufacturing Facility
Count

Natural Gas Pipeline
Length

Oil Gas Well Count

Port Count

Power Plant Count

Primary Road Length

Processing Plant Count

Natural Hazards

Railroad Length

Refinery Count

Secondary Road Length

Storage Count

Station Count

Landslide Susceptibility
Area Coverage (Very High)

FEMA NRI Risk Score

FEMA NRI Coastal Flood
Risk Score

FEMA NRI Resilience
Score

Coverage of Areas >30%
Grade Slope

FEMA NRI Earthquake
Risk Score

FEMA NRI Expected
Annual Loss Score

FEMA NRI Landslide Risk
Score

FEMA NRI Riverine Flood
Risk Score

FEMA NRI Social
Vulnerability Score

FEMA NRI Wildfire Risk
Score

FEMA NRI Earthquake
Risk Score

Area Coverage Soil Frost
Action Potential (Low,
Moderate, High)

Area Coverage of Soil
Steel Corrosion Potential
(Low, Moderate, High)

Smart CO₂ Transport-Route Planning Tool



- **Alpha version** (Leveckis et al. 2024)
- Open-source & stand-alone
- Utilizes Monte Carlo Tree Search

EDX connects to GitHub –
We welcome feedback!

Available on
EDX



- Model-based Reinforcement Learning
- Heuristic algorithm -
‘near optimal’ solutions

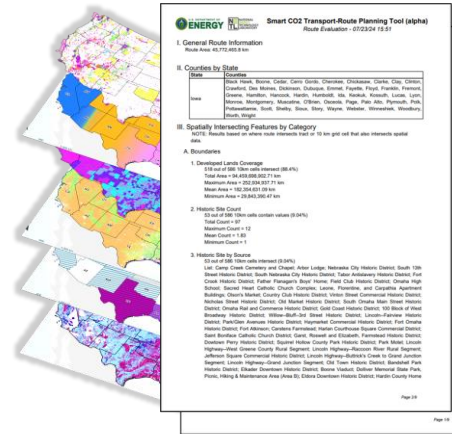
Help documentation

*Outputs spatial
data and report*

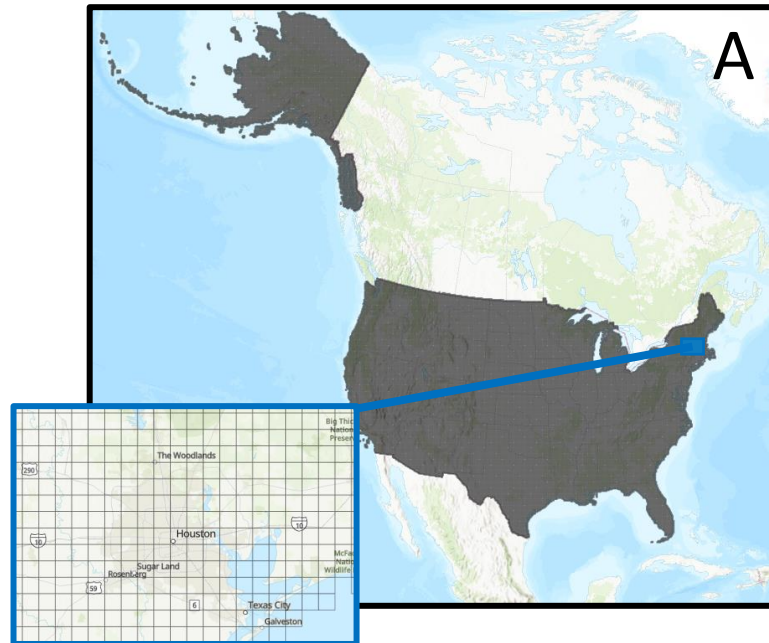
Output Reports

PDF Includes:

- Table of contents
- Line length or polygon area evaluated
- States and Counties crossed
- For each of the **60+ spatial layers**:
 - **Number, percent, and area** of cells and Census Tracts intersected
 - **Statistics** for scored values (e.g., National Risk Index maximum, mean, minimum)
 - Lists of **historical sites, protected areas, and urban areas that also intersect cells**



Provides insights by *spatial intersections* against *geodatabase layers* joined to
(A) 10km multivariate grid or
(B) Census Tracts (where applicable)

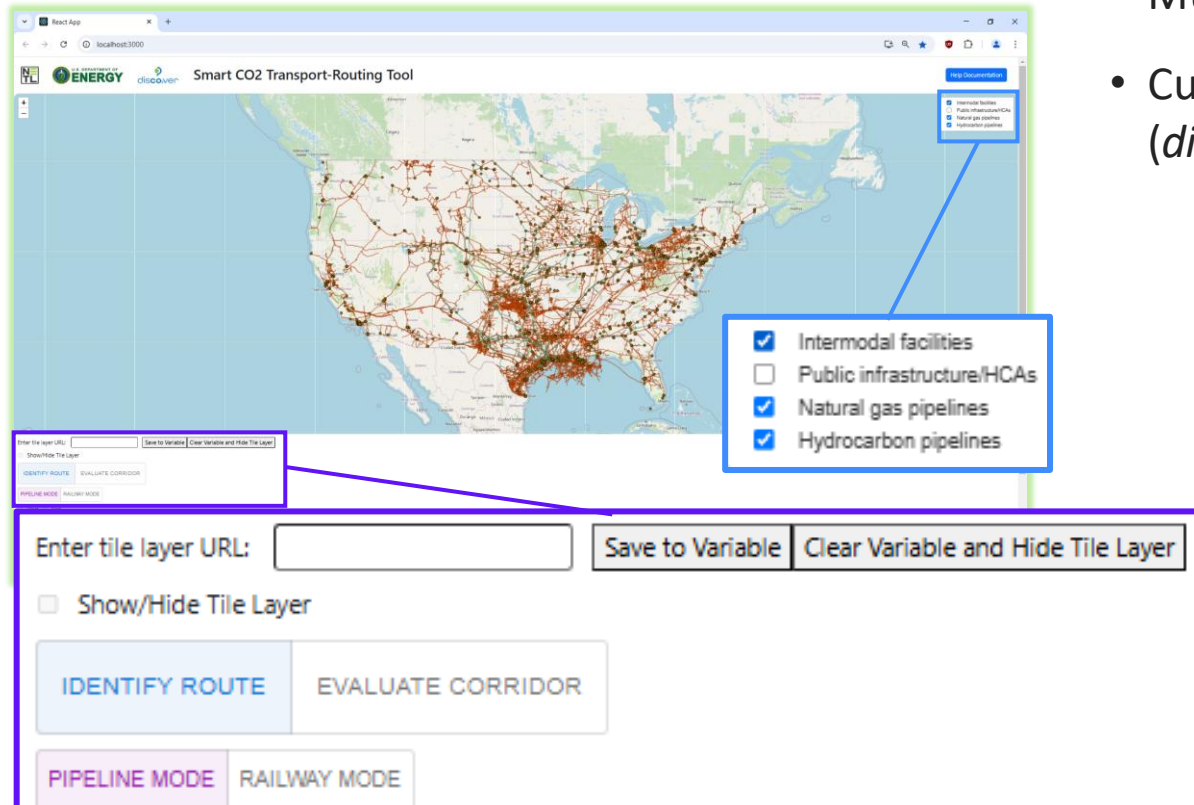


Updates & Enhancements

Beta Version Release Anticipated Spring 2025

Updated user interface & database

- View key layers in map
- Revised database

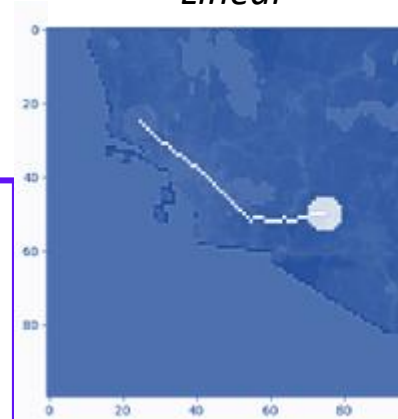


Implemented capabilities

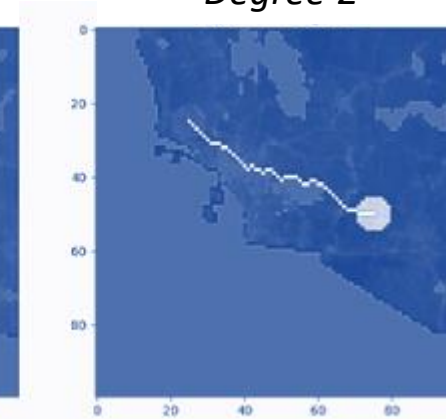
- Intermodal functionality
- Multiprocessing support
- Customize agent behavior (*distance vs cost*)



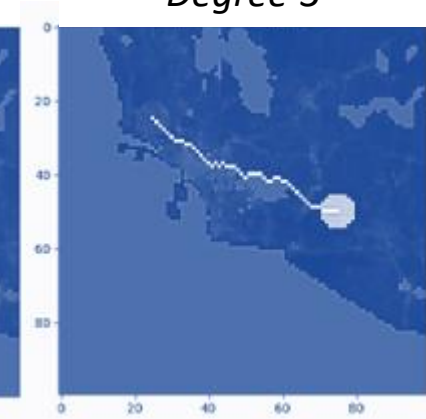
Linear



Exponential
Degree 2



Exponential
Degree 3



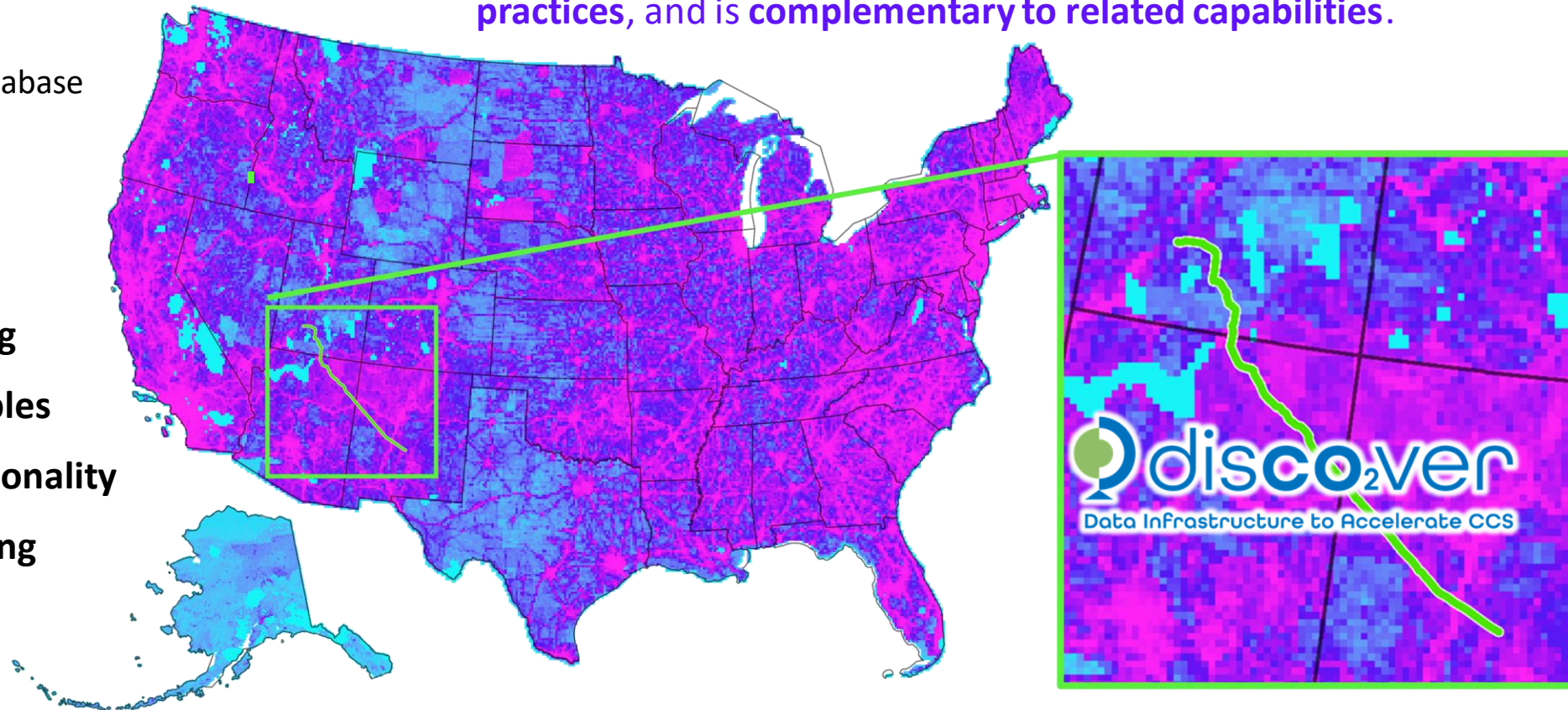
Increasing Useability & Usefulness

Next Steps

- **Version 2** (Anticipated Spring 2025)
 - + rail mode
 - + updated geospatial database
 - + view data in UI
 - + enhanced smart logic
- Enable **dynamic weighting**
- Add more **mapped variables**
- Expand **intermodal functionality**
- Support **dynamic weighting**
- Decrease **run times**

Valued Delivered

Interactive, stand-alone, geospatial tool designed to accelerate CO₂ transport route planning that accounts for legislation, best practices, and is complementary to related capabilities.



DOE CO₂ Transport Toolbox

X Currently supports

/ In progress

- Not in current scope

	Build for...	Supports...	Tool is...				Analytics apply...					Variables include...							Baseline Data Published	Outputs Include
			Open-Source	Stand-alone	Spatial	Temporal	AI/ML	Multi-scale	Multi-modal	Multi-stops	Phase-based	Land Use	Energy infrastructure	Public infrastructure	Economic	Community	Metrics	Risk Likelihood		
CO ₂ Transport Cost Model	Industry, regulators, researchers (government, academic, non-profit)	Estimating the cost of new CO ₂ pipelines	X	X	X	X	-	X	-	-	-	-	X	X	X	-	/	-	-	Pipeline diameter, number of pumps, cash flows, NPV, break-even CO ₂ price
SimCCS Pipeline Network Model		Transport network modeling and cost analysis	X	-	X	X	-	X	X	X	X	X	X	X	X	X	-	-	-	Optimal network; costs for capture, transport, and storage
Smart CO ₂ Transport-Route Planning Tool		Inform planning, development, and repurposing; risk assessments	X	X	X	-	X	X	X	-	-	X	X	X	X	X	X	X	X	Optimal network as spatial layer; report of route evaluation against variables

NETL RESOURCES

*Thank
you!*

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