Report presentation: National Industrial Sector Decarbonization

Extent of Carbon Capture Opportunities and Network Optimization across the United States

Carbon Solutions

Presenters:

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by the Center for Applied Environmental
Law and Policy (CAELP)

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Motivation

What might national decarbonization of the *INDUSTRIAL SECTOR* via CCS look like?

- Which sectors should be considered?
- Is there adequate storage, and where is it located?
- What is the pipeline footprint?
- What communities are impacted?

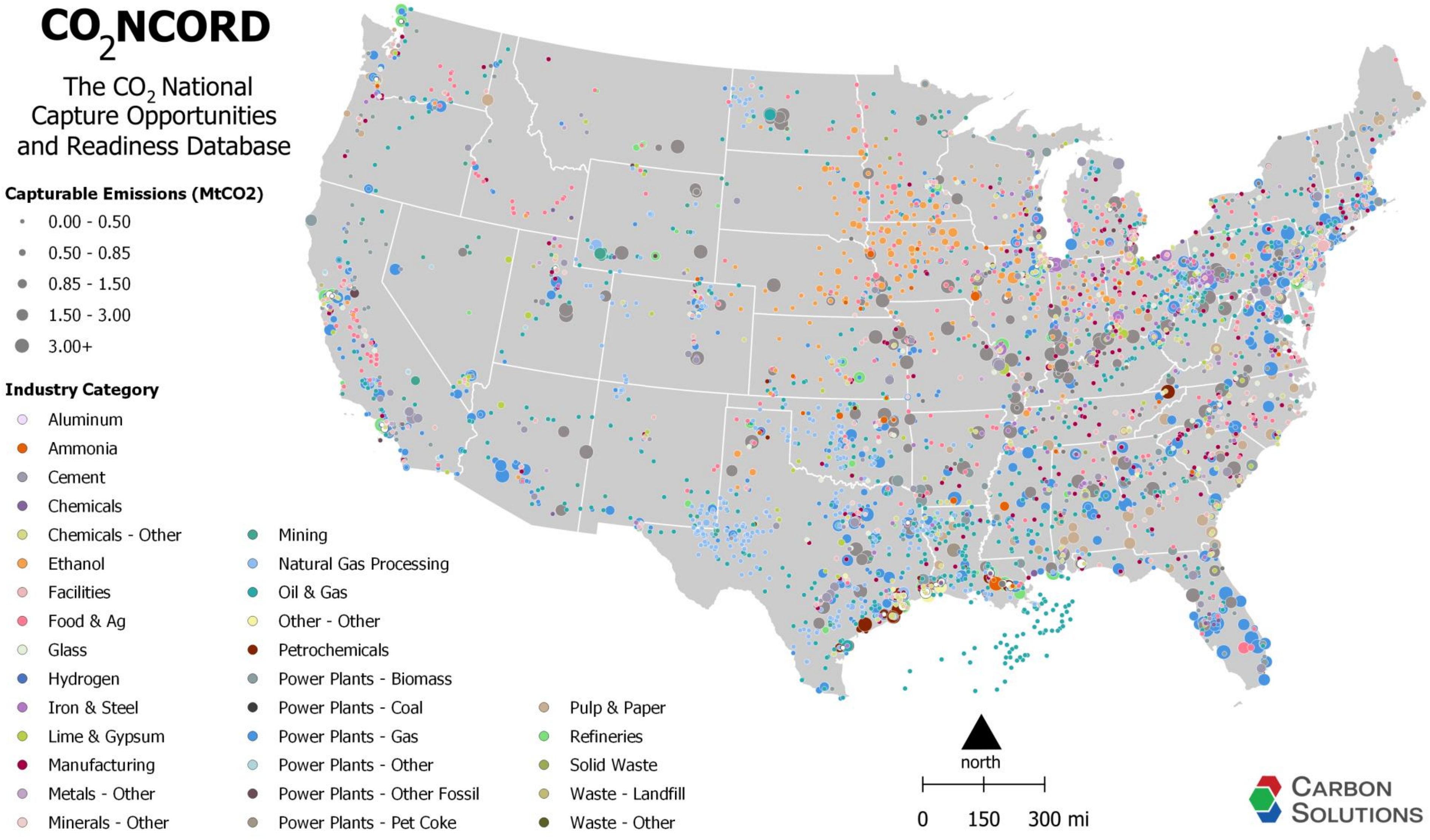
CO_2NCORD

Description

- **SOFTWARE:** Most advanced screening-level CO_2 capture database.

Motivation

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



More information:

[Sale, Kat: CO_2NCORD: Finding New Opportunities for Carbon Capture with CO_2NCORD]

COMPANY SOFTWARE

CO_2NCORD

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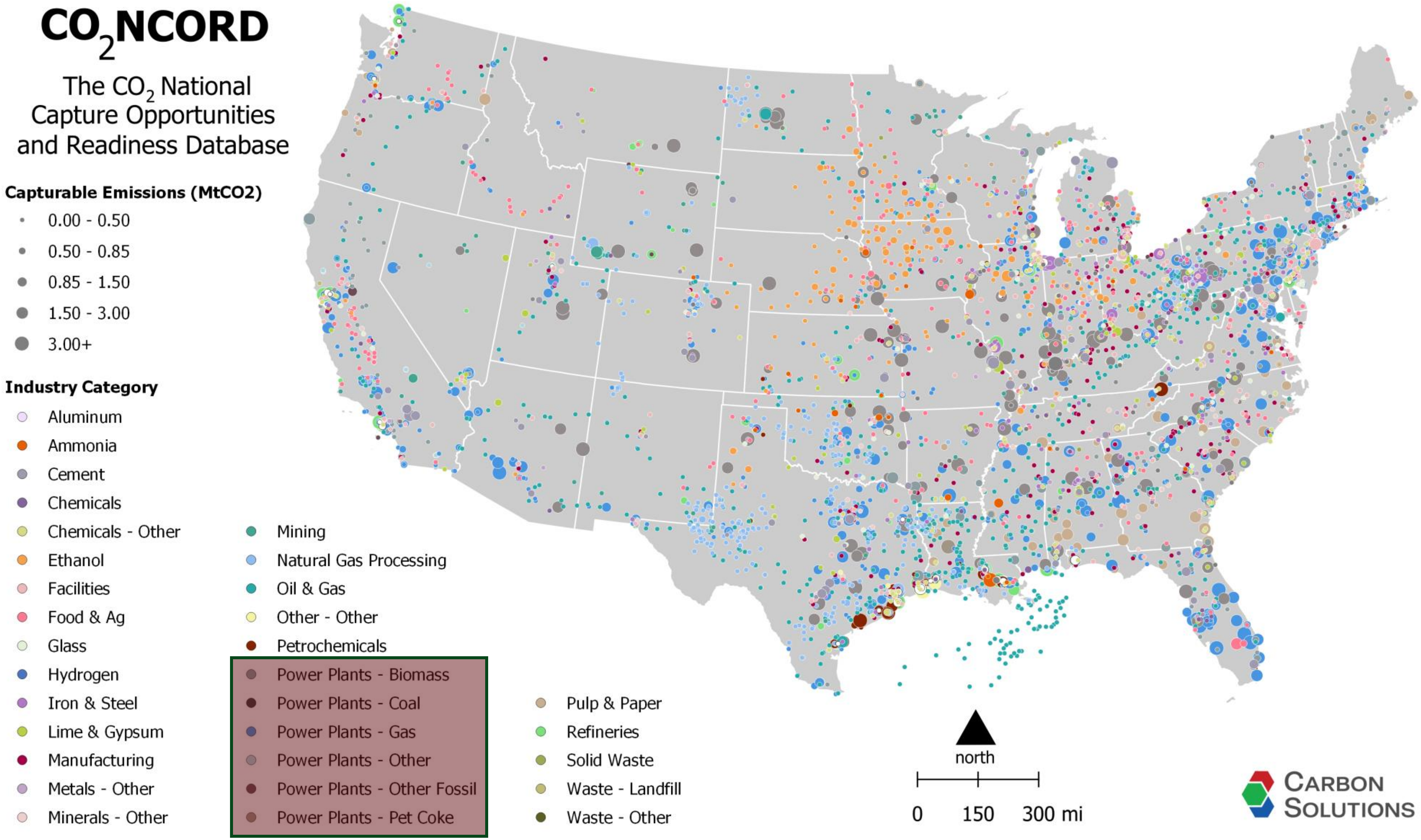

Exclude power sector

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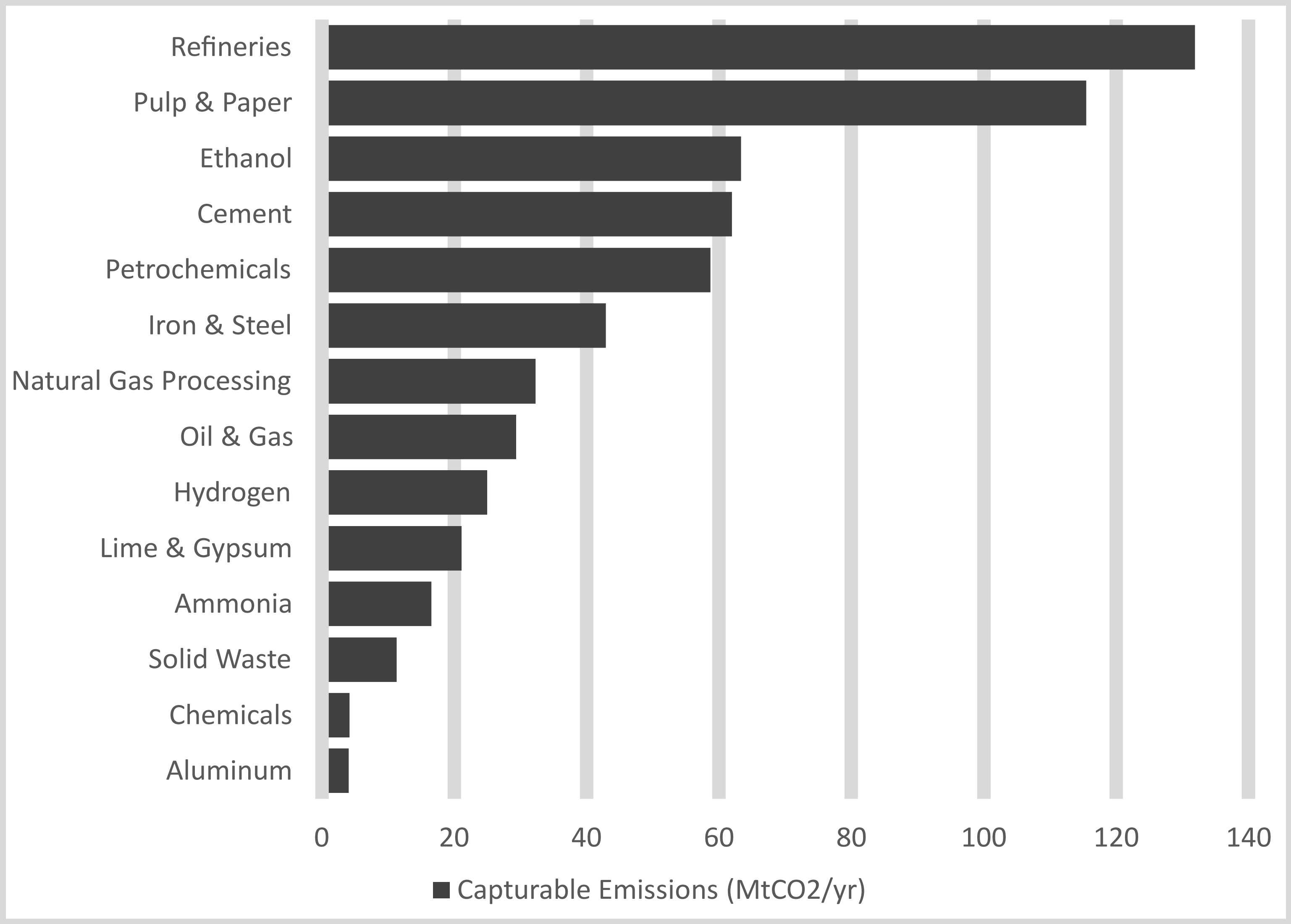
Which sectors should be considered?

Considerations

- Eligible for 45Q
- Priorities
  - Sectors with large emissions, as a whole
  - Sectors with large emissions per facility

Total emissions for all sectors: 618 $MtCO_2$/yr



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COMPANY SOFTWARE

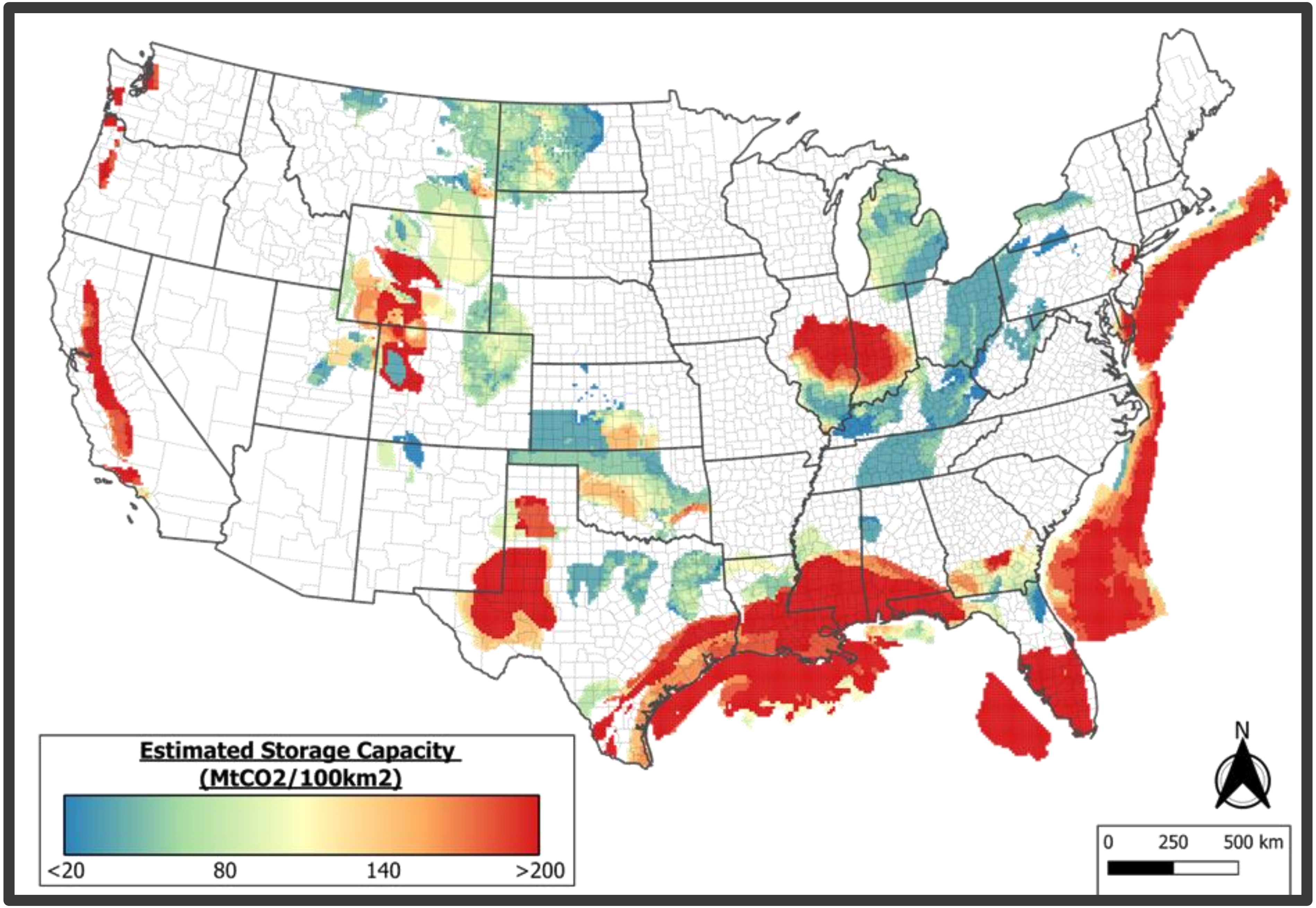
SCO_2T^{PRO}

Description

- **SOFTWARE:** Most advanced screening-level **CO_2 storage** model & database.

Motivation

- Capture complex CO_2 storage with fast-running models.
- Rapidly characterize individual storage reservoirs.
- Regional/national assessment of CO_2 storage potential.



More information: Ogland-Hand, J. *et al.* How to Net-Zero America: Nationwide Cost and Capacity Estimates for Geologic CO_2 Storage.

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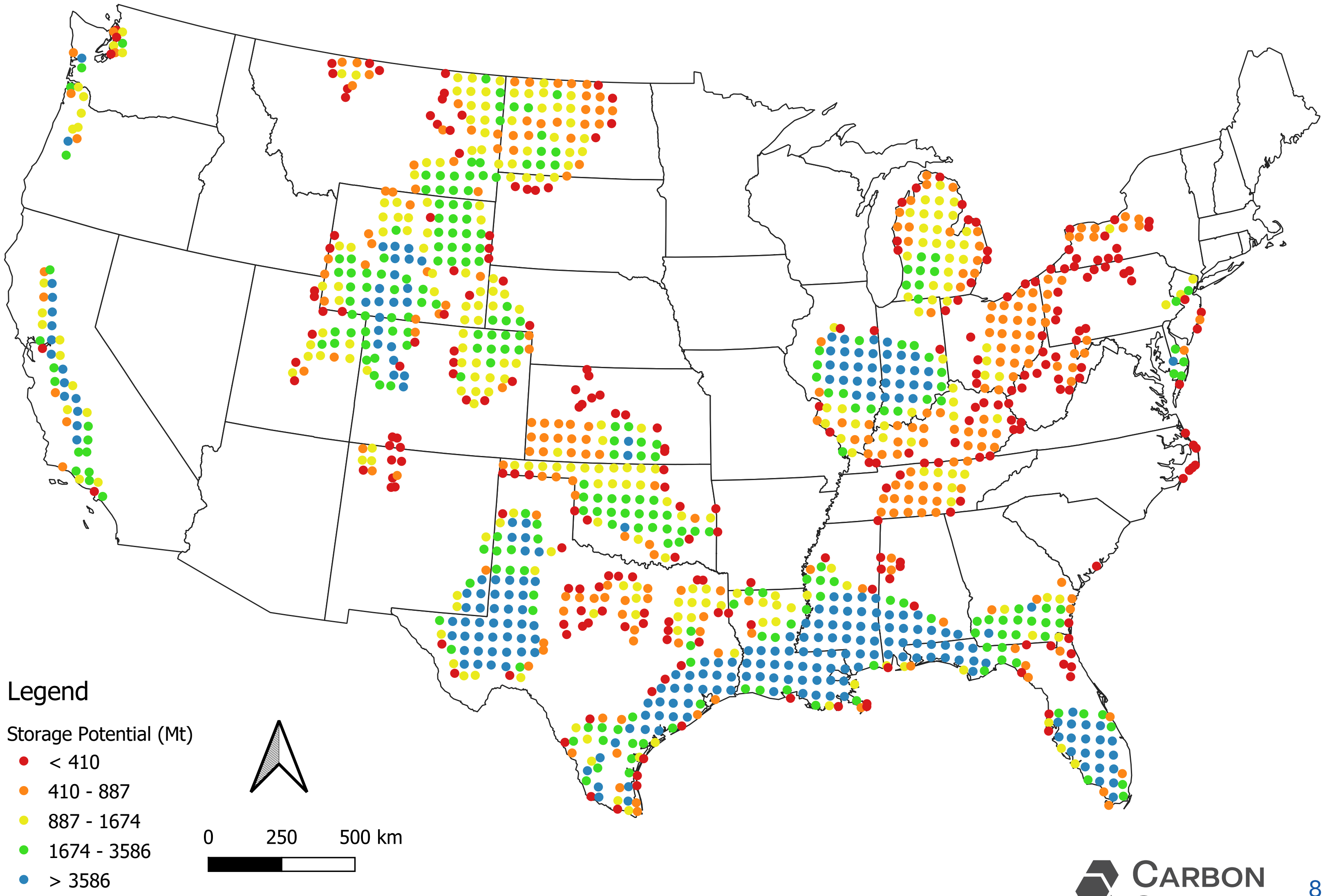
Is there adequate storage, and where is it?

Considerations

- When there is stacked storage, selected lowest cost.
- Exclude offshore storage
- Aggregate to 50k



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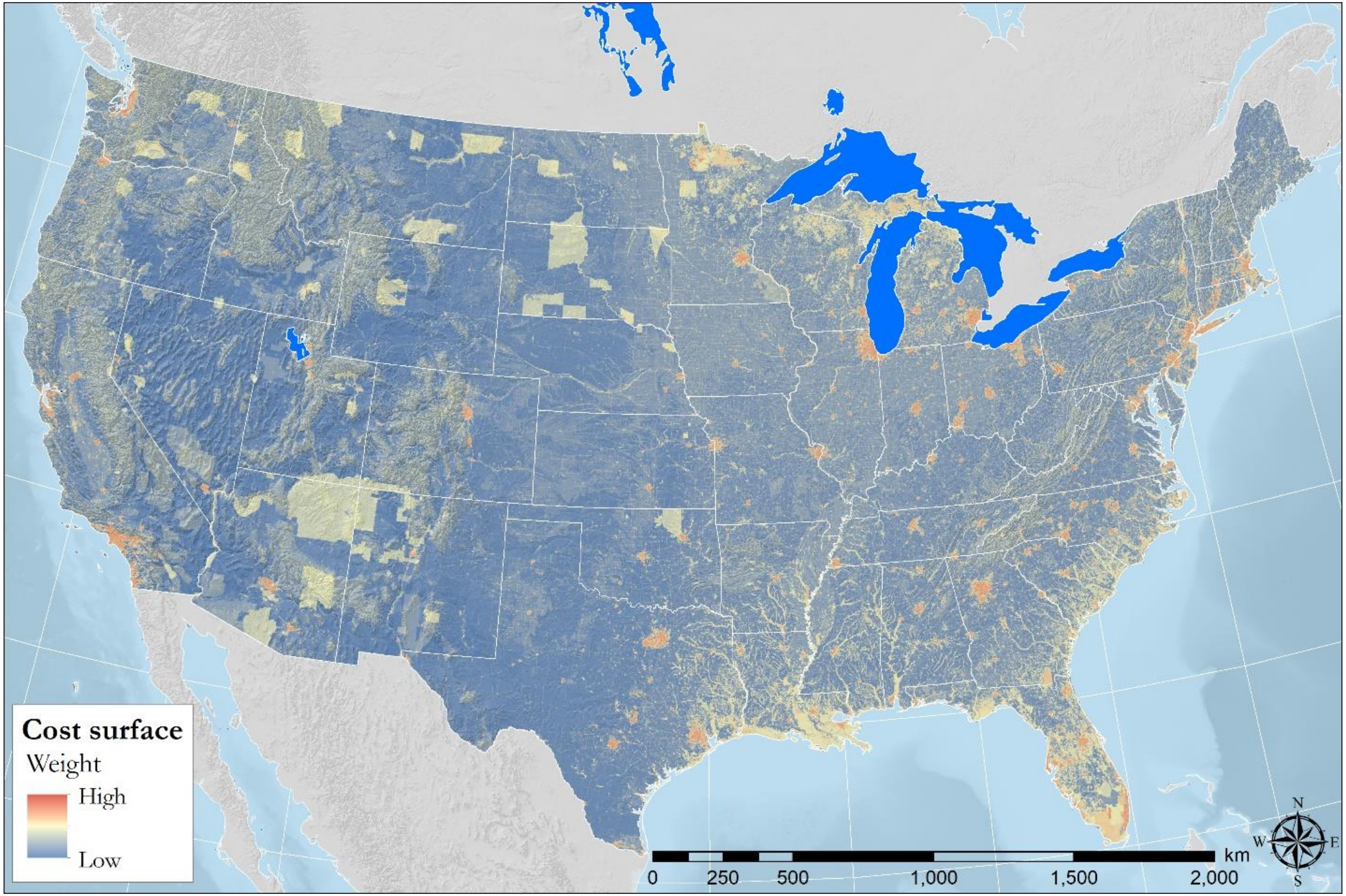
CostMAP^PRO

Description

- **SOFTWARE:** Most advanced screening-level **CO_2 trans-portation** & routing model (or any pipelines, transmission lines).

Motivation

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

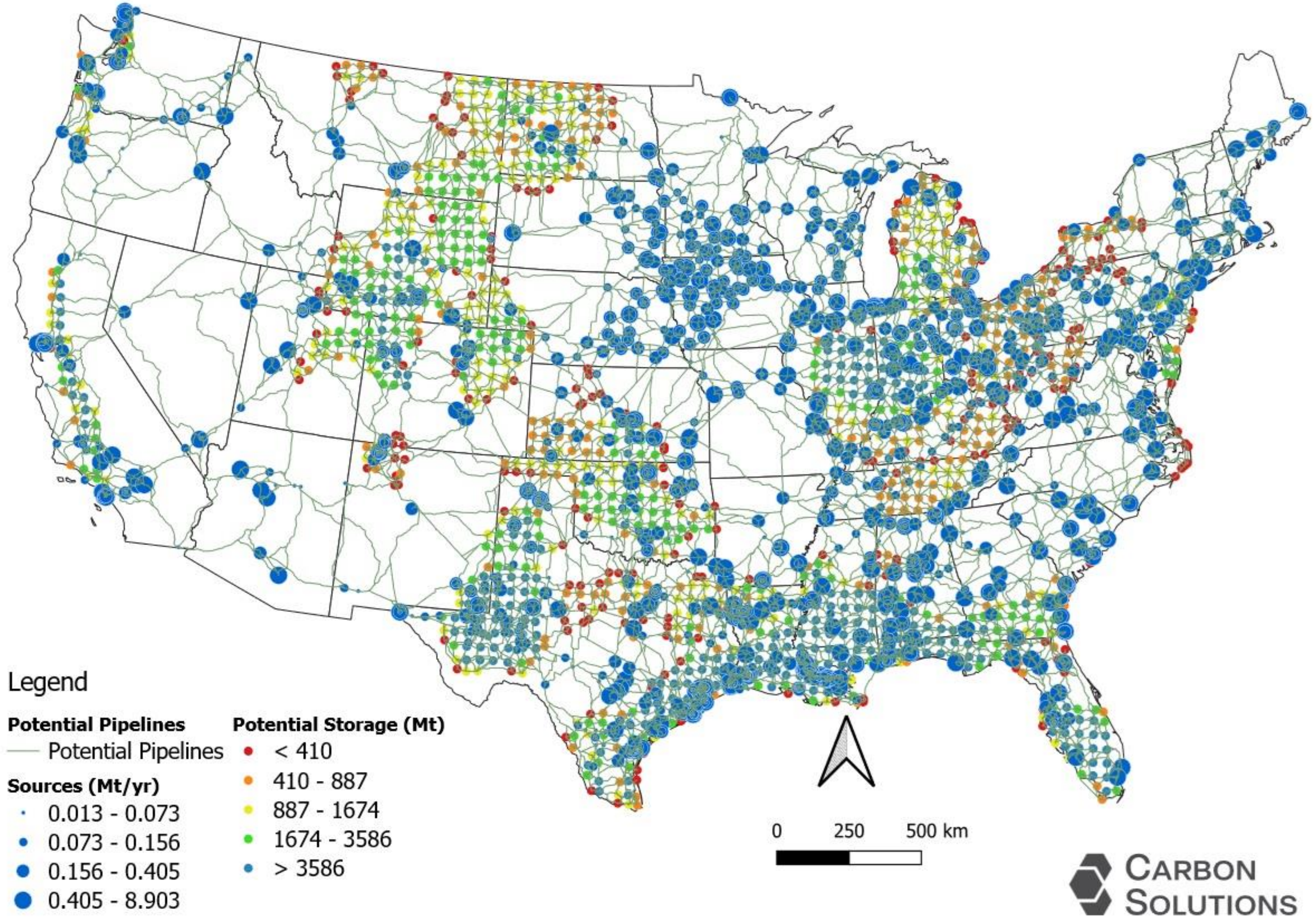


More information: Hoover, B., Yaw, S. & Middleton, R. S. CostMAP: an open-source software package for developing cost surfaces using a multi-scale search kernel. *International Journal of Geographical Information Science,* 34, 2019.

What is the pipeline footprint?

Considerations

- Link sources to storages
- Costs and routing changed based on:
  - Population density
  - Land Use
  - Federal Lands
  - Slope
  - Railway
  - Rivers
  - Roads
  - Transmission lines
  - Pipeline



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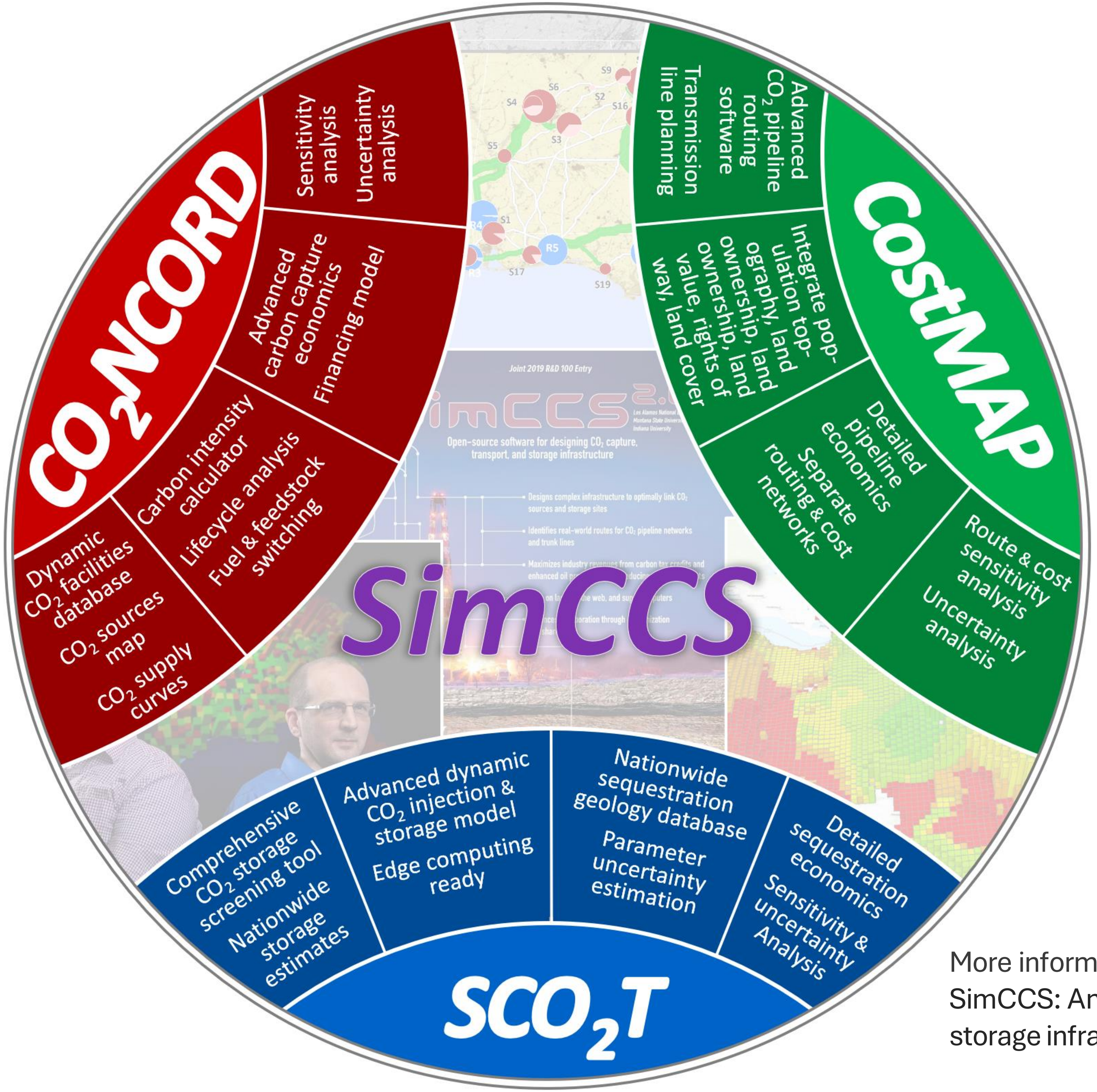


SimCCS^{PRO} *Software*

SimCCS^{PRO} **(system analysis)**

- Decision support across the CCS value chain.
- Leading sub-models for CO_2 capture, transport, & storage.

CO$_2$***NCORD*** **(capture)**

- Dynamic, customizable CO_2 capture database.
- 10,000+ sources.

CostMAP^{PRO} **(transport)**

- Advanced, multiscale, multi-attribute pipeline routing.

SCO$_2$***T***^{PRO} **(storage)**

- World's most advanced & accurate tool for dynamic CO_2 storage & costs.

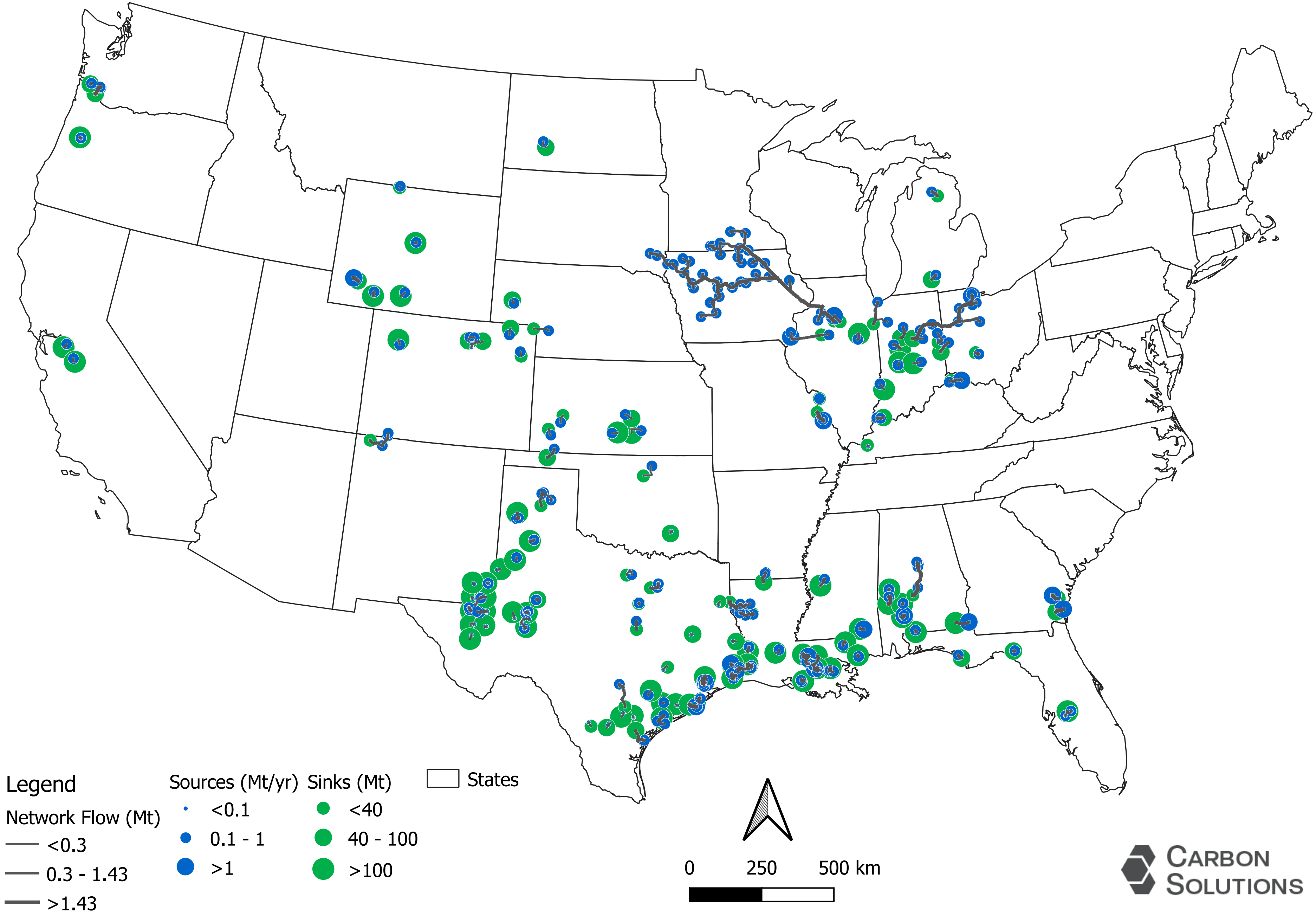
More information: Middleton, R. S., Yaw, S., Hoover, B. & Ellett, K. M. SimCCS: An open-source tool for optimizing CO_2 capture, transport, and storage infrastructure. *Environmental Modeling and Software* **124**, (2020).

Results

Initial modeling scenarios

- Require a certain amount of CO_2 to be captured at intervals up to all CO_2.
- How does the mix of industrial sectors change?
- What is the transportation network required?
- Where are geologic storage sites relative to industrial emissions?

Sectors	100 Mt	200 Mt	300 Mt	400 Mt	500 Mt	600 Mt	618 Mt
Refineries	5%	36%	66%	87%	95%	100%	100%
Pulp & Paper	20%	39%	52%	58%	75%	98%	100%
Ethanol	41%	23%	49%	79%	94%	99%	100%
Cement	0%	0%	7%	21%	66%	96%	100%
Petrochemicals	22%	78%	83%	93%	93%	100%	100%
Iron & Steel	0%	0%	0%	22%	62%	94%	100%
Natural Gas Processing	30%	38%	63%	79%	85%	97%	100%
Oil & Gas	7%	7%	22%	41%	53%	78%	100%
Hydrogen	0%	2%	47%	87%	95%	100%	100%
Lime & Gypsum	**55%**	52%	56%	57%	71%	96%	100%
Ammonia	41%	66%	70%	78%	92%	100%	100%
Solid Waste	0%	0%	0%	16%	33%	95%	100%
Chemicals	42%	61%	58%	64%	72%	94%	100%
Aluminum	0%	0%	18%	30%	53%	77%	100%
Total	***16%***	***31%***	***48%***	***64%***	***81%***	***97%***	***100%***



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Results: 100 Mt/yr

Annual Capture ($MtCO_2$/yr)	100
# Sources	300
# Sinks	116
Network Length (km)	6,529
Total Cost ($/tCO2)	$55.03
Source Cost ($/t$CO_2$)	$38.38
Transport Cost ($/t$CO_2$)	$9.88
Sink Cost ($/$CO_2$)	$6.77

Sectors	100 Mt	200 Mt	300 Mt	400 Mt	500 Mt	600 Mt	618 Mt
Refineries	5%	36%	66%	87%	95%	100%	100%
Pulp & Paper	20%	39%	52%	58%	75%	98%	100%
Ethanol	41%	23%	49%	79%	94%	99%	100%
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Hydrogen	0%	2%	47%	87%	95%	100%	100%
Lime & Gypsum	55%	**52%**	56%	57%	71%	96%	100%
Ammonia	41%	***66%***	70%	78%	92%	100%	100%
Solid Waste	0%	0%	0%	16%	33%	95%	100%
Chemicals	42%	***61%***	58%	64%	72%	94%	100%
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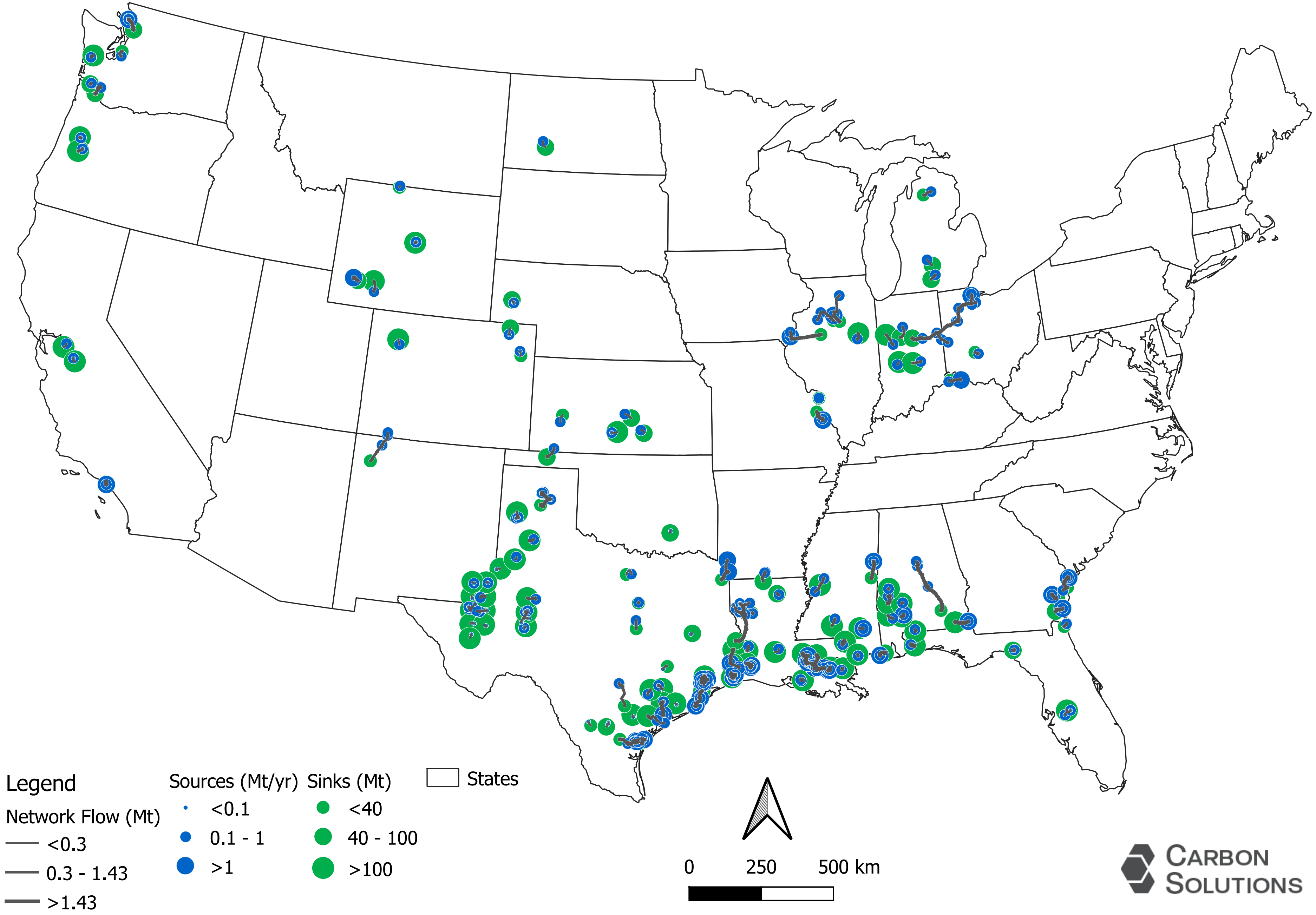
Carbon Solutions



Results: 200 Mt/yr

Annual Capture ($MtCO_2$/yr)	200
# Sources	427
# Sinks	116
Network Length (km)	5,005
Total Cost ($/tCO2)	$65.53
Source Cost ($/t$CO_2$)	$53.77
Transport Cost ($/t$CO_2$)	$5.23
Sink Cost ($/t$CO_2$)	$6.53

Sectors	100 Mt	200 Mt	300 Mt	400 Mt	500 Mt	600 Mt	618 Mt
Refineries	5%	36%	***66%***	87%	95%	100%	100%
Pulp & Paper	20%	39%	***52%***	58%	75%	98%	100%
Ethanol	41%	23%	49%	79%	94%	99%	100%
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Iron & Steel	0%	0%	0%	22%	62%	94%	100%
Natural Gas Processing	30%	38%	***63%***	79%	85%	97%	100%
Oil & Gas	7%	7%	22%	41%	53%	78%	100%
Hydrogen	0%	2%	47%	87%	95%	100%	100%
Lime & Gypsum	55%	52%	**56%**	57%	71%	96%	100%
Ammonia	41%	66%	**70%**	78%	92%	100%	100%
Solid Waste	0%	0%	0%	16%	33%	95%	100%
Chemicals	42%	61%	**58%**	64%	72%	94%	100%
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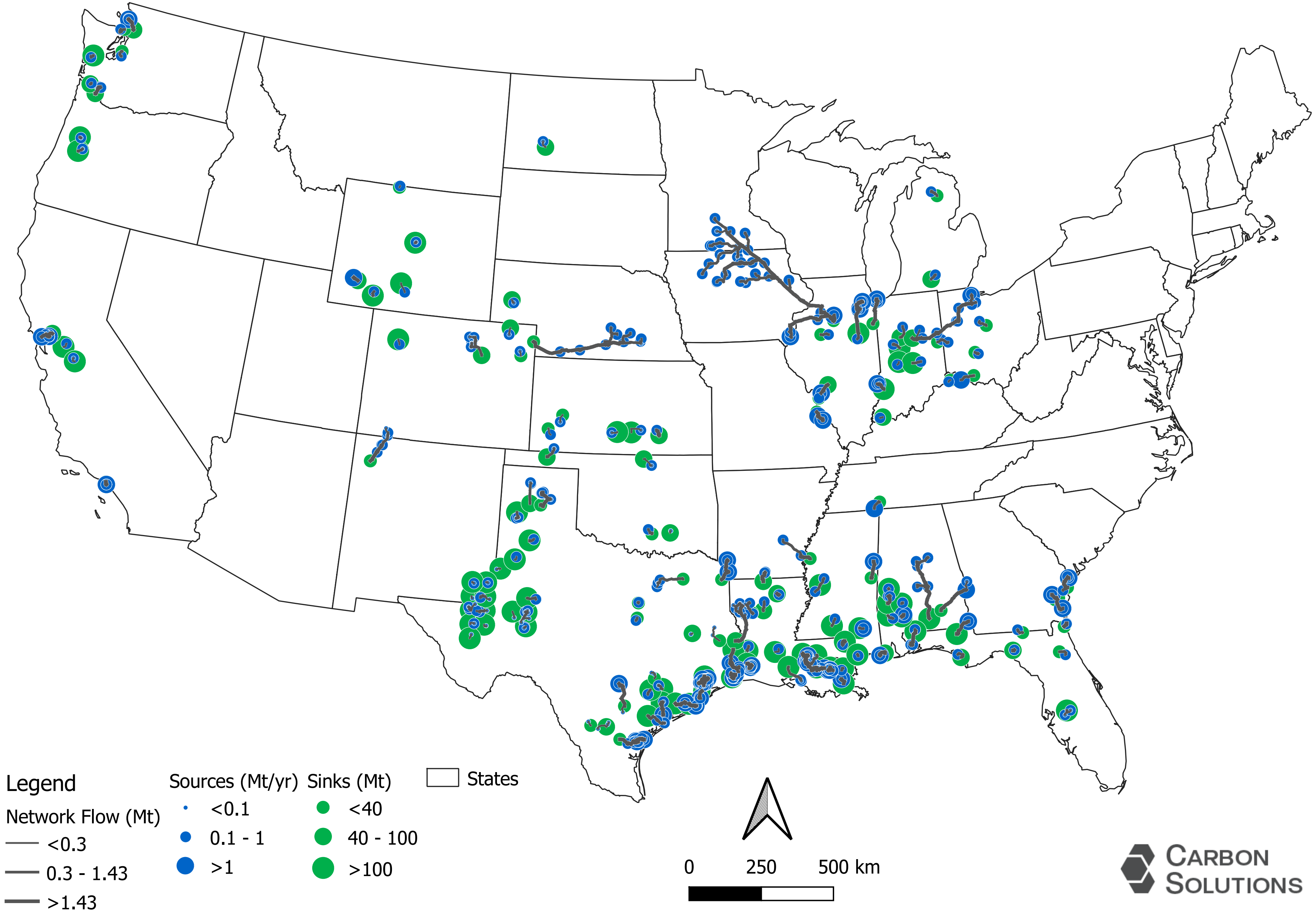

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Results: 300 Mt/yr

Annual Capture ($MtCO_2$/yr)	300
# Sources	670
# Sinks	136
Network Length (km)	9,235
Total Cost ($/tCO2)	$69.04
Source Cost ($/t$CO_2$)	$55.89
Transport Cost ($/t$CO_2$)	$6.47
Sink Cost ($/$CO_2$)	$6.67

Sectors	100 Mt	200 Mt	300 Mt	400 Mt	500 Mt	600 Mt	618 Mt
Refineries	5%	36%	66%	87%	95%	100%	100%
Pulp & Paper	20%	39%	52%	58%	75%	98%	100%
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Iron & Steel	0%	0%	0%	**22%**	62%	94%	100%
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Hydrogen	0%	2%	47%	87%	95%	100%	100%
Lime & Gypsum	55%	52%	56%	57%	71%	96%	100%
Ammonia	41%	66%	70%	78%	92%	100%	100%
Solid Waste	0%	0%	0%	**16%**	33%	95%	100%
Chemicals	42%	61%	58%	64%	72%	94%	100%
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Sectors	100 Mt	200 Mt	300 Mt	400 Mt	500 Mt	600 Mt	618 Mt
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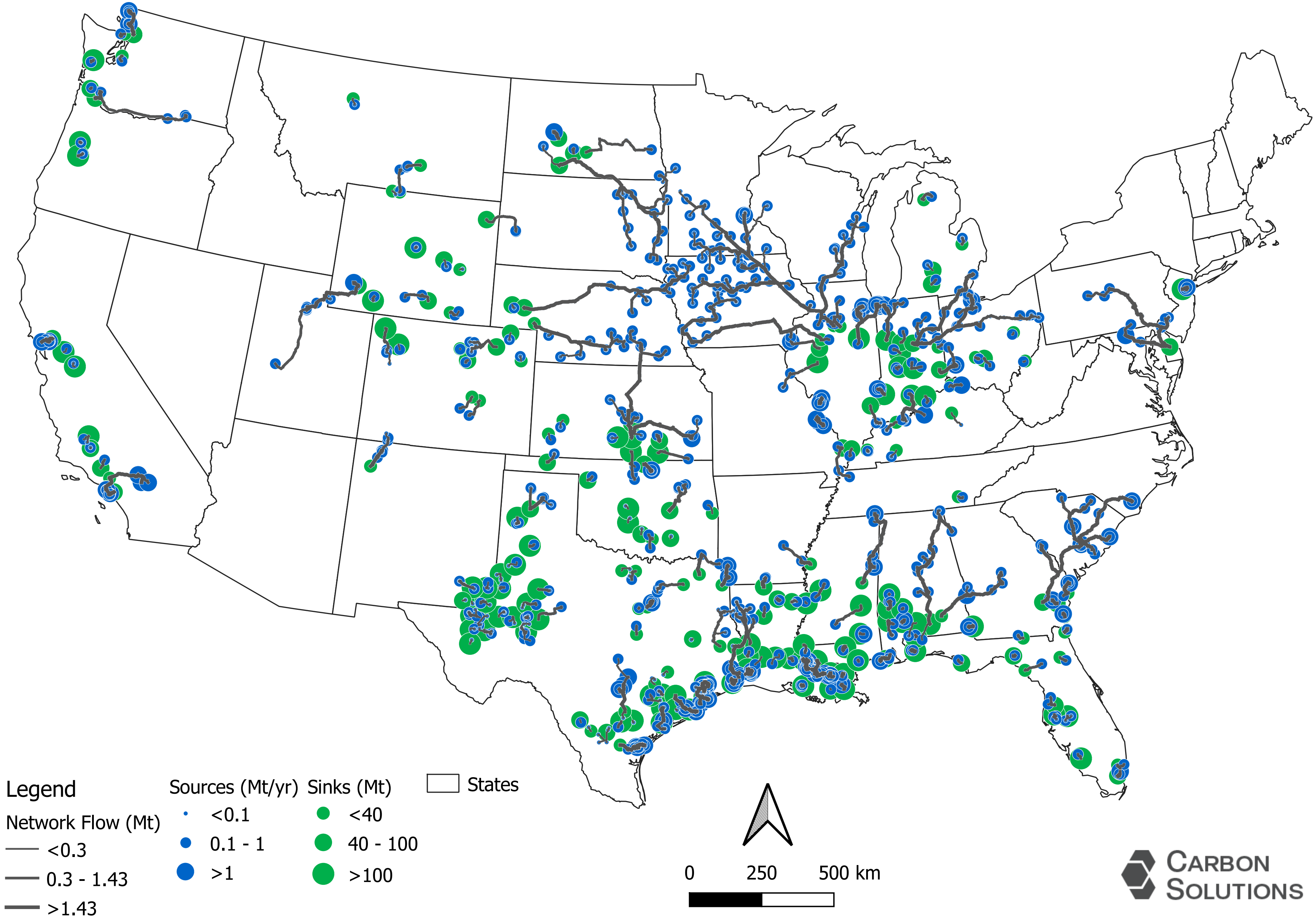

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Results: 500 Mt/yr

Annual Capture ($MtCO_2$/yr)	500
# Sources	1296
# Sinks	209
Network Length (km)	26,846
Total Cost ($/tCO2)	$76.19
Source Cost ($/t$CO_2$)	$58.06
Transport Cost ($/t$CO_2$)	$11.40
Sink Cost ($/$CO_2$)	$6.74

Sectors	100 Mt	200 Mt	300 Mt	400 Mt	500 Mt	600 Mt	618 Mt
Refineries	5%	36%	66%	87%	95%	100%	100%
Pulp & Paper	20%	39%	52%	58%	75%	98%	100%
Ethanol	41%	23%	49%	79%	94%	99%	100%
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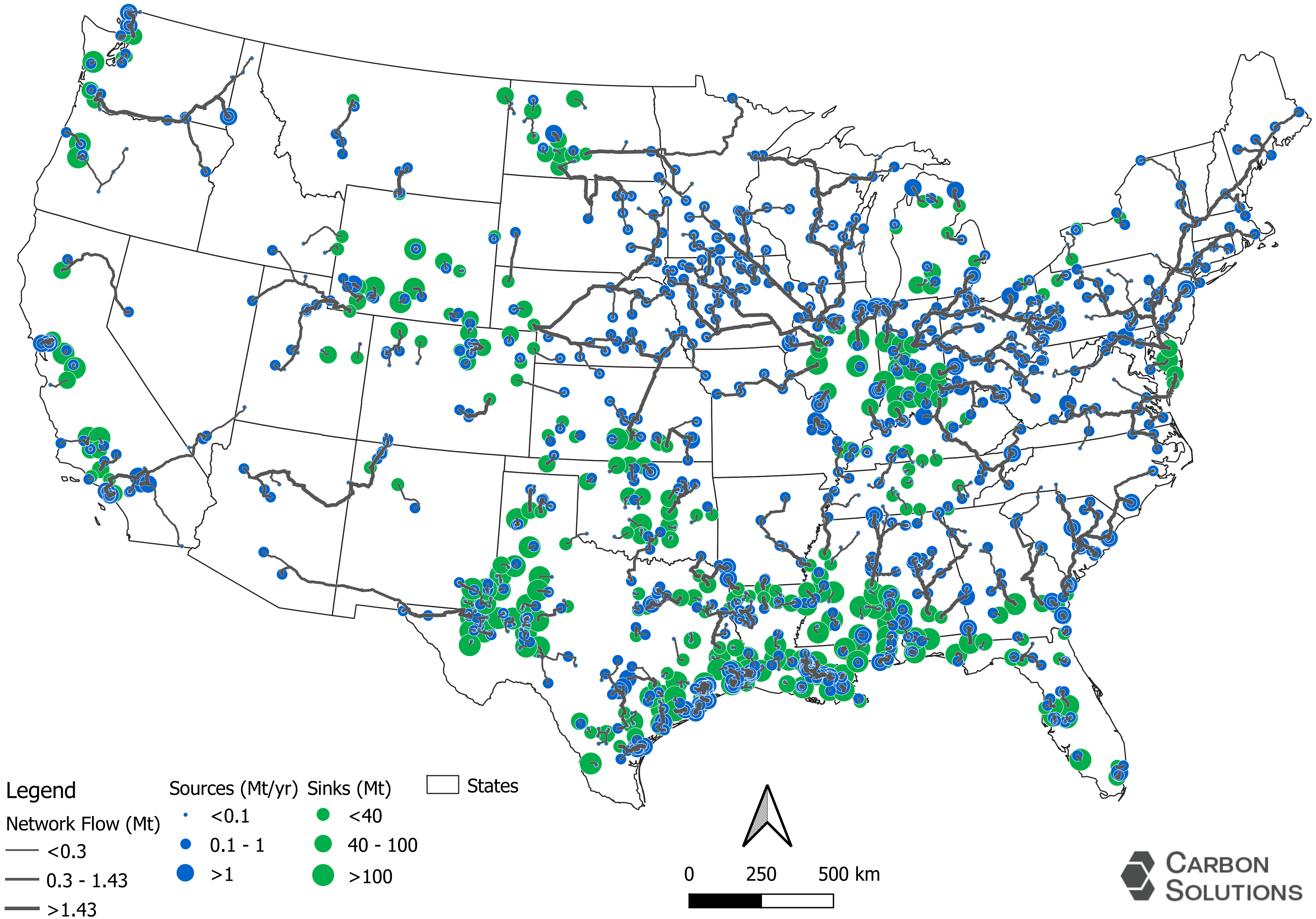
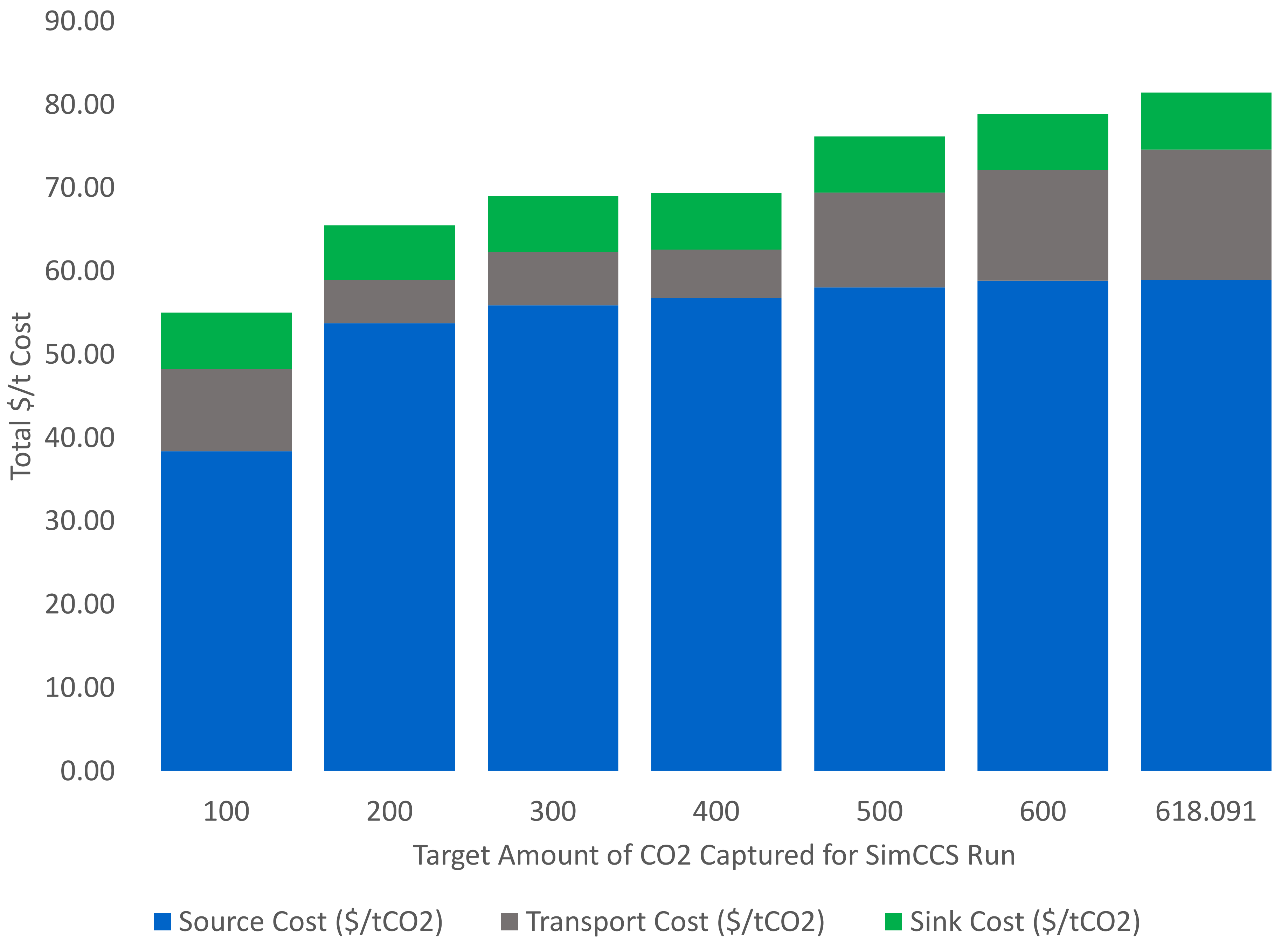
Carbon Solutions



Results: 618.091 Mt/yr

Annual Capture ($MtCO_2/yr$)	618.091
# Sources	1874
# Sinks	298
Network Length (km)	54,684
Total Cost ($/tCO2)	$81.46
Source Cost ($/tCO$_2$)	$58.98
Transport Cost ($/tCO$_2$)	$15.63
Sink Cost ($/tCO$_2$)	$6.84



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Results table

	Annual Capture Amount (MTCO2/yr)						
	100	200	300	400	500	600	618.091
# Sources	300	427	670	987	1296	1693	1874
# Sinks	116	116	136	182	209	257	298
Network Length (km)	6,529	5,005	9,235	14,681	26,846	43,060	54,684
Total Cost ($/t$CO_2$)	55.03	65.53	69.04	69.41	76.19	78.88	81.46
Source Cost ($/t$CO_2$)	38.38	53.77	55.89	56.77	58.06	58.85	58.98
Transport Cost ($/t$CO_2$)	9.88	5.23	6.47	5.84	11.40	13.30	15.63
Sink Cost ($/t$CO_2$)	6.77	6.53	6.67	6.80	6.74	6.73	6.84

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Key Takeaways

Sources:

- The three largest sectors by emissions (refineries, pulp & paper, ethanol) have 50% of emissions captured at 300 Mt.
- No one large-emitting sector captures all emissions, cheaply, at low-capacity goals

Pipelines:

- At low capture rates, longest pipelines due to insufficient proven storage in MN, IA, and NE.
- Large jump in pipelines required for last emitters; ~12k km from 400Mt to 500Mt; ~16k km from 500Mt to 600Mt, and 11k km for last 18Mt.

Storage:

- Average storage costs least volatile due to lowest-cost formations

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Additional study considerations

- Which industries are selected if you set a price, not a capacity, requirement?
- How do CCS costs differ by region?
- How might trunklines (centrally located pipelines with decreased costs) impact which industrial sectors use CCS?

Environmental Justice Considerations

How does CCS impact communities?

Each component can have different impacts

Emissions

- What are potential co-benefits related to capture?

Pipelines

- What are the risks and benefits related to pipelines?

Storage

- Where is storage relative to environmental justice communities?

Environmental Justice Definitions

SVI (Social Vulnerability Index from Centers for Disease Control):

- A tract in the 85th percentile of the overall cumulative sum of 16 variables across four themes: Socioeconomic Status, Household Characteristics, Racial & Ethnic Minority Status, Housing Type & Transportation.

DOE-DCR (Department of Energy – Disadvantaged Community Reporter):

- A tract in the 80th national percentile of the cumulative sum of the 36 burden indicators and has at least 30% of households classified as low-income.

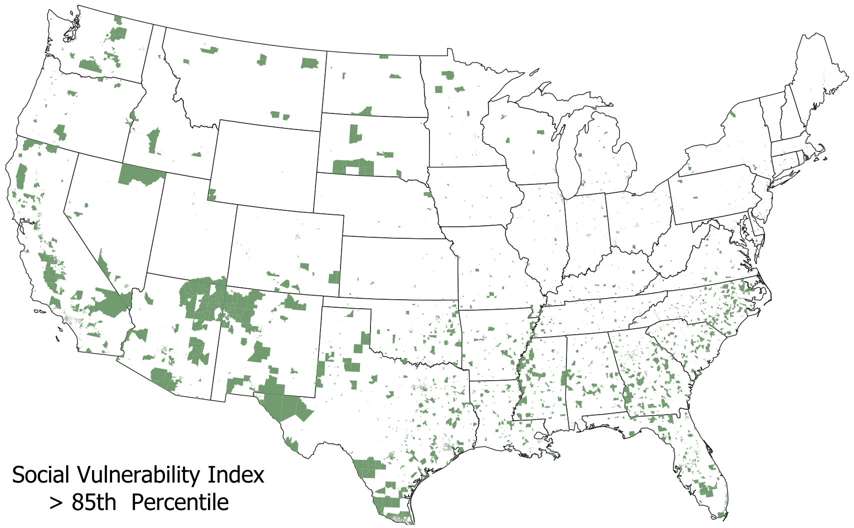
CEJST Pollution (Climate and Economic Justice Screening Tool - Council on Environmental Quality):

- A tract that has at least one abandoned mine land OR Formerly Used Defense Sites OR is at or above the 90th percentile for proximity to hazardous waste facilities OR proximity to Superfund sites (National Priorities List (NPL)) OR proximity to Risk Management Plan (RMP) facilities AND are at or above the 65th percentile for low income.

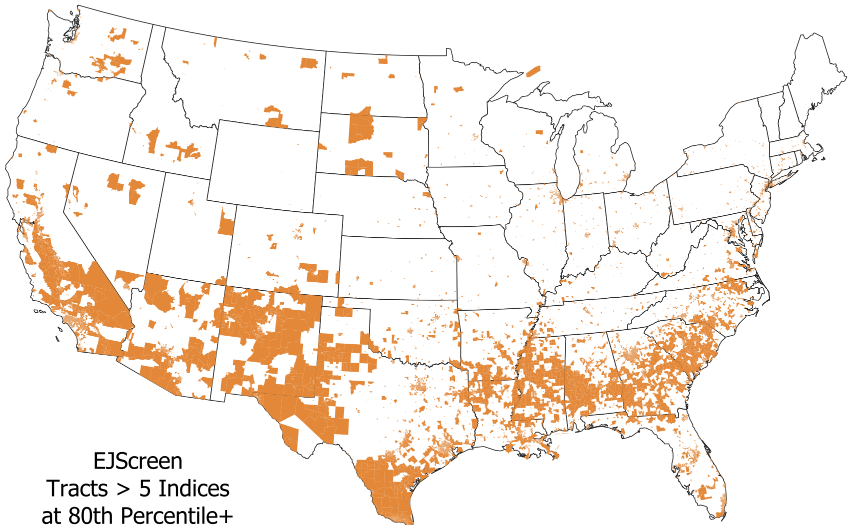
EJ Screen (Environmental Protection Agency:

- A tract that has more than five EJ Indexes exceeding the 80th percentile AND at least one Supplemental Index exceeding the 80th percentile.

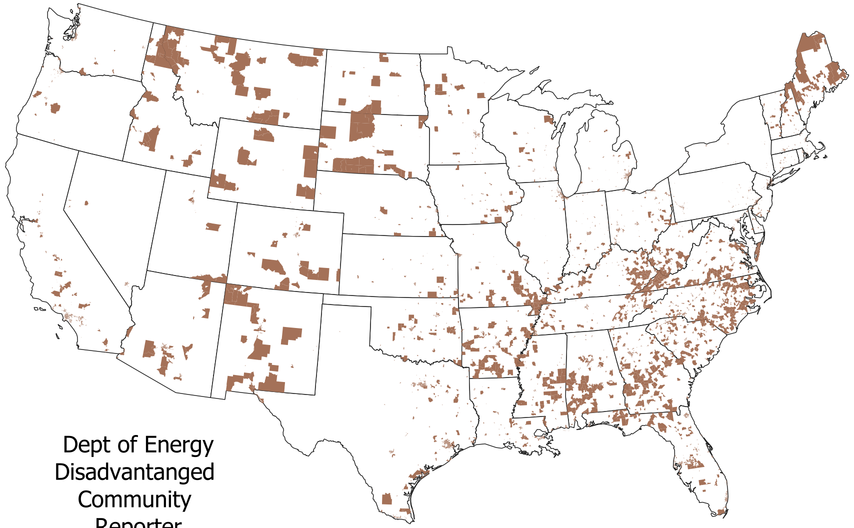
Different approaches to EJ communities



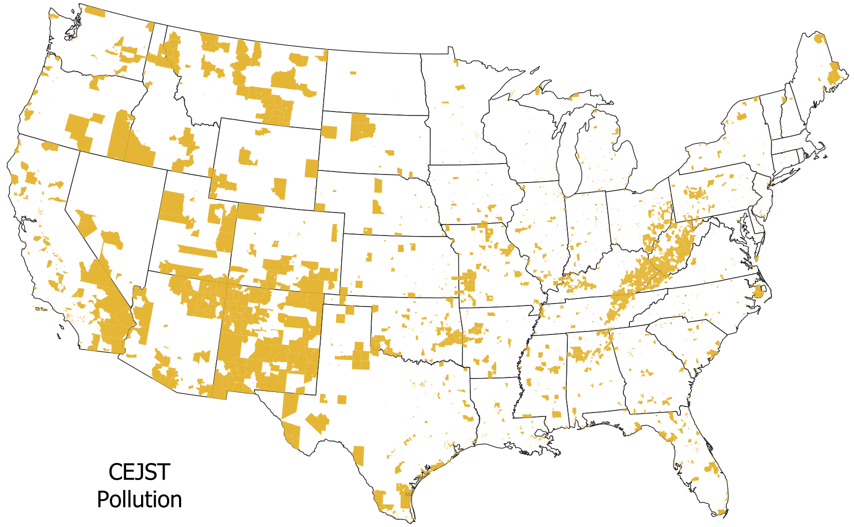
Social Vulnerability Index
> 85th Percentile



EJScreen
Tracts > 5 Indices
at 80th Percentile+



Dept of Energy
Disadvantanged
Community
Reporter



CEJST
Pollution

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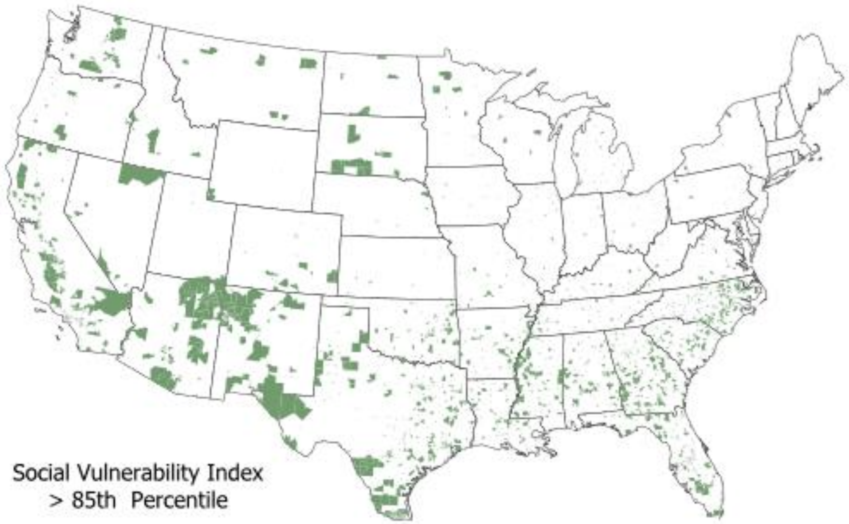
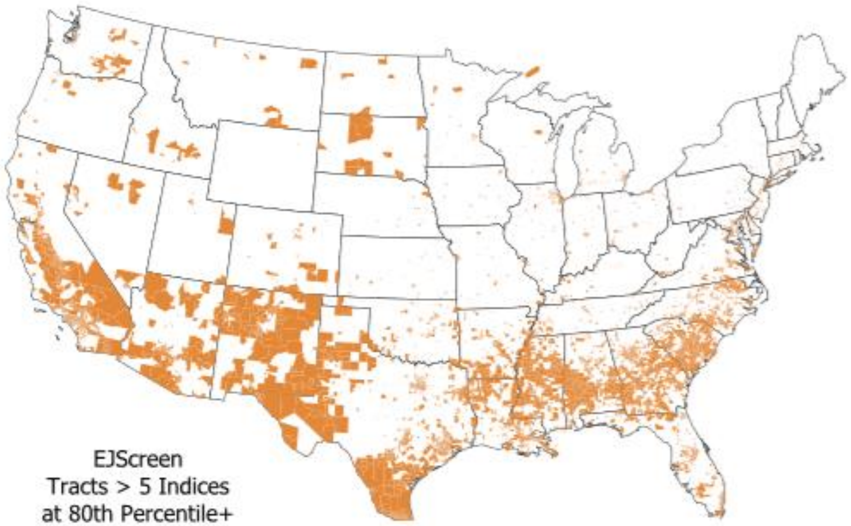
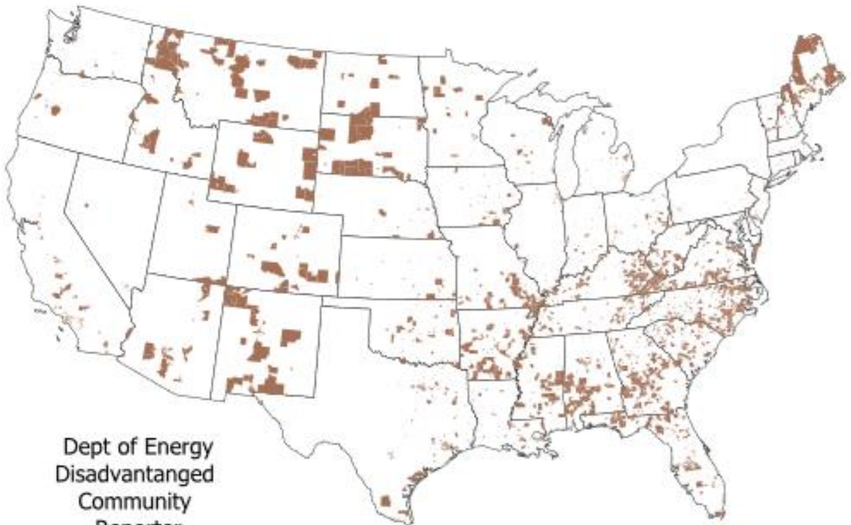
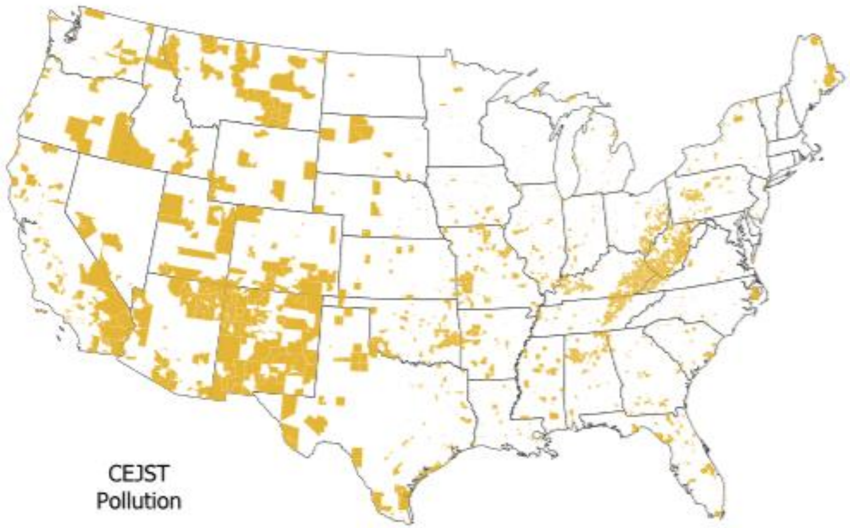
Different approaches to EJ communities









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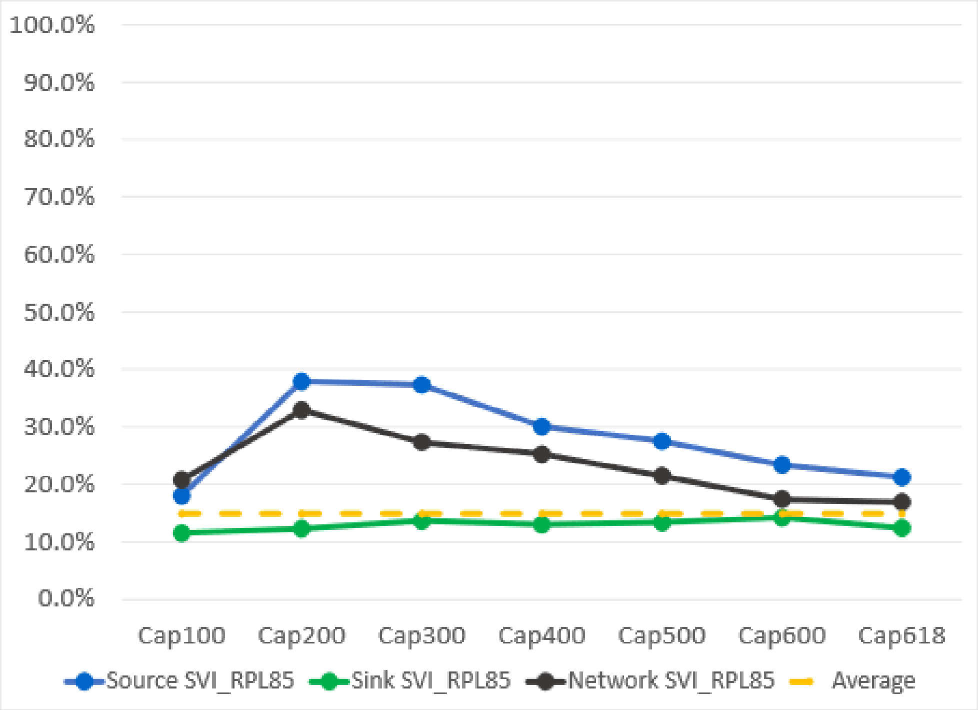
Count of Qualifying EJ Tracts

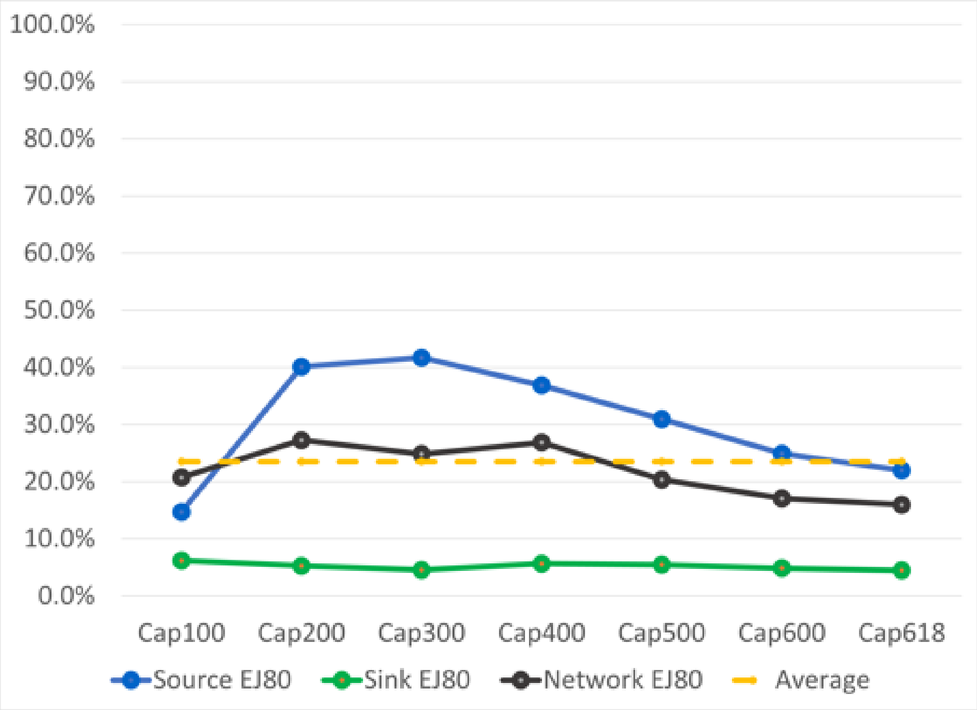
	DCR National	CEJST Pollution	EJ Screen	SVI
Count of Census Tracts	74,170	74,134	86,081	84,122
% of DAC-EJ Census Tracts (count)	20.5% (15,172)	12.3% (9,135)	23.5% (20,211)	14.9% (12,504)

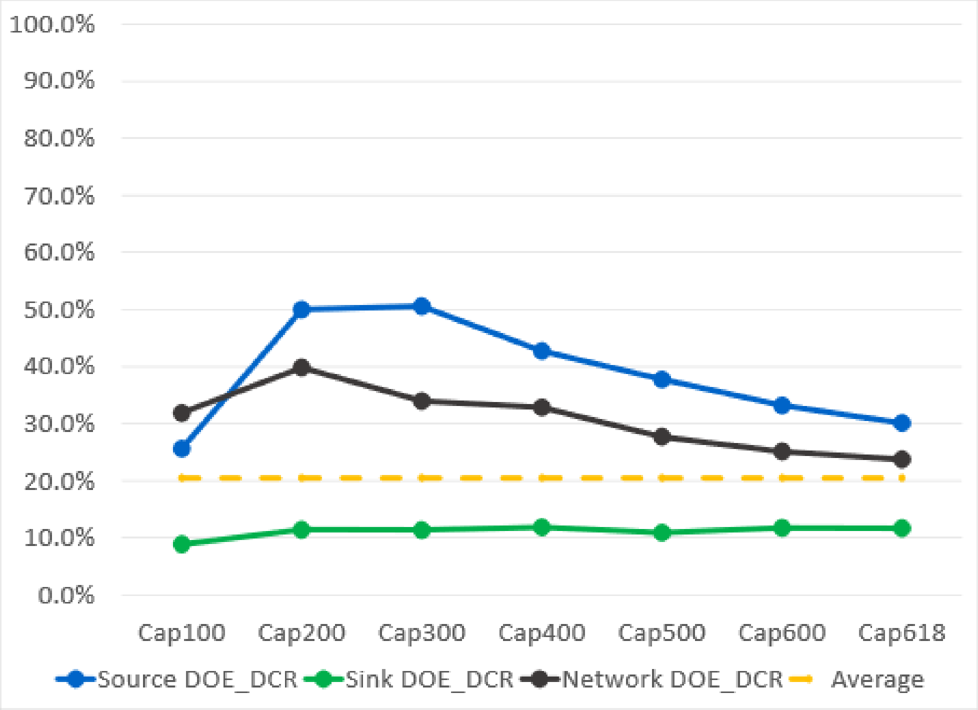
Identifying CCS Infrastructure in EJ Communities

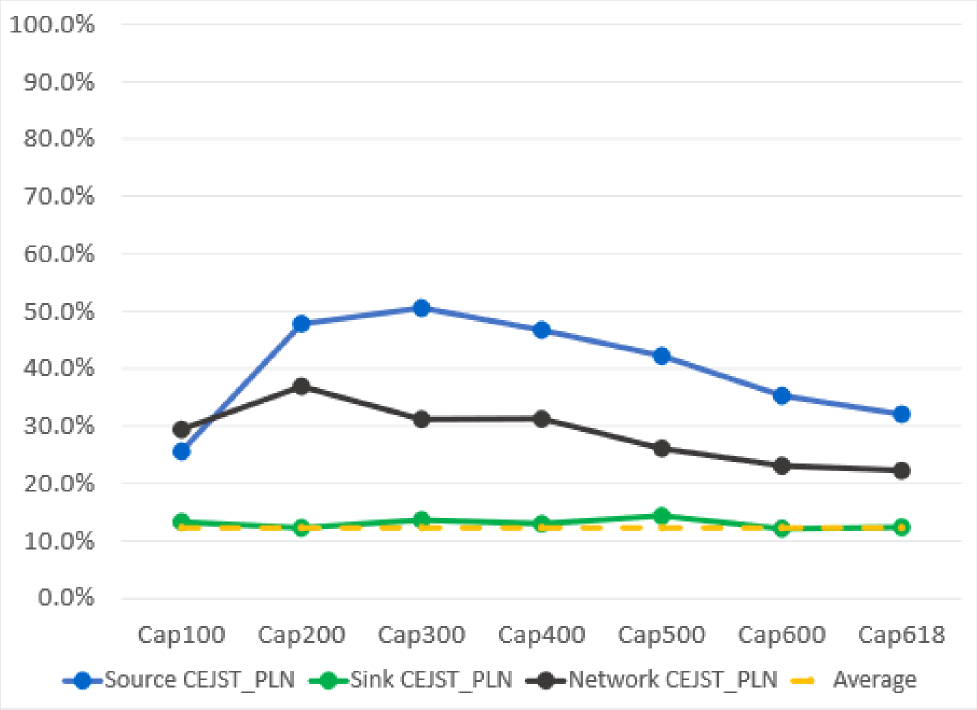
$$\frac{\text{Count of EJ tracts where } x \text{ activity took place}}{\text{All tracts where } x \text{ activity took place}} = \% \text{ of Impacted EJ Tracts for } x$$

Where *x* can be either capture, transport, or storage of CO_2









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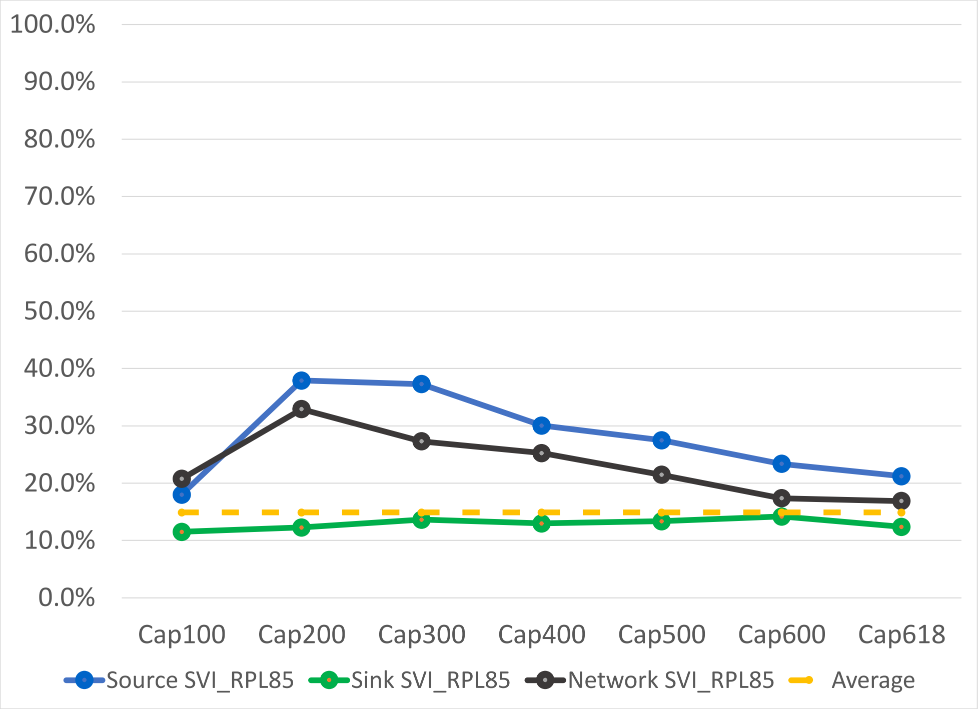

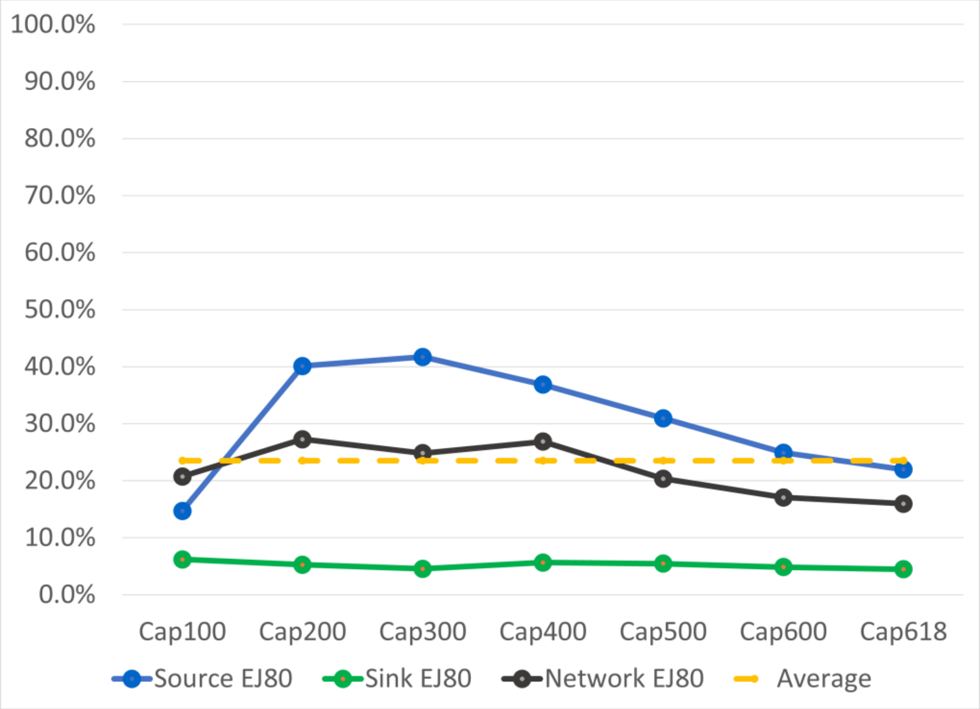

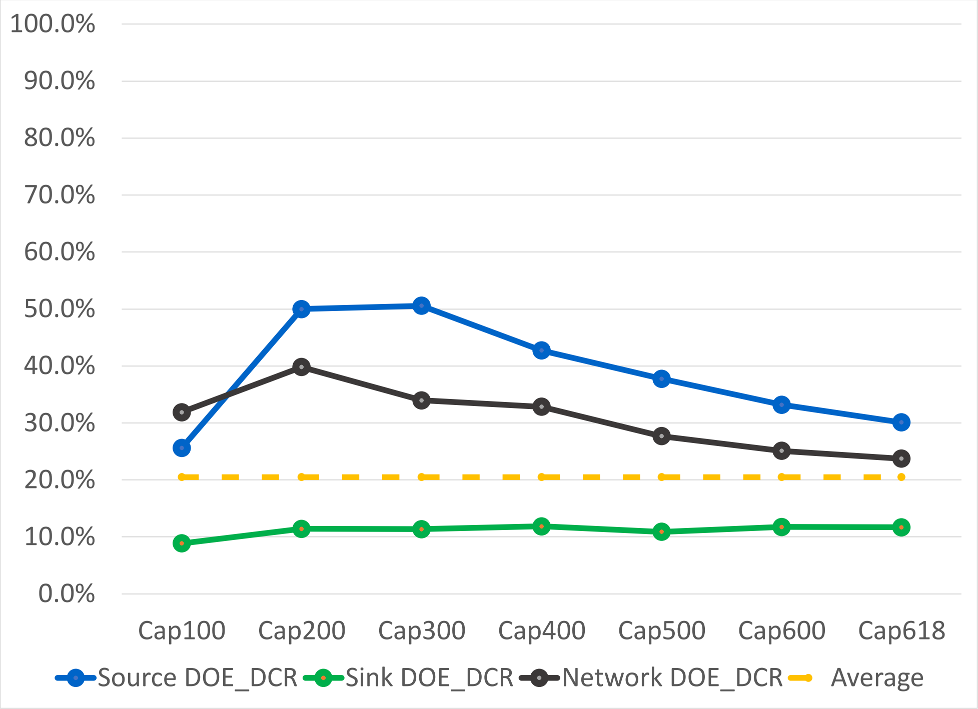

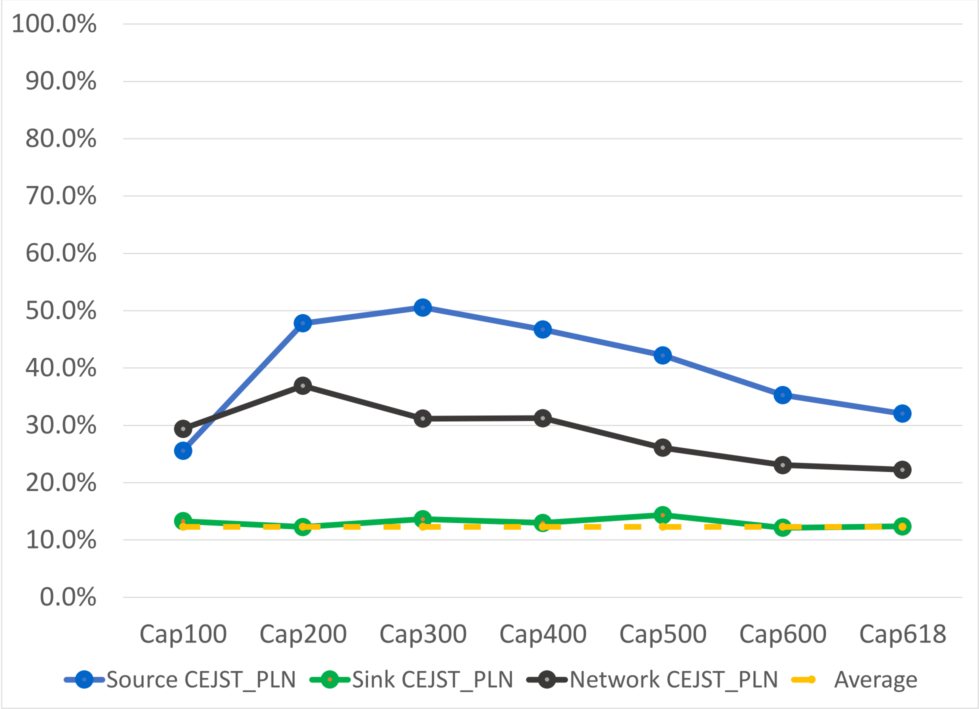

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Key Takeaways

Defining EJ Communities

- Wide range of qualifying EJ tracts depending on definitions.
- Importance of using different definitions to better understand CCS infrastructure impact.

Capture:

- Important to understand how capturing CO_2 will impact DAC-EJ communities given that capture are in a larger percentage of these communities.

Thanks!

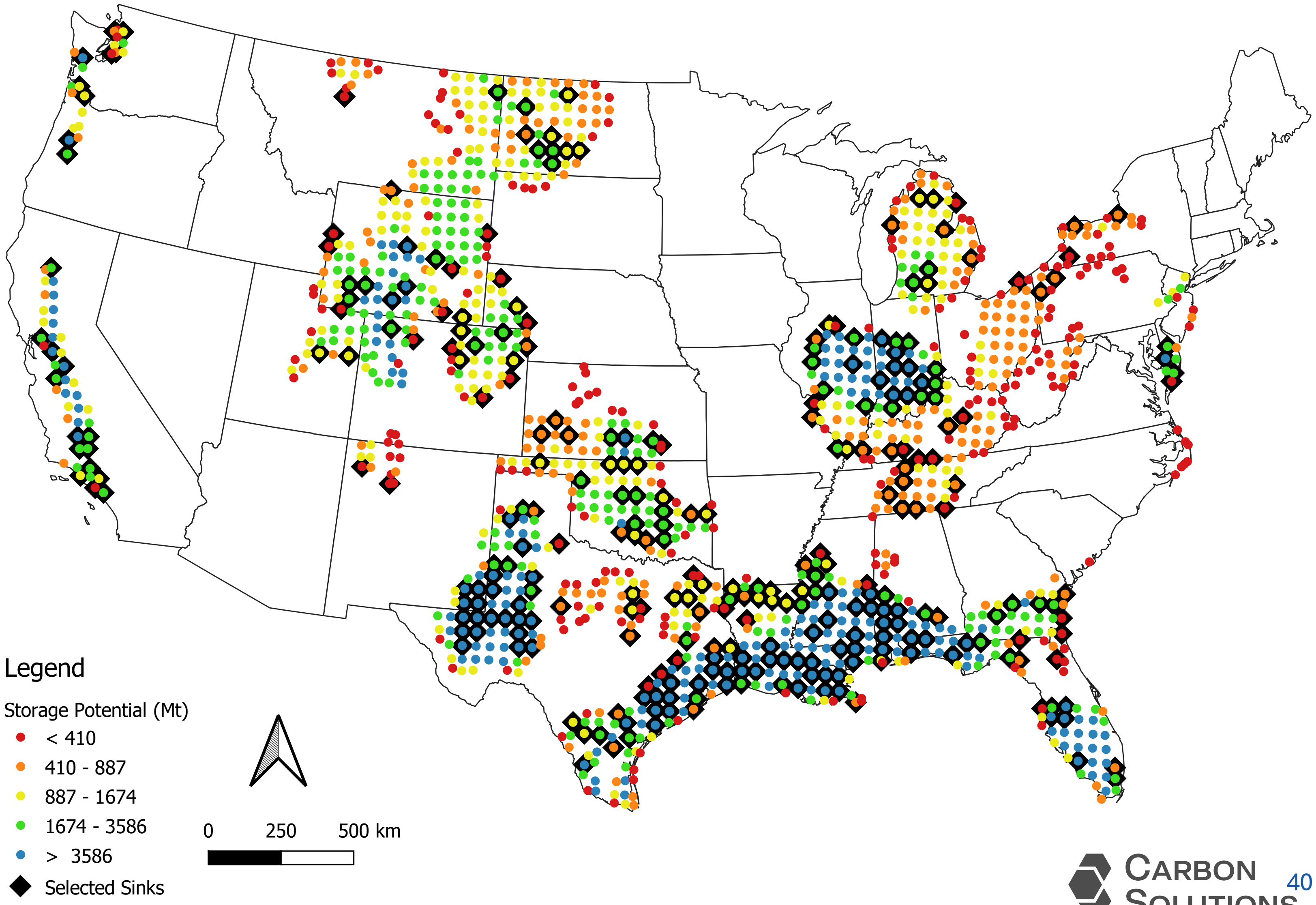
Full report, presentation, & webinar recording will be available on www.carbonsolutionsllc.com

Additional slides

Why are geology costs so consistently low?

Possible versus selected

- In most areas, inexpensive storage appears to be available
- What remains unclear: how first projects will impact subsequent projects



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