SimCCS$^{3.0}$: An Open-source Toolset for Regional CCS Infrastructure Decision Support

FE-1207-20-FY21

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LA-UR-22-28397

U.S. Department of Energy

National Energy Technology Laboratory
Carbon Management Project Review Meeting
August 15 - 19, 2022

Project Scope

– Produce a toolset that can be utilized by a range of users to help address emerging CCUS infrastructure deployment challenges including,

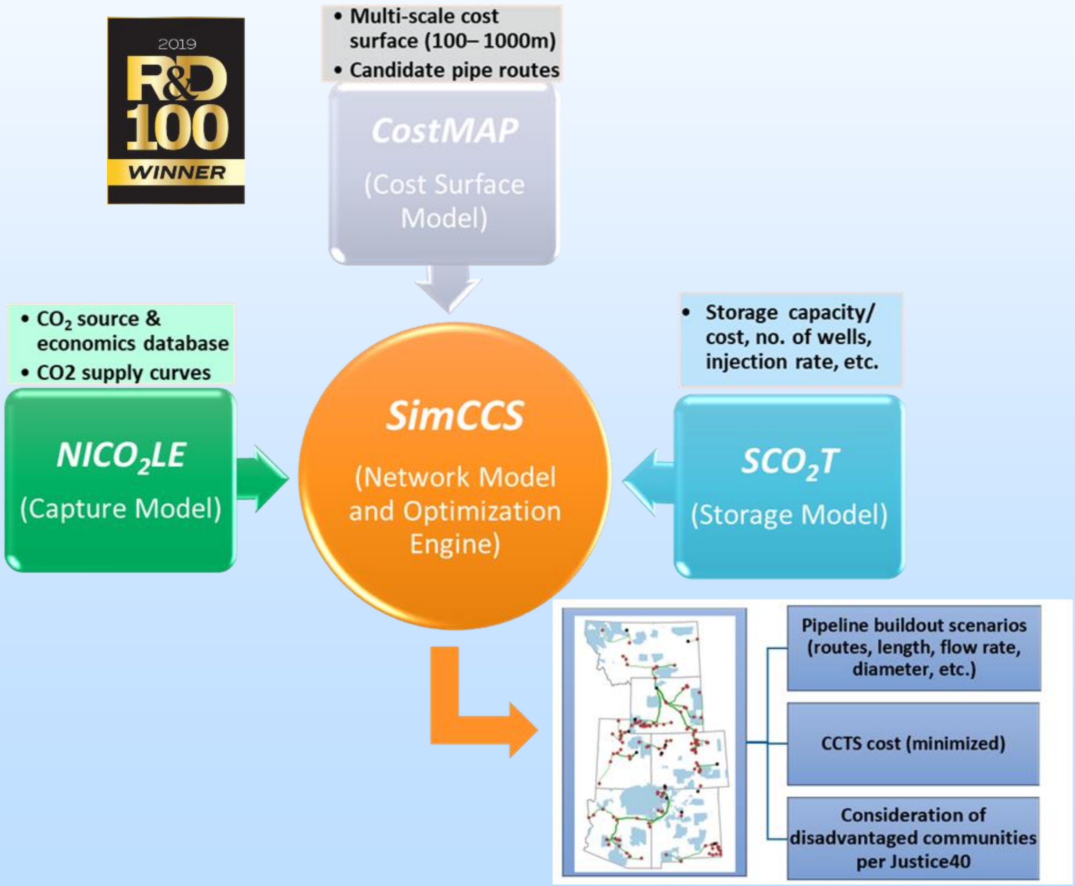
- National-scale, regional-scale deployment
- Phased deployment
- Account for disadvantaged communities per Justice40 initiative
- Account for environmentally sensitive areas
- Dynamic nature of future CO_2 capture (decommissioning of sources, new sources, variable capture amounts)
- Potential utilization of existing CO_2 pipelines

Project Participants

- LANL: Martin Ma, Richard Pratt, Mengmeng, Daniel Livingston, Shriram Srinivansan, Rajesh Pawar
- Resources for the Future (RFF): Alan Krupnick, Shih-Shyang Shih, Alexandra Thompson

Technology Background

– *SimCCS* can help determine optimal, regional network of CO_2 sources, CO_2 sinks and CO_2 transport infrastructure that meet desired CCS goals



- ***$NICO_2LE$***
  - ➢ Understand commercial-scale capture opportunities.
  - ➢ Geodatabase: Source locations, CO_2 streams, & capture costs.
- ***SCO_2T***
  - ➢ Rapidly calculate realistic injection & storage & costs.
- ***CostMAP***
  - ➢ Identify likely corridors.
  - ➢ Develop candidate pipeline routes for *SimCCS* optimization engine.

SimCCS is publicly available @ https://simccs.lanl.gov/

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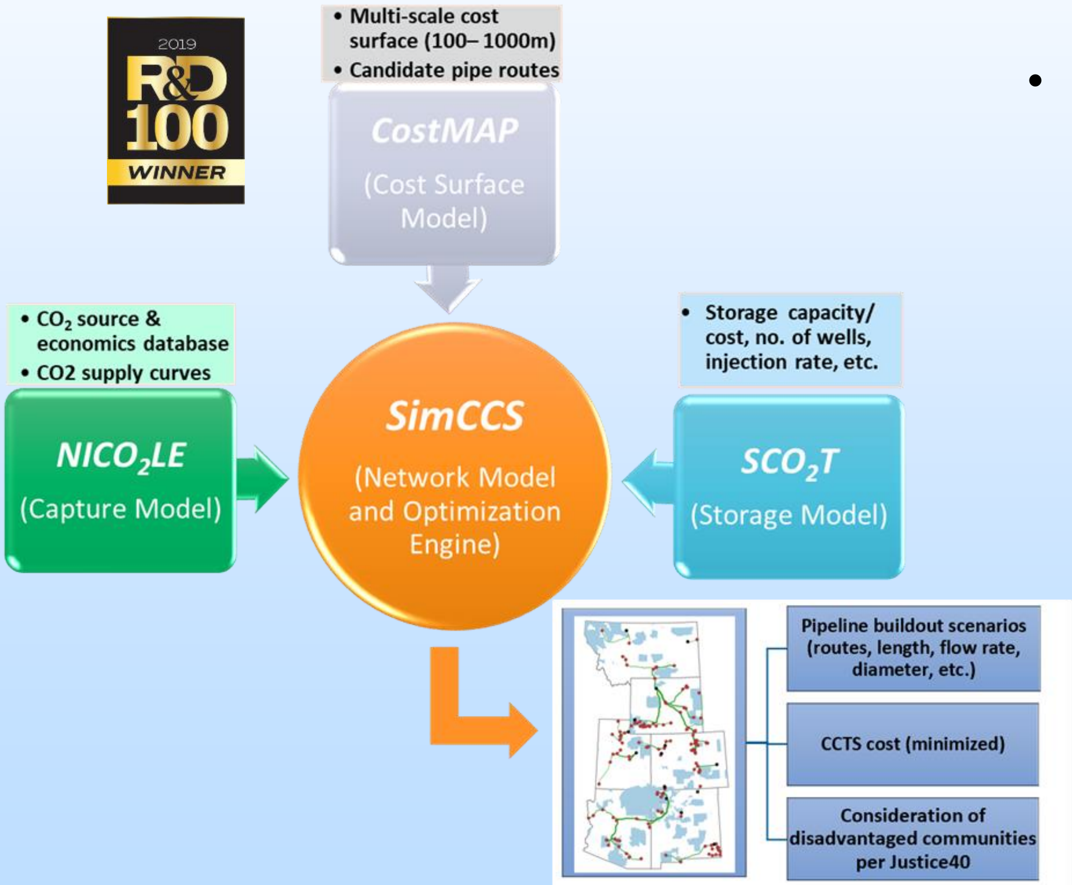
– *SimCCS* can help determine optimal, regional network of CO_2 sources, CO_2 sinks and CO_2 transport infrastructure that meet desired CCS goals



- LANL is utilizing *SimCCS* to support infrastructure modeling:
  - ➢ National scale CCS pipeline network modeling
  - ➢ Three regional CCUS initiatives (CUSP, SECARB-USA, MRCI)
  - ➢ One energy transition initiative (I-WEST)
  - ➢ SJB-CarbonSAFE

SimCCS is publicly available @ https://simccs.lanl.gov/

Major FY22 Accomplishments

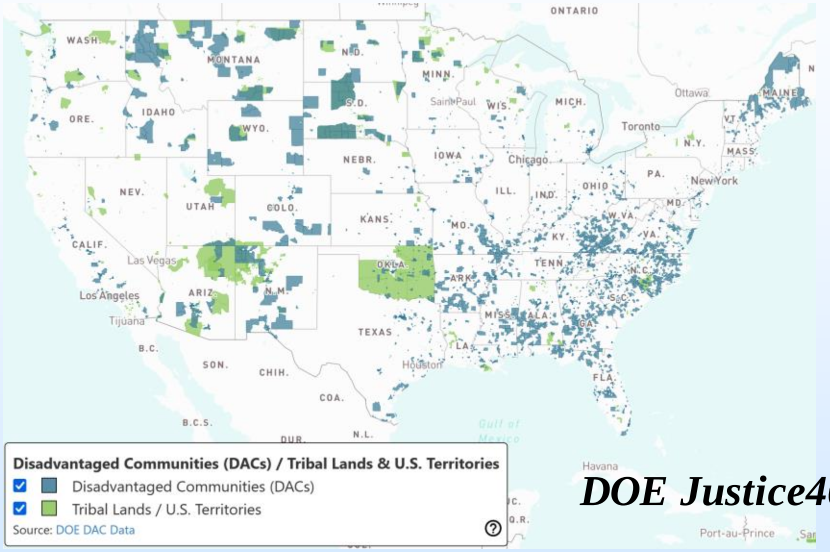
- Released new version of *SCO_2T* (python-based) to take into account monitoring and PISC costs
- Released new version *CostMAP* code
  - Multi-scale cost surfaces (100 m & 1000 m resolution) using the latest GIS data are available for public use
- Incorporated environmental & social impacts in CO_2 pipeline transport network modeling
- Updated publicly available code *$SimCCS^{2.0}$* to *$SimCCS^{3.0}$*
  - Phase-based modeling capability
  - Consideration of existing CO_2 pipelines
- Major applications include national scale CCS deployment modeling, regional scale CCS deployment modeling (I-WEST)

Technical Progress

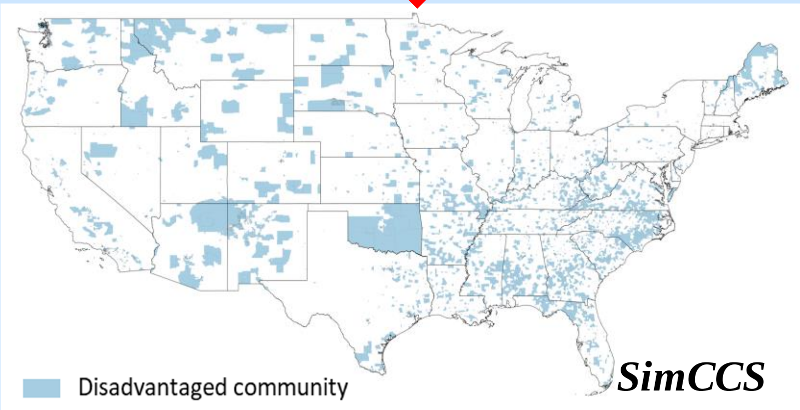
Accounting for Disadvantaged Communities in Network Modeling

- **Objective**: Adding capabilities to *SimCCS* modeling framework that incorporates disadvantaged community (DC) impacts on CO_2 pipeline routes.

- **Major accomplishments**:
  - Updated *CostMAP* GUI/code and generated cost surface with DC GIS layer
  - Applications: national scale CCS pipeline network modeling, I-WEST, CUSP, SECARB-USA, and MRCI



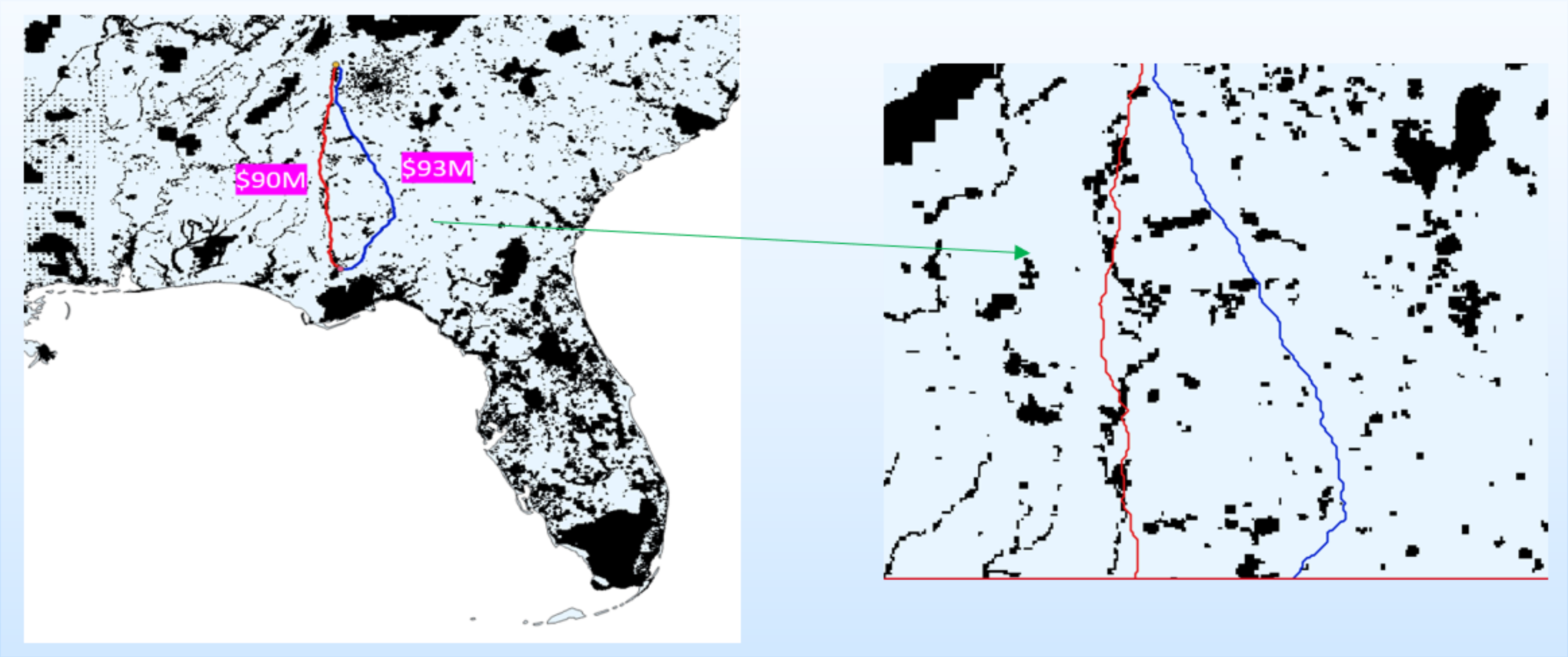
DOE Justice40



SimCCS

Impact of Environmentally Sensitive Lands (Protected Areas, Parks, Critical Habitats) on Routing

– Optimal paths with (blue) and without (red) considering environmentally sensitive layers

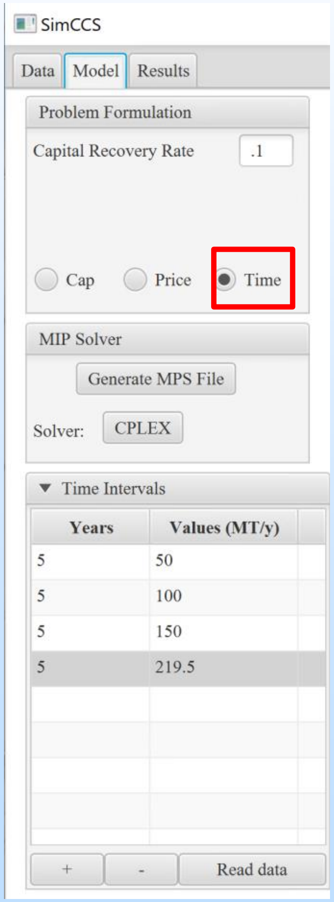


- Blue optimal path significantly avoids environmentally sensitive areas.
- Increase pipeline development cost to avoid environmental impacts.

Phase-based CCS Infrastructure Deployment Modeling

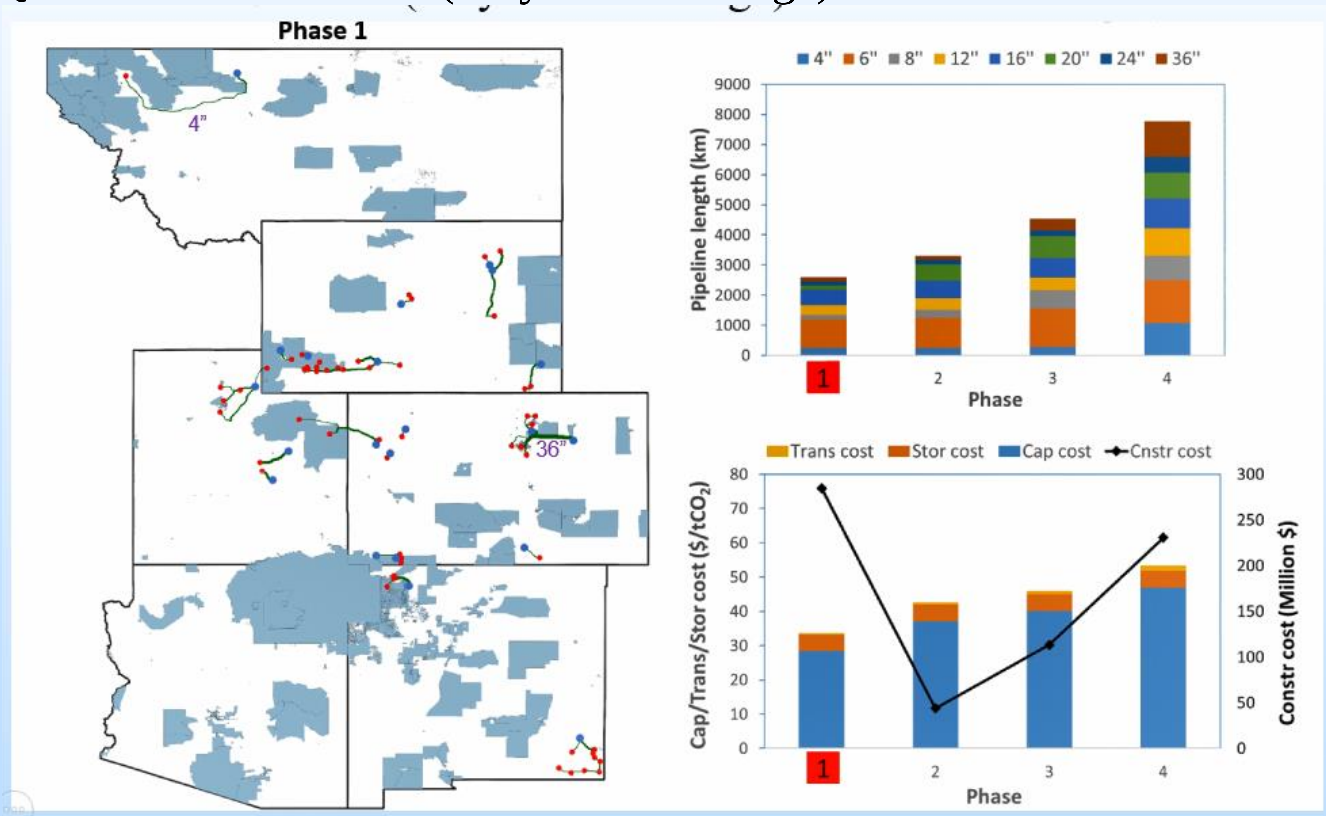
– Integrated temporal model (time mode) into the main code – *SimCCS*$^{3.0}$

- Used for scenarios where things change over time
  - ➢ Dynamic nature of future CO_2 capture (decommissioning of sources, new sources, variable capture amounts)
  - ➢ 45Q tax credit
- Dynamically construct infrastructure over time
- Project period is broken up into a number of phases and each phase has its own set of cost and capacity parameters



Phase-based CCS Infrastructure Deployment Modeling

– Phased CCS infrastructure buildout – I-WEST as an example
  - Incremental CO_2 capture to meet net-zero emissions by 2050
  - Pipelines do not cross disadvantaged communities
  - 45Q tax credits - $50/ton (only saline storage)



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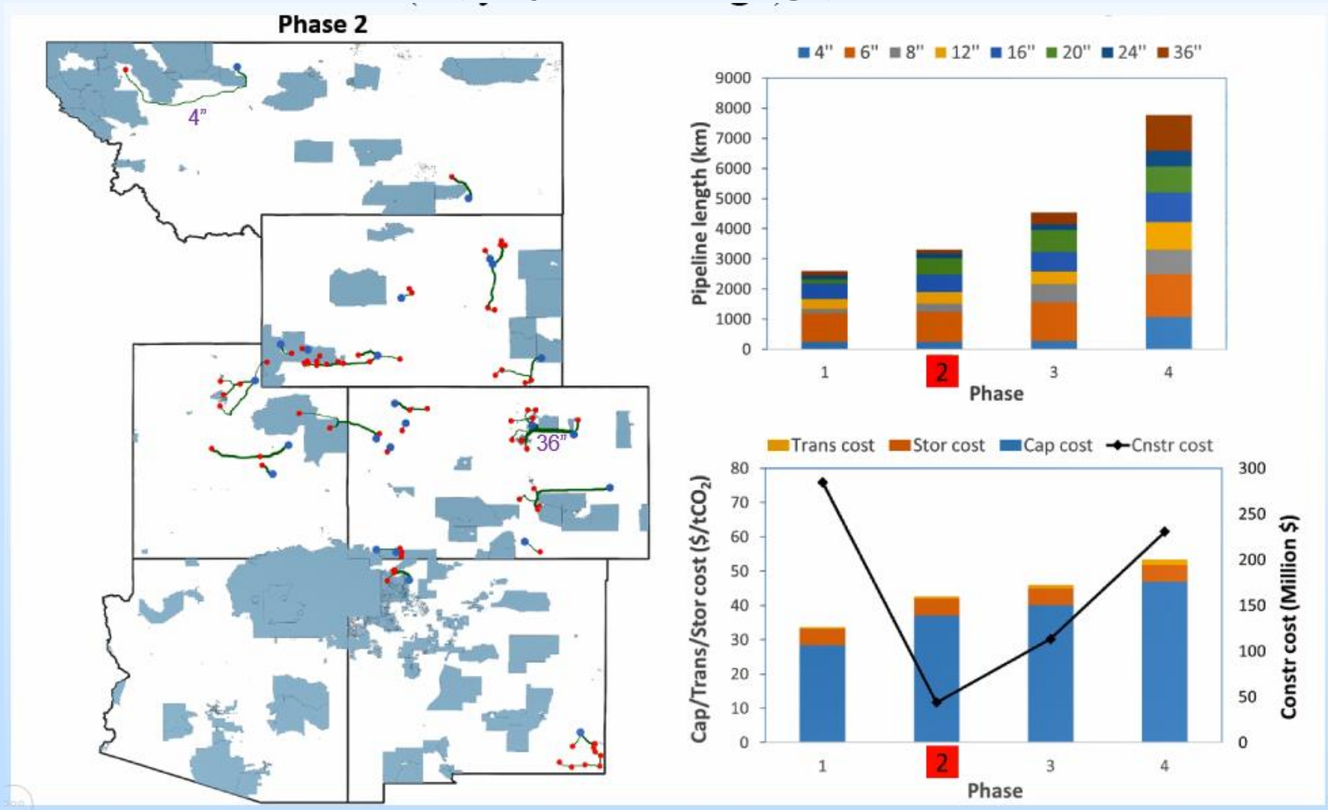

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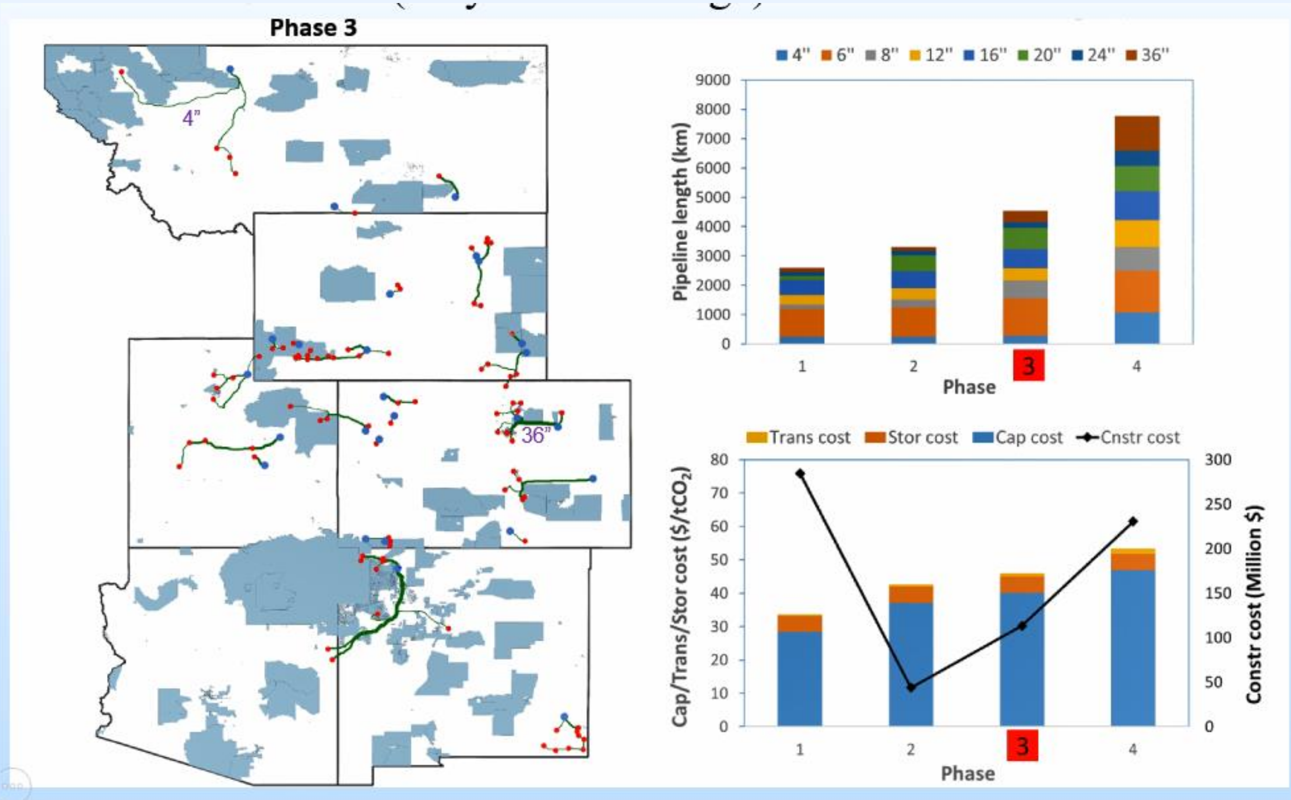

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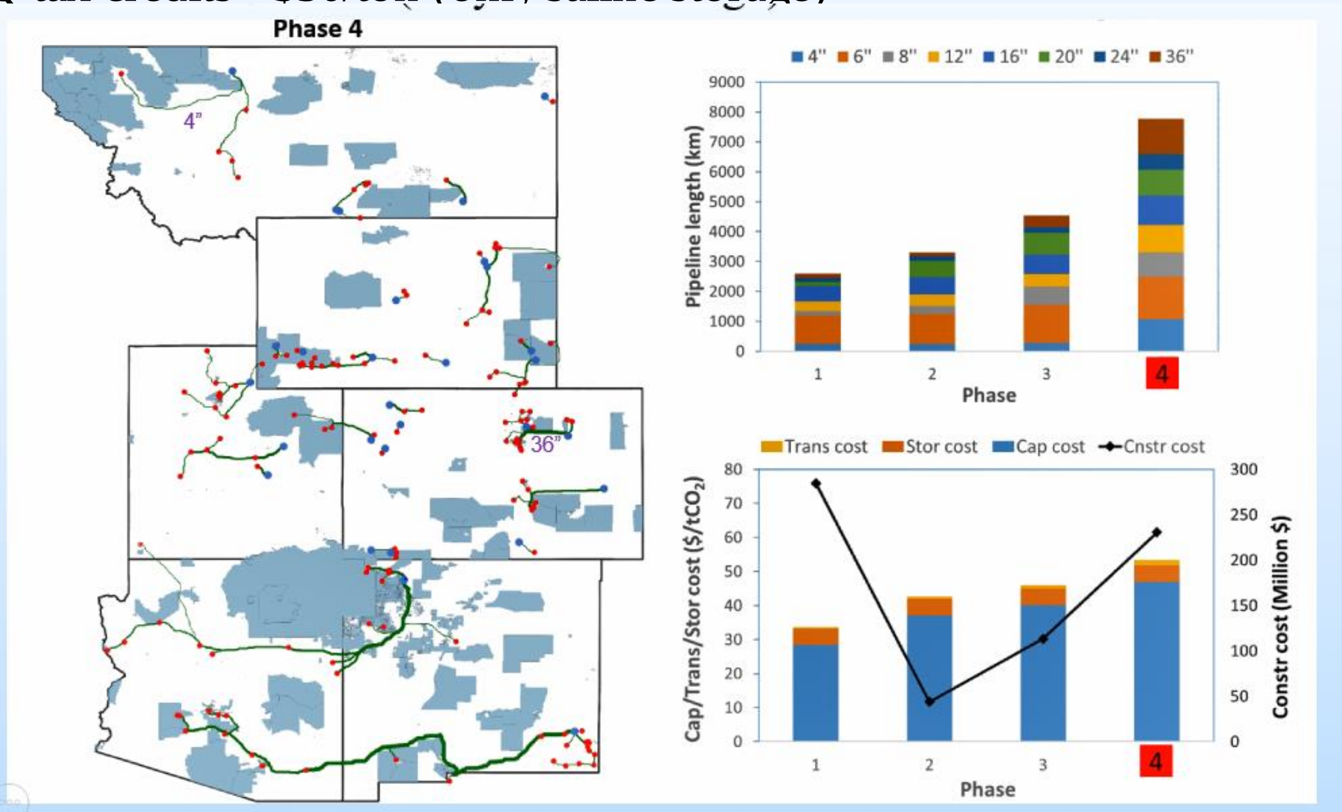
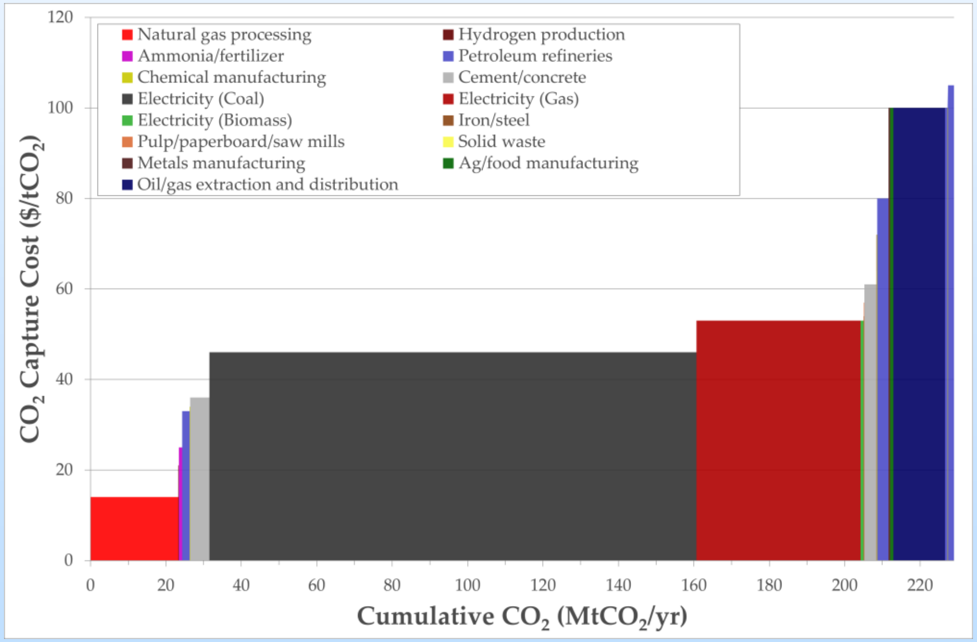
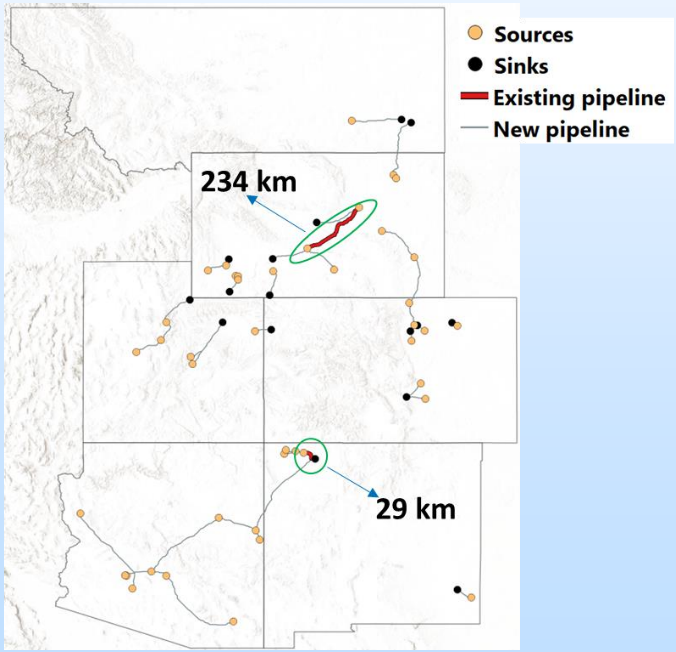


Technical Progress - Others

- Updated database for *SimCCS*' capture model – *NICO$_2$LE*
- Consideration of existing CO_2 pipelines in modeling
- Dynamic 45Q tax credit

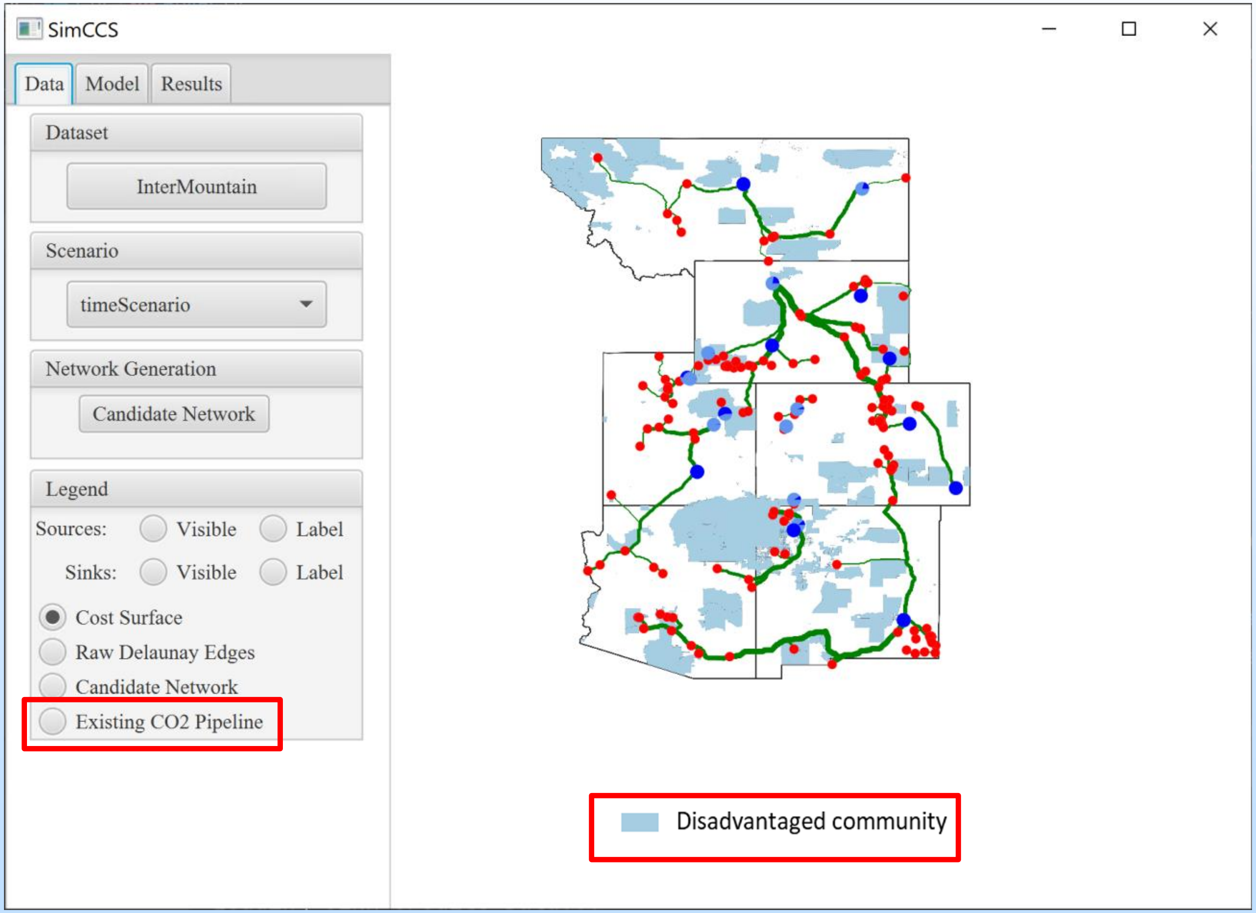


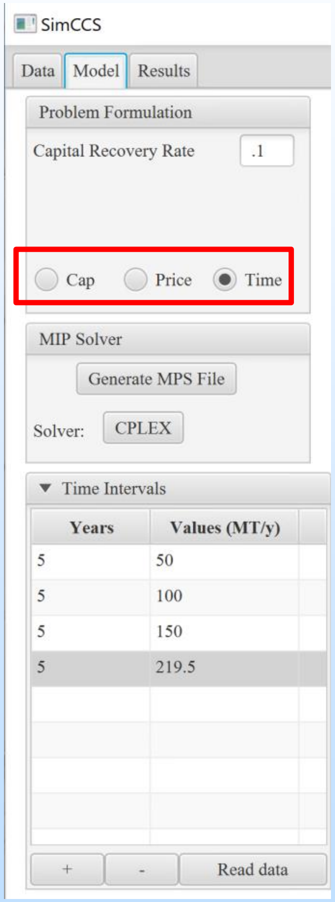
I-WEST CO_2 supply curve (output from *NICO$_2$LE*)



Utilization of existing CO_2 pipeline (I-WEST as an example)

SimCCS$^{3.0}$ User Interface



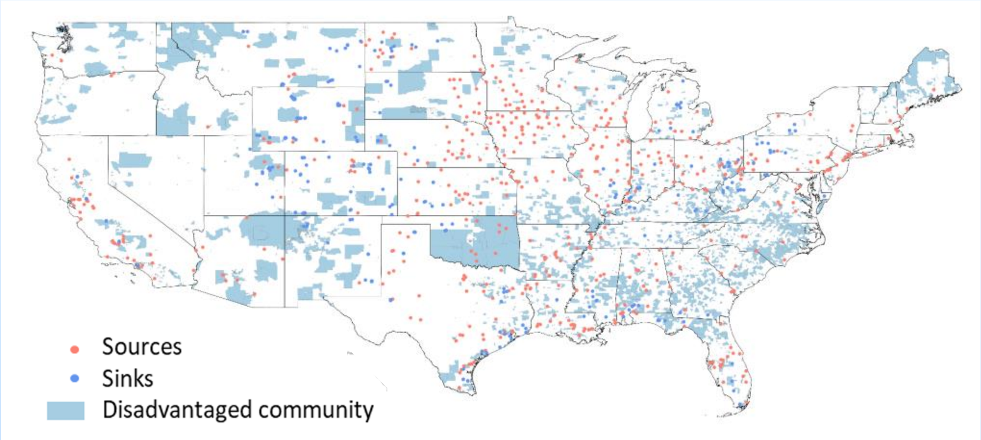


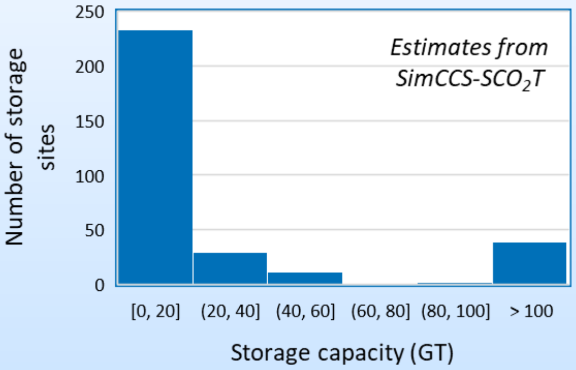
Application: National Scale CCS Pipeline Network Modeling

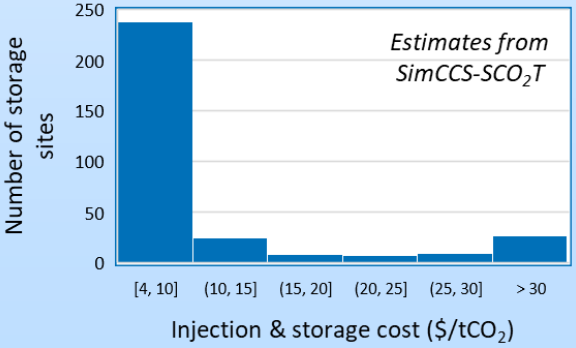
- **Objective**: Use *SimCCS* platform to understand potential national scale CCS infrastructure deployment scenarios
- In coordination with DOE-FECM
- In collaboration with OnLocation Inc.

Scenario: Climate Goals

- Net Zero GHG emissions by 2050 via the use of economy-wide Cap-and-Trade constraint
- Zero carbon power sector by 2035, includes abatement by use of Direct Air Capture offsets.
- Inclusion of natural gas indirect emissions by region in carbon cap; regionality and emission factors to be provided by FE-261.







- 671 regional point sources
- Yearly captured CO_2 amounts vary over a 26-year period (up to 2050)
- 314 geologic sinks – saline formations only (NATCARB)

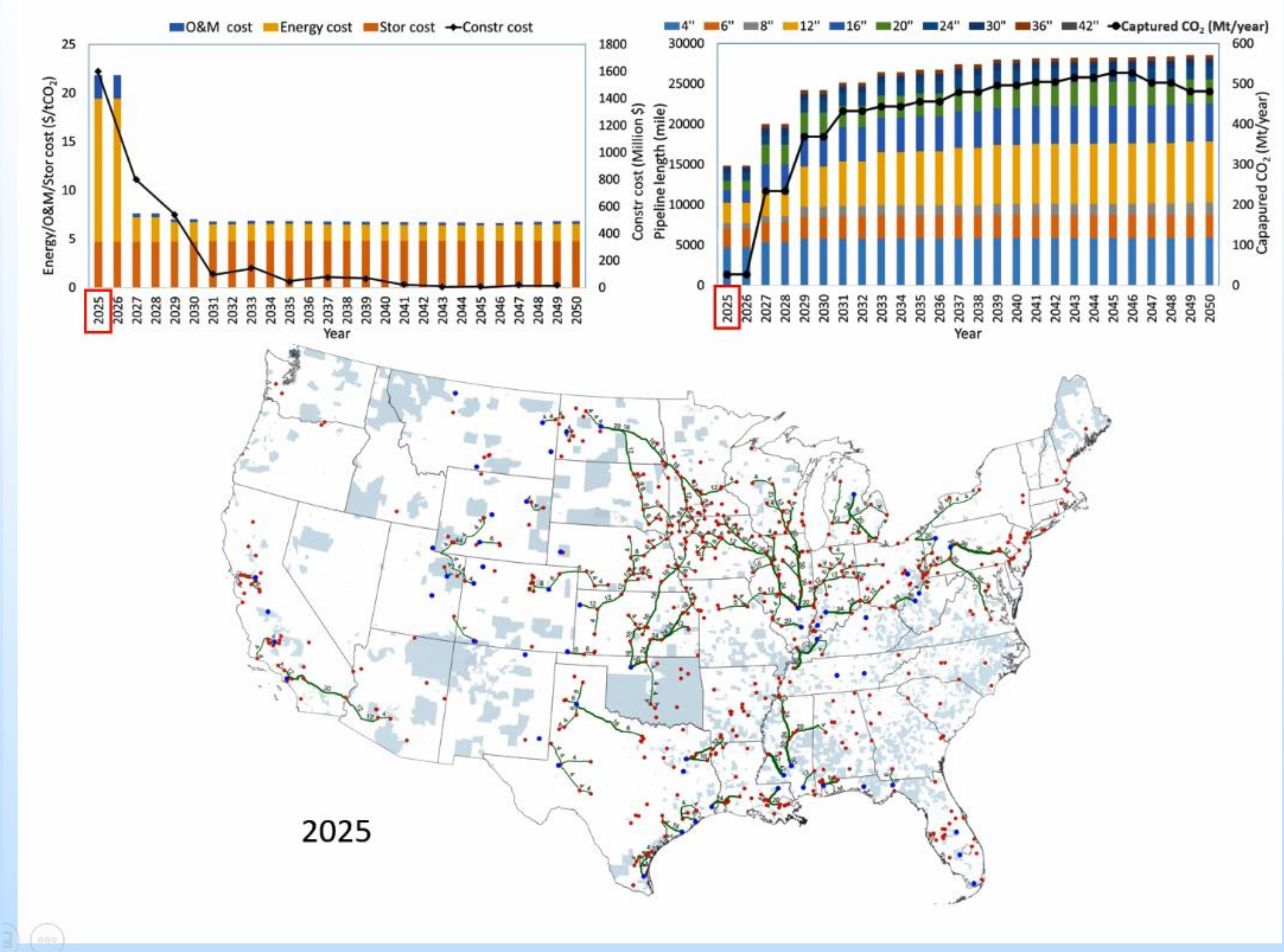
Case Studies

– Case 1: Pipelines do not cross DCs (Disadvantaged Communities)

– Case 2: Pipeline can cross DCs

– Case 3: Pipeline do not cross DCs and existing CO_2 pipelines are utilized where possible

Case 1: Pipelines do not cross DCs



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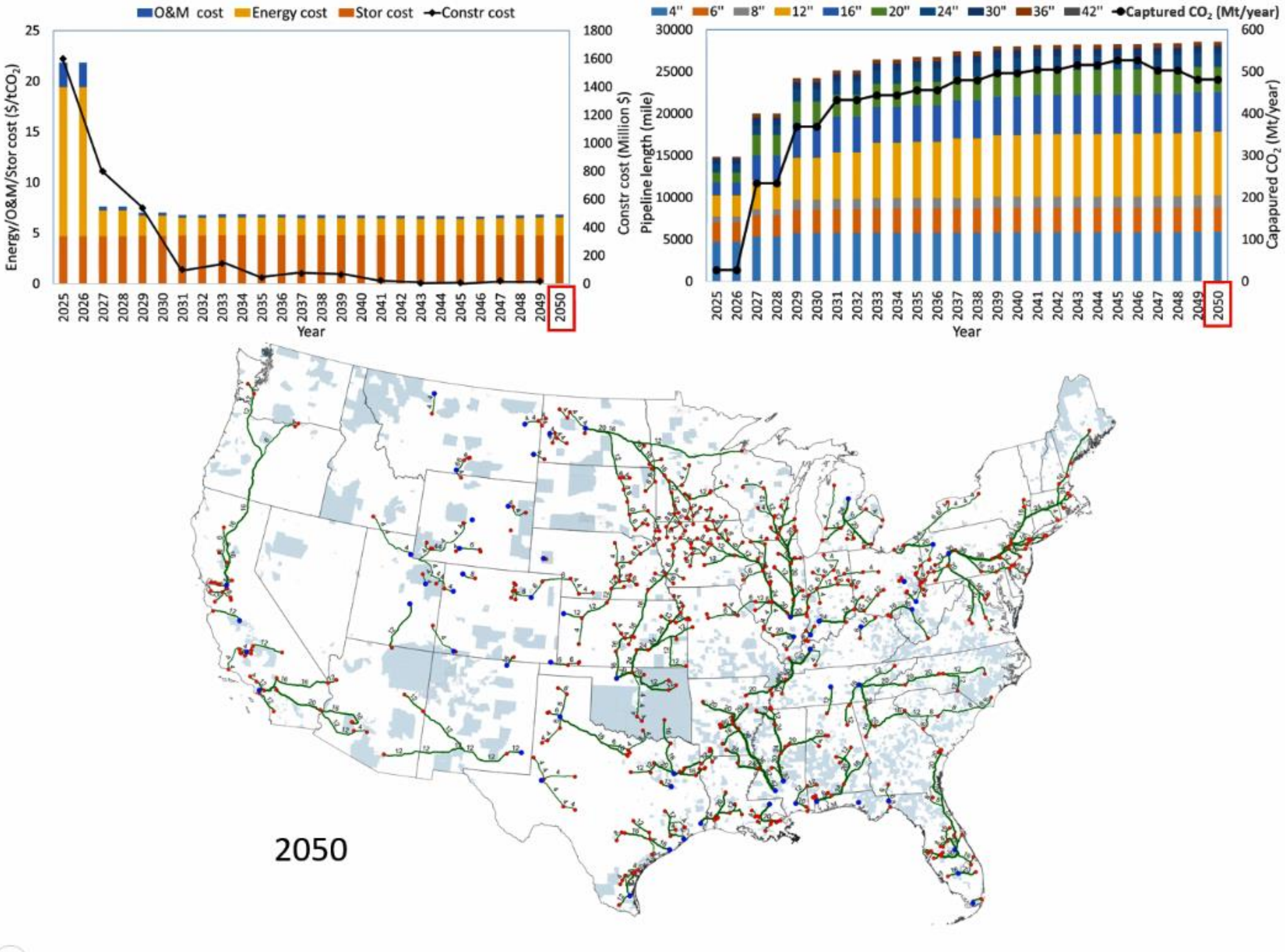

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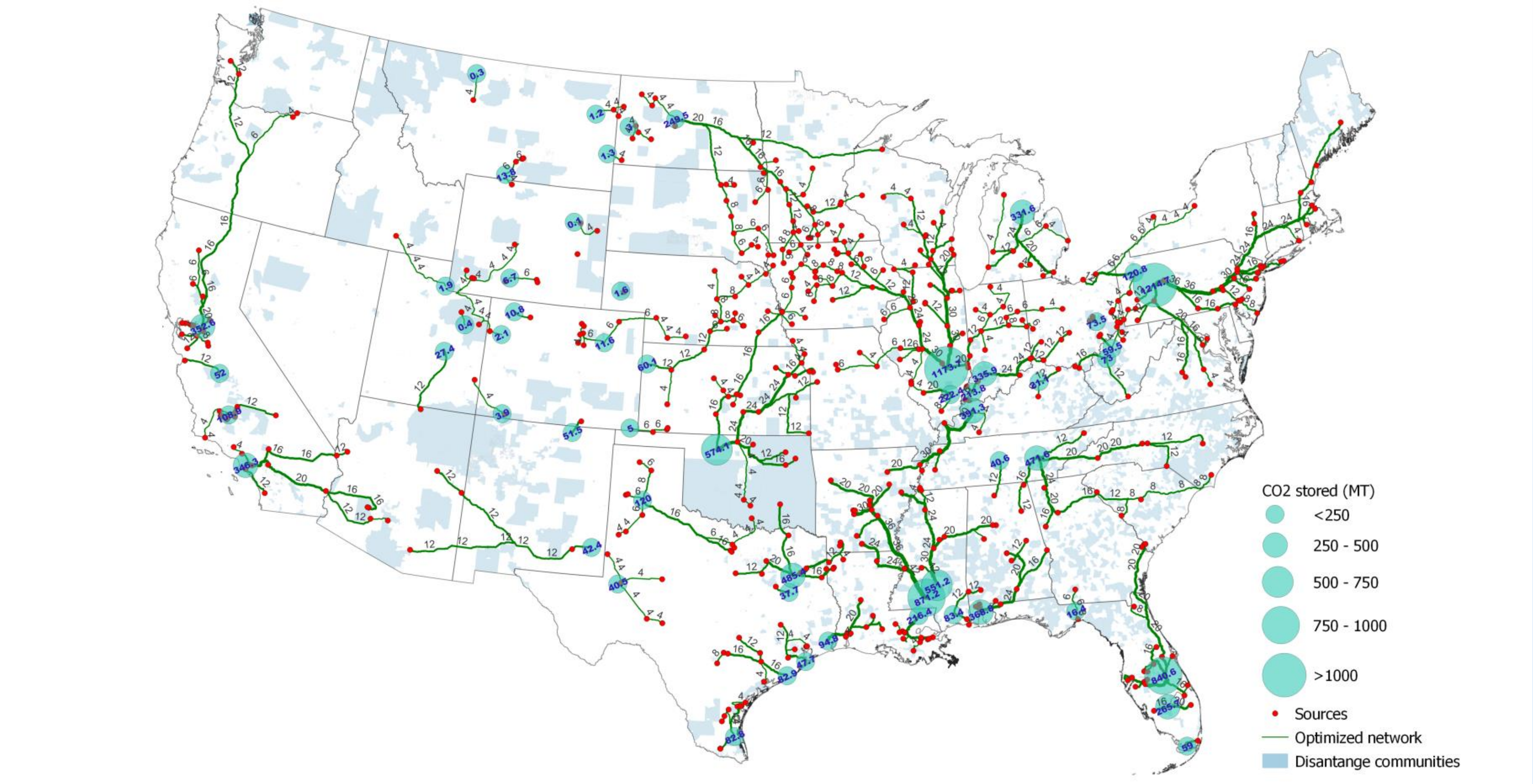
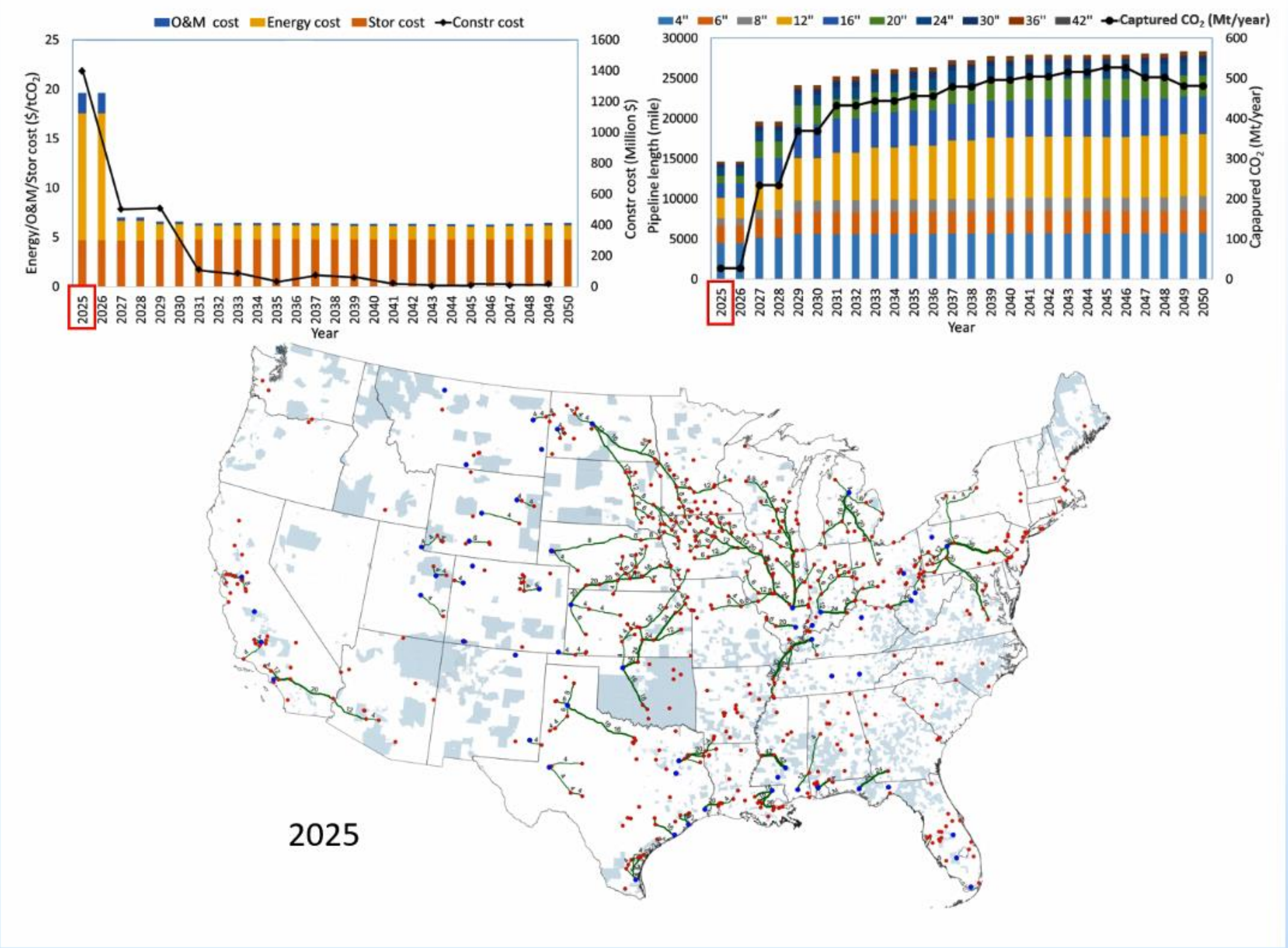


- Total pipeline length: 28,547 miles
  - By 2035: 26,704 miles (93.5%)

Case 2: Pipelines can cross DCs



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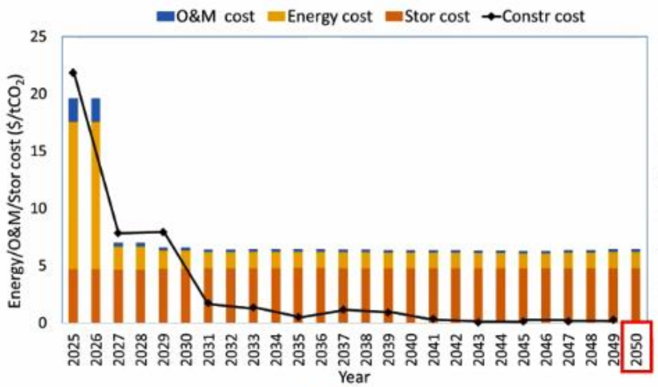

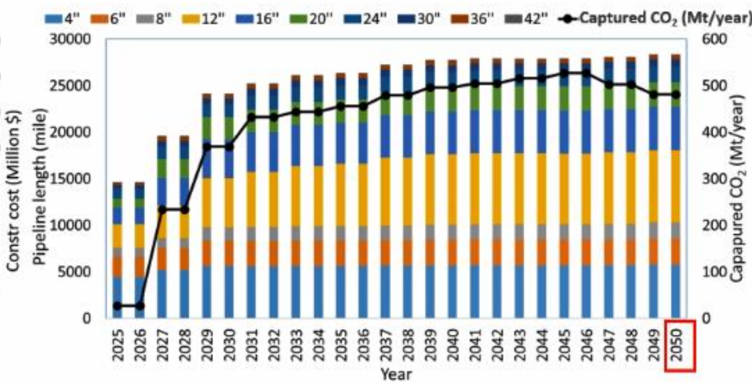

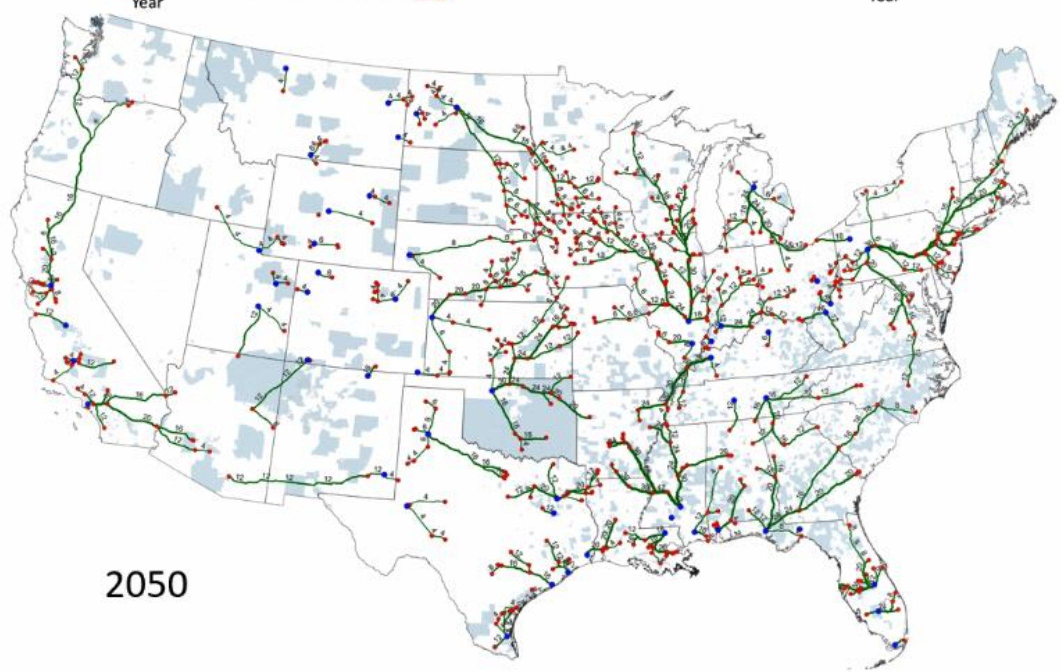

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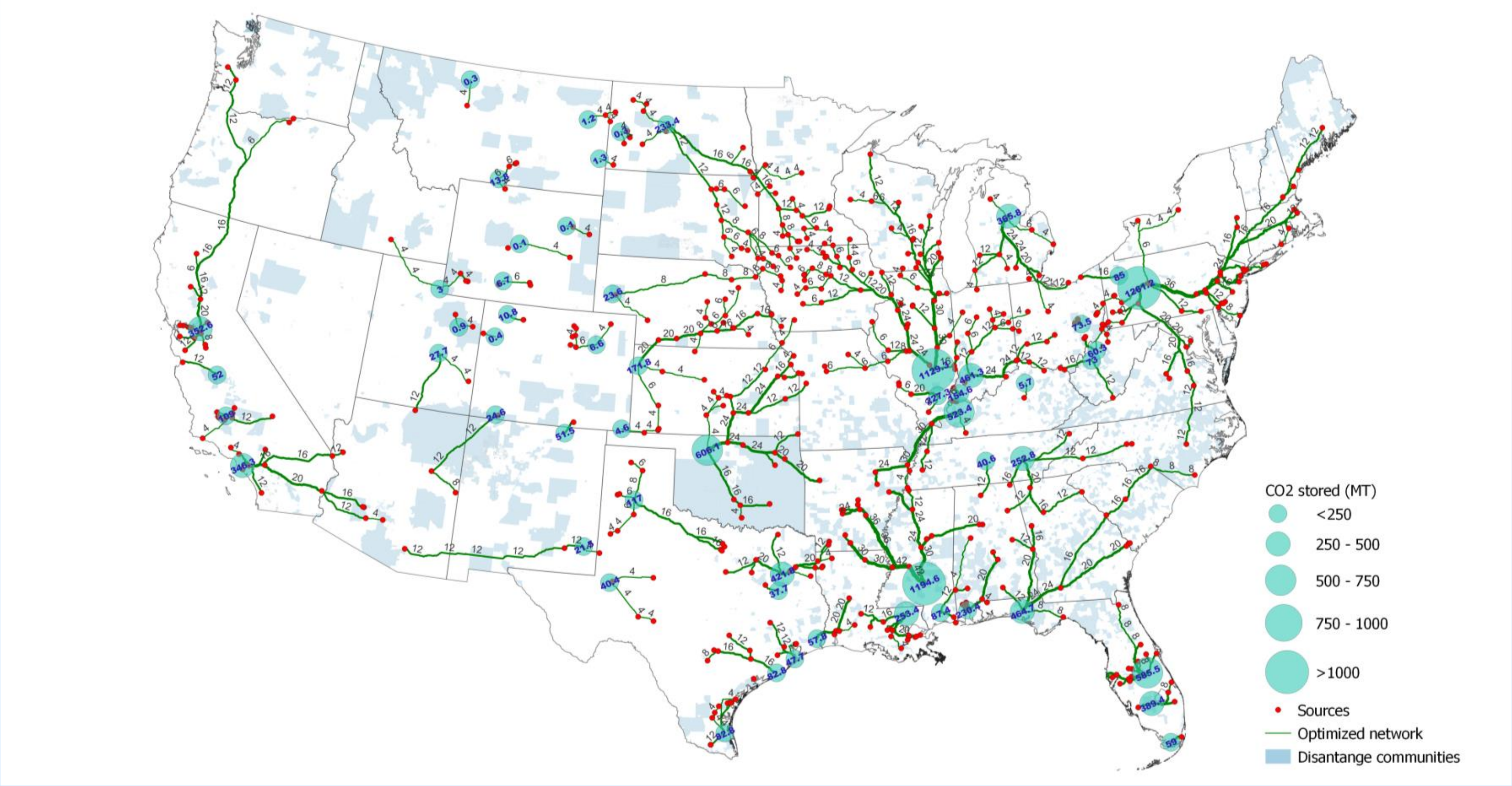
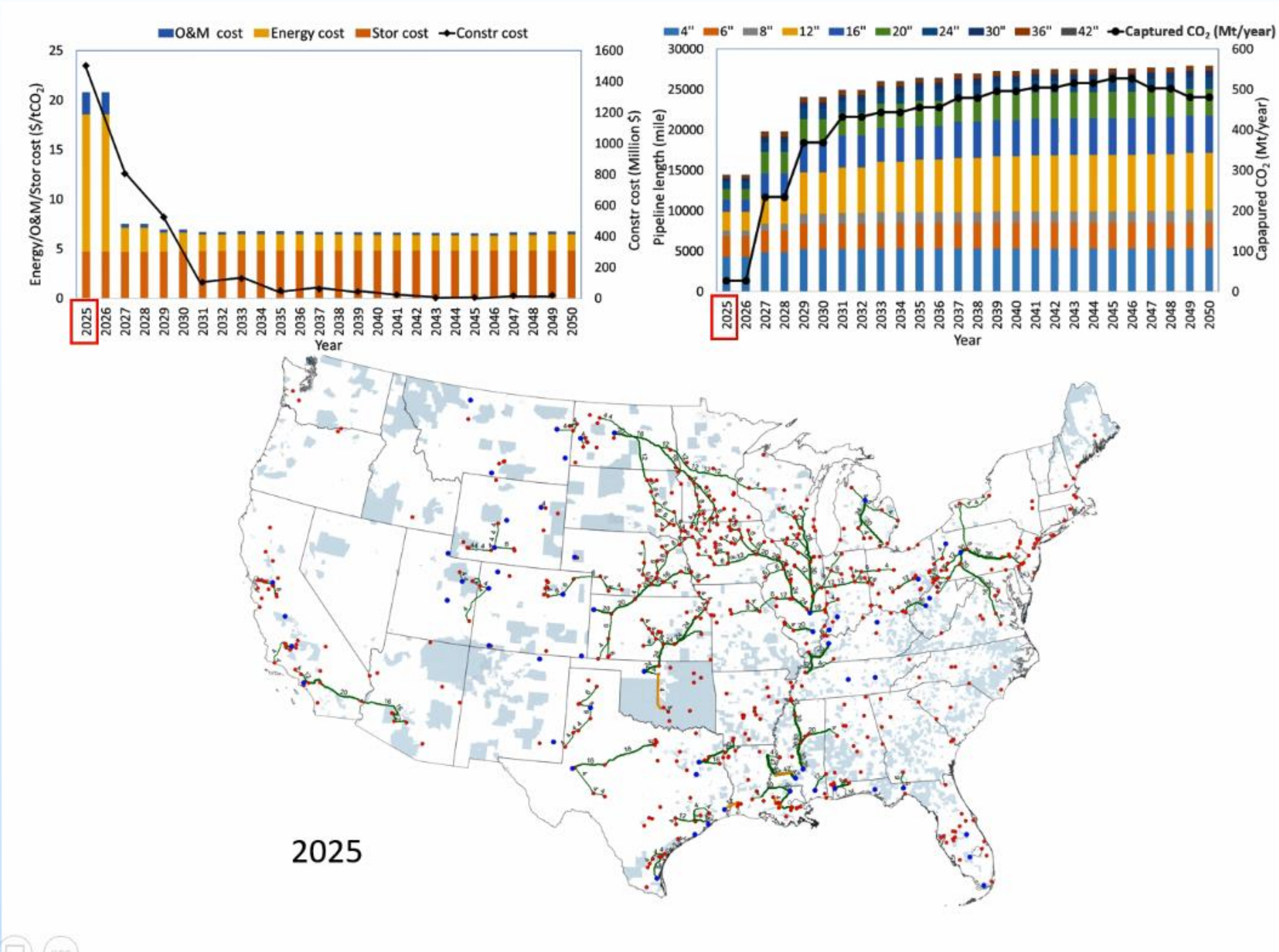


- Total pipeline length: 28,354 miles
  - ~193 miles shorter compared to Case 1
  - By 2035: 26,359 miles (93%)

Case 3: Pipelines do not cross DCs and existing pipelines are utilized



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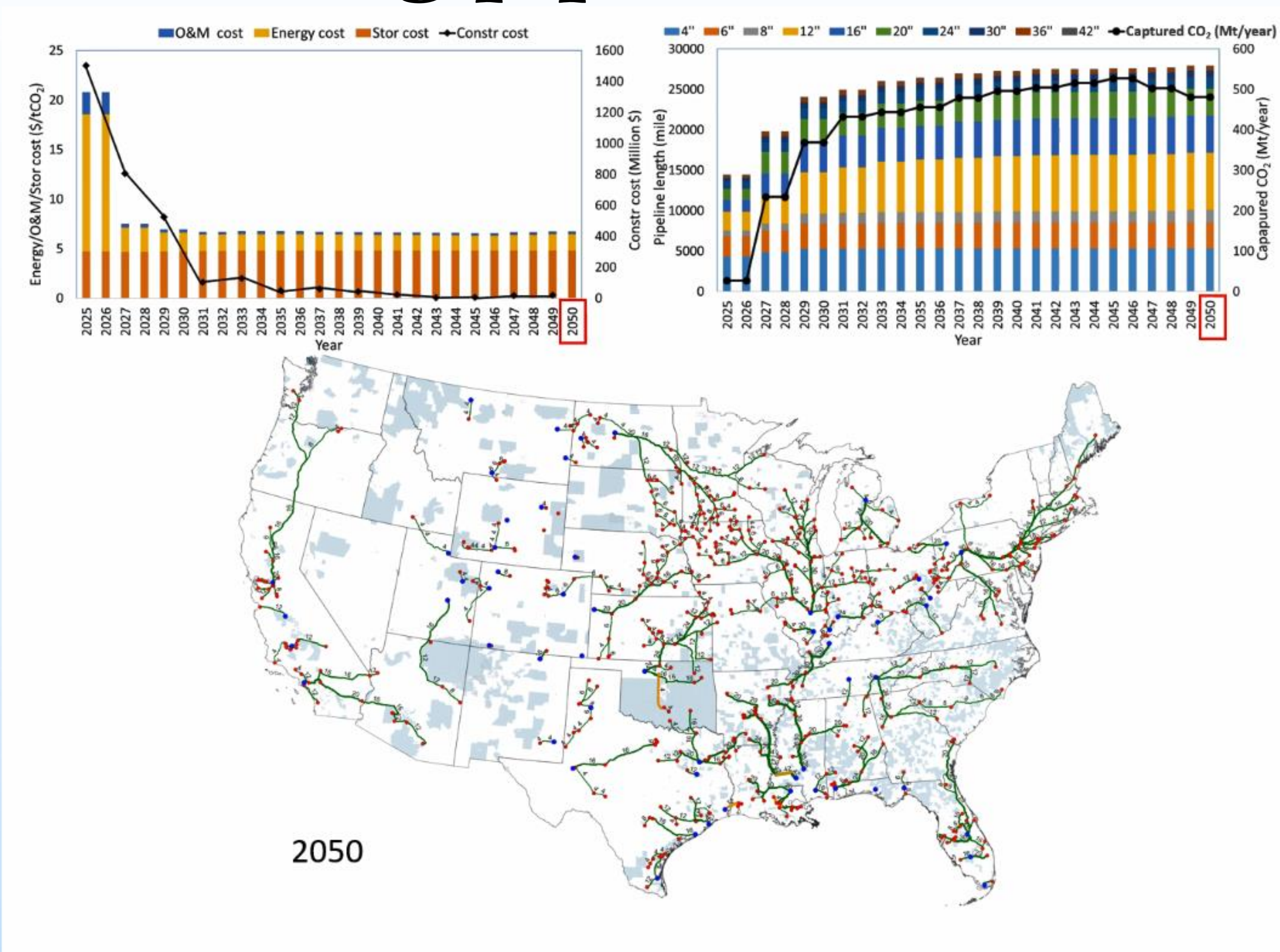

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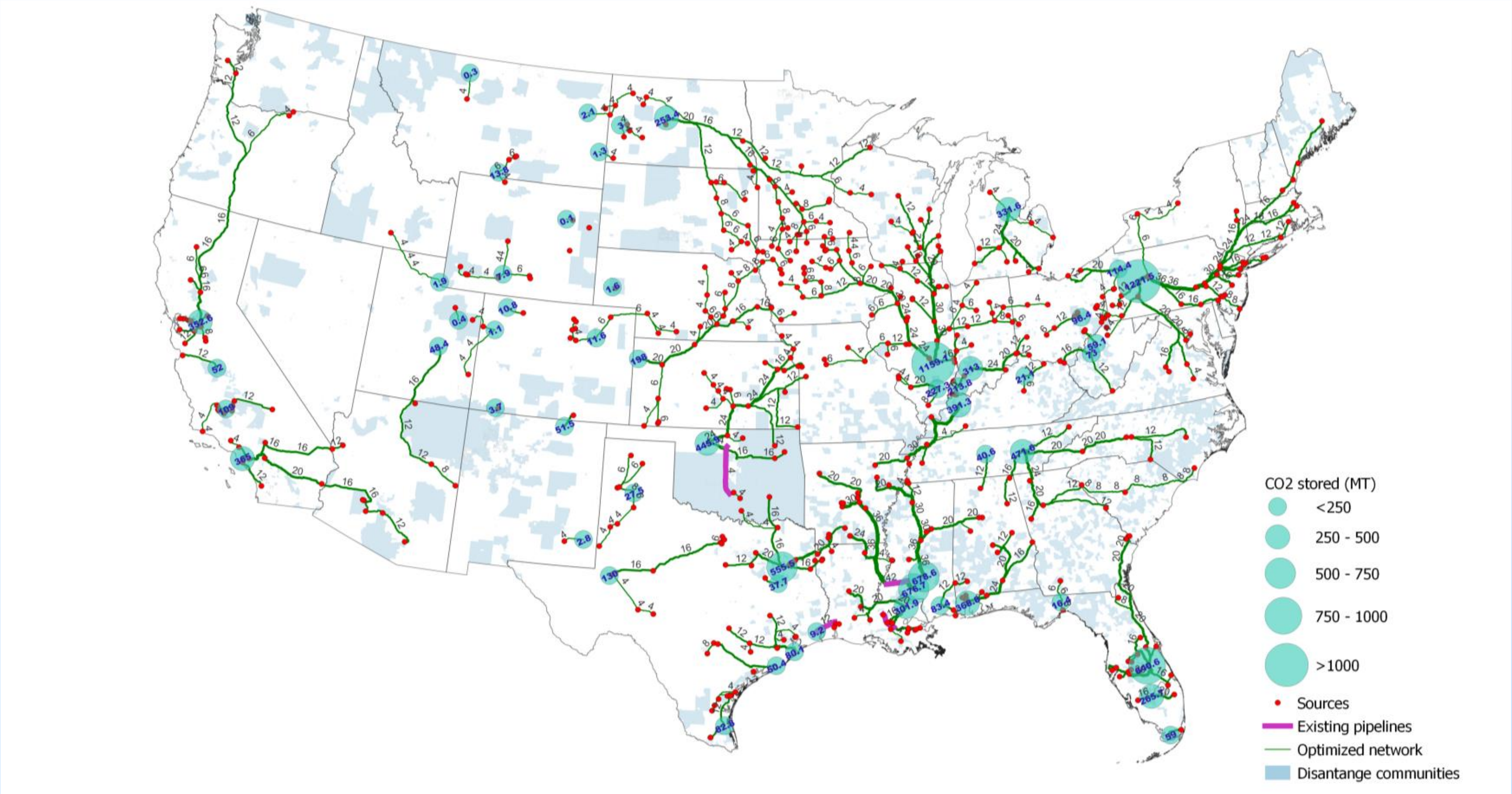

- Total pipeline length: 27,941 miles
  - By 2035: 26,431 miles (94.6%)
  - ~271 miles of existing CO_2 pipelines are utilized

Summary

- *SimCCS*$^{3.0}$ has been demonstrated to be an effective toolset to support the CCS pipeline infrastructure decision making
- Deployment of large-scale CCS will require large-scale regional infrastructure:
  - Capture CO_2 from multiple sources and transport it to multiple sinks
- ~28,000 miles of new pipelines will need to be constructed to capture and store the emissions (as identified in OnLocation scenario).
  - ~93% - 95% of new pipelines will have to be constructed by 2035 to meet the goal of zero carbon power sector (91.4% emissions are from power sector)
  - ~271 miles of existing CO_2 pipelines can be potentially utilized
  - The eastern, mid-western, western regions of US will need to have higher number of trunk lines to facilitate transport of captured CO_2

Thank you

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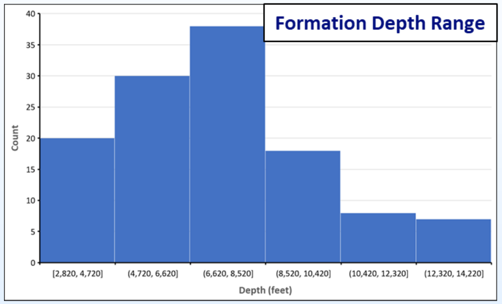
Backup

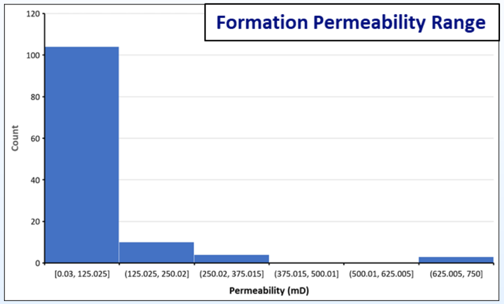
Appendix

- Funding
  - $425,000
- Overall Project Performance Dates
  - August 2020 – August 2022
- Project Participants
  - LANL: Bailian Chen, Daniel Livingston, Martin Ma, Meng Meng, Rajesh Pawar, Rich Pratt
  - Resources for the Future (RFF): Alan Krupnick, Shih-Shyang Shih, Alexandra Thompson

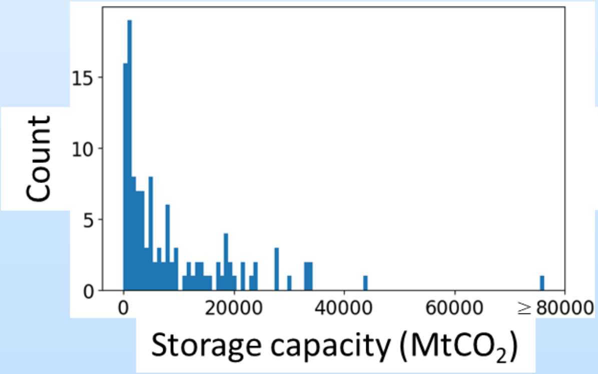
CO_2 Storage Modeling (*SCO_2T*)

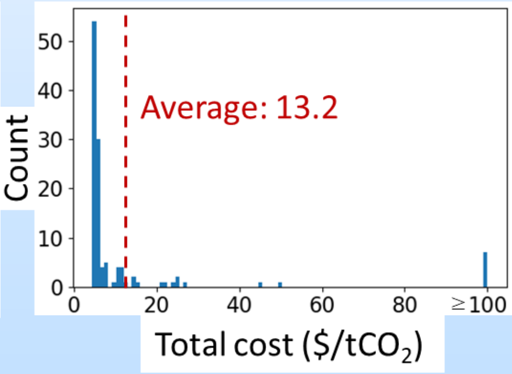
- **Why:** Rapidly calculate realistic injection & storage & costs.
- **Outputs:** Dynamic injectivity, storage capacity, plume dimensions, CO_2 density/brine production, storage economics.



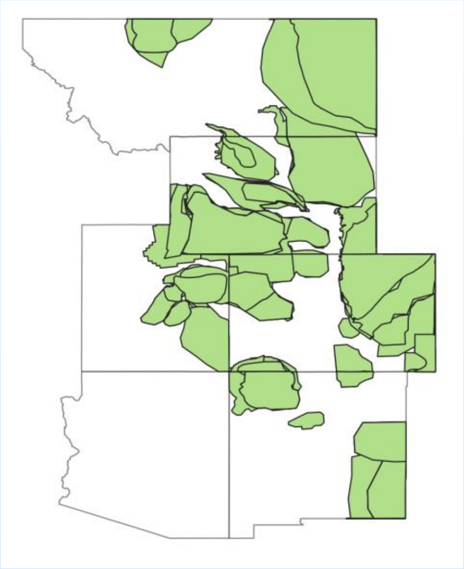


SCO_2T





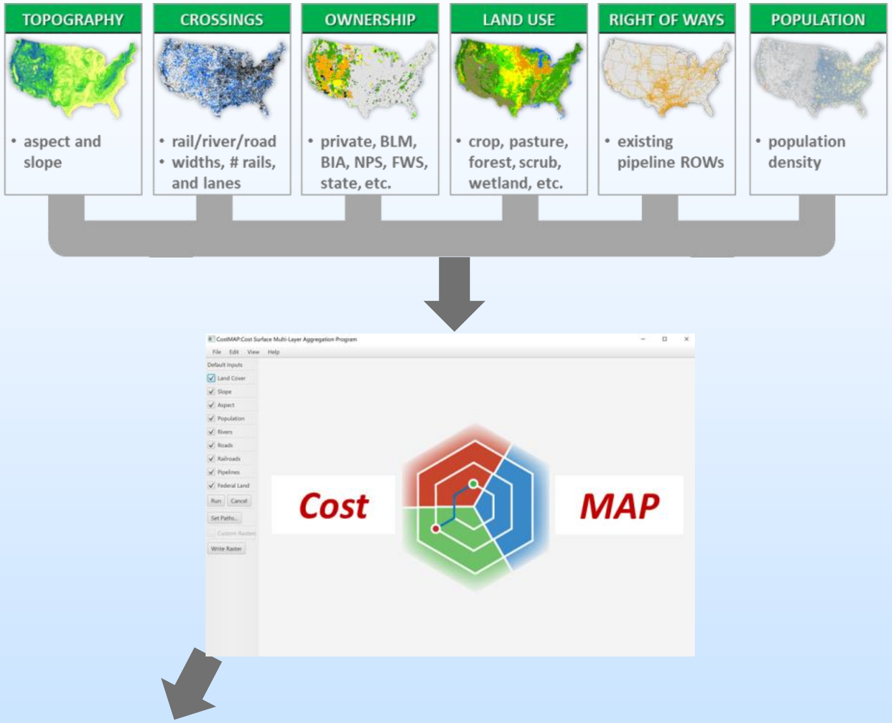
- Total capacity: 1079 GTons
- Sufficient to store ~220 MTons/yr for ~4900 yrs

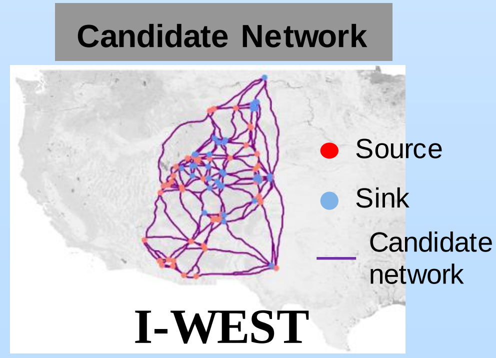


Saline formations in the I-WEST

Construction Cost Surface Modeling (*CostMAP*)

- **Why**: Identify likely corridors; develop candidate pipeline routes for SimCCS optimization engine.
- **How**: Nonlinear integration of ROWs (e.g., pipelines), barriers (e.g., rivers, lakes), population, topography, land use, ownership…
- **Beta version**:
  - *CostMAP*[Beta] (Nationwide) has been developed with the most recent GIS datasets.
  - Multi-resolution: 100 m – 1000 m.

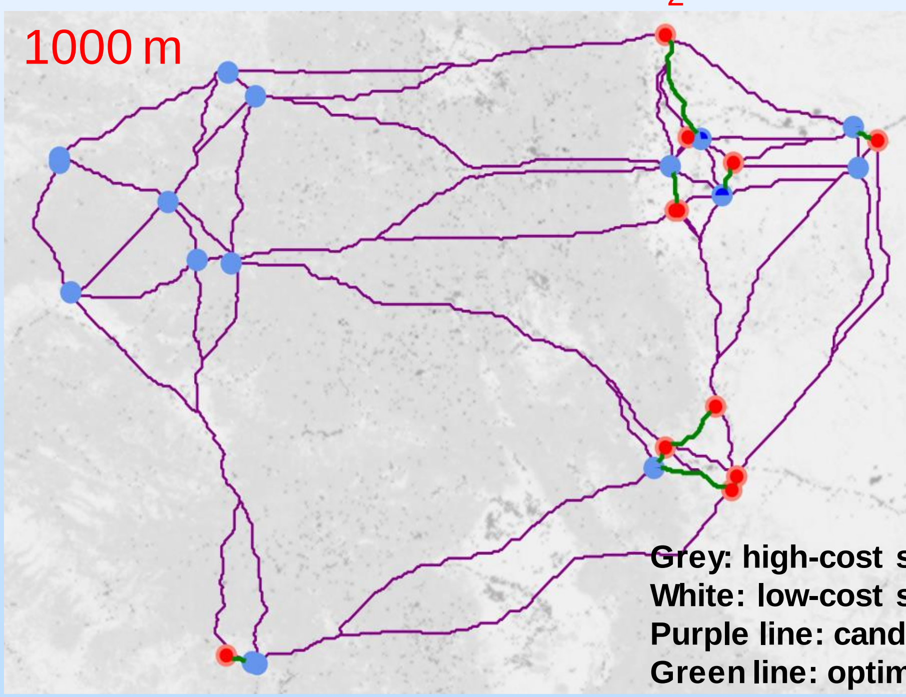




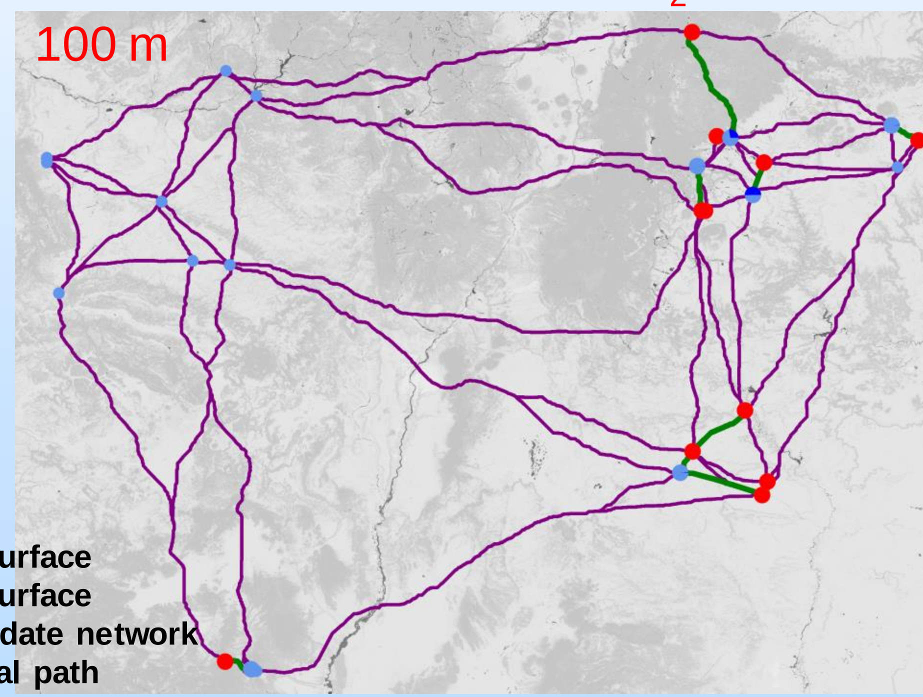
Construction Cost Surface Modeling (*CostMAP*)

– Multi-resolution cost surface (1000 m vs. 100 m; Colorado case study)
  - Higher resolution cost surface leads to finer candidate routes.
  - However, it requires significantly larger computer memory.

Total cost: 22.13 $/tCO_2$



Total cost: 22.3 $/tCO_2$



Grey: high-cost surface
White: low-cost surface
Purple line: candidate network
Green line: optimal path