CO_2 on the Move! Transportation Challenges and Opportunities

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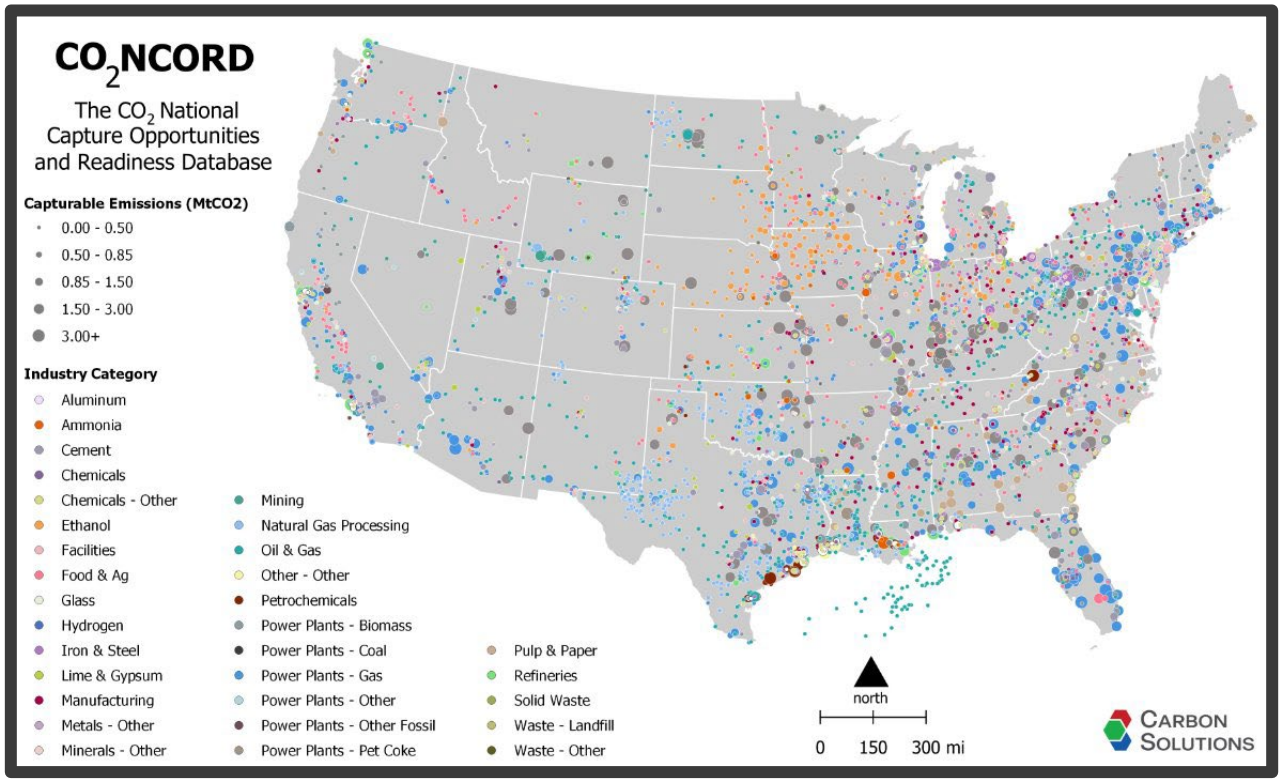
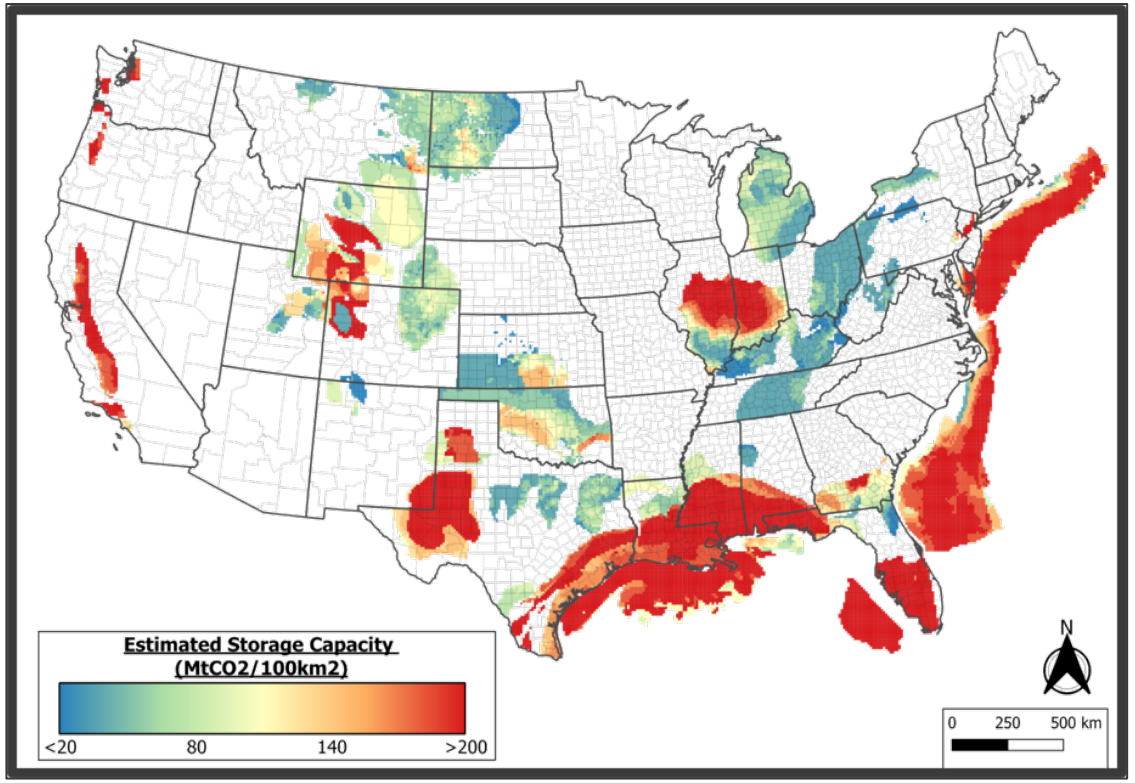
November 20 2024

Carbon Solutions

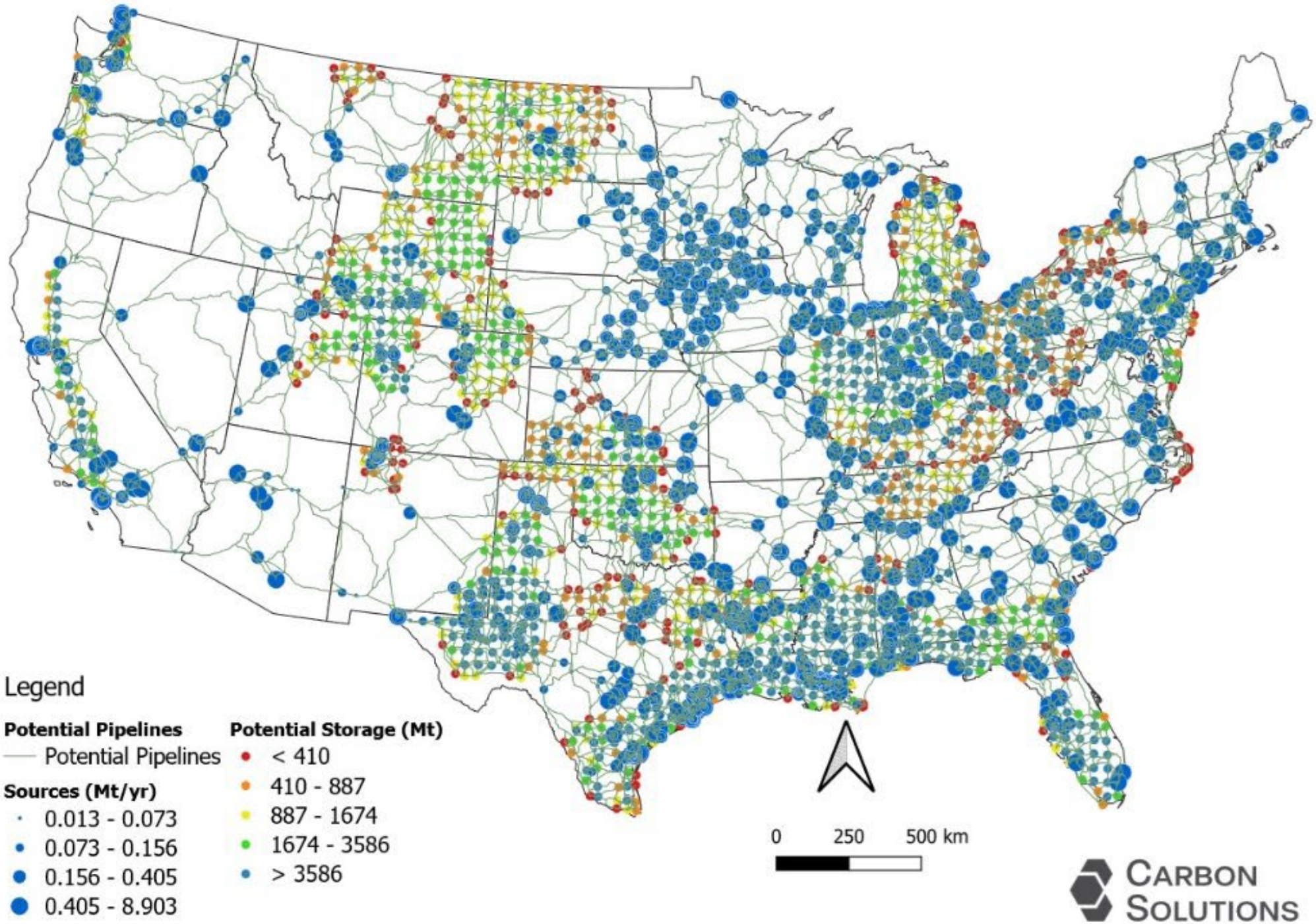
By 2050, U.S. CCS demand will reach 1-1.7 billion tonnes CO_2/yr[1]. Not all CO_2 is located near a suitable CO_2 storage location.





[1] *E. Larson, C. Greig, J. Jenkins, E. Mayfield, A. Pascale, C. Zhang, J. Drossman, R. Williams, S. Pacala,R.Socolow, EJ Baik, R. Birdsey, R. Duke, R. Jones, B. Haley,E. Leslie, K.Paustian, and A. Swan, Net-Zero America: Potential Pathways, Infrastructure, and Impacts, Final report, Princeton University, Princeton, NJ, 29 October 2021*

CO_2 transportation is the missing link in the carbon management value chain.



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Pipelines are typically the safest, cheapest CO_2 transportation option. Rail, truck, barge, and ships play a role in certain situations.

	M$/yr													
Mt														
2	0.14	1.40	7.01	14.02	28.03	42.05	56.07	70.08	84.10	140.16	210.24	280.33	350.41	420.49
0.95	0.12	1.20	6.02	12.03	24.06	36.09	48.12	60.15	72.18	120.31	179.75	235.52	276.28	317.60
0.9	0.12	1.19	5.97	11.94	23.87	35.81	47.74	59.68	71.62	118.18	170.98	223.65	262.41	301.74
0.85	0.12	1.18	5.92	11.84	23.68	35.52	47.37	59.21	71.05	111.98	162.21	211.78	248.55	285.88
0.8	0.12	1.17	5.87	11.75	23.49	35.24	46.99	58.73	70.02	105.79	153.44	199.90	234.68	270.02
0.75	0.12	1.17	5.83	11.65	23.30	34.96	46.61	57.78	65.88	99.59	144.67	188.03	220.82	254.16
0.7	0.12	1.16	5.78	11.56	23.12	34.67	46.23	54.16	61.74	93.40	135.90	176.16	206.95	238.30
0.65	0.11	1.15	5.73	11.46	22.93	34.39	43.59	50.54	57.61	87.20	127.13	164.29	193.08	222.44
0.6	0.11	1.14	5.68	11.37	22.74	34.11	40.49	46.91	53.47	81.00	118.36	152.42	179.22	206.58
0.55	0.11	1.13	5.64	11.27	22.55	31.60	37.38	43.29	49.33	74.81	109.59	140.54	165.35	190.72
0.5	0.11	1.12	5.59	11.18	22.36	29.01	34.27	39.67	45.20	68.61	100.82	128.67	151.49	174.86
0.45	0.11	1.11	5.54	11.09	21.79	26.41	31.17	36.05	41.06	62.42	92.05	116.80	137.62	159.01
0.4	0.11	1.10	5.50	10.99	19.72	23.82	28.06	32.43	36.92	56.22	83.28	104.93	123.76	143.15
0.35	0.11	1.09	5.45	10.90	17.64	21.23	24.95	28.80	32.79	50.03	74.51	93.06	109.89	127.29
0.3	0.11	1.08	5.40	10.80	15.56	18.64	21.84	25.18	28.65	43.83	65.74	81.19	96.02	111.43
0.25	0.11	1.07	5.35	10.71	13.48	16.04	18.74	21.56	24.51	37.63	56.98	69.31	82.16	95.57
0.2	0.11	1.06	5.31	9.49	11.40	13.45	15.63	17.94	20.38	31.44	47.15	57.44	68.29	79.71
0.15	0.11	1.05	5.26	7.92	9.33	10.86	12.52	14.32	16.24	25.24	37.28	45.57	54.43	63.85
0.1	0.10	1.04	5.21	6.36	7.25	8.27	9.41	10.69	12.10	19.05	27.40	33.70	40.56	47.99
0.06	0.10	1.03	4.92	5.11	5.59	6.19	6.93	7.80	8.79	14.09	19.49	24.20	29.47	35.30
0.055	0.10	1.03	4.79	4.96	5.38	5.93	6.62	7.43	8.38	13.47	18.51	23.01	28.08	33.71
0.05	0.10	1.03	4.66	4.80	5.17	5.67	6.31	7.07	7.97	12.85	17.52	21.83	26.70	32.13
0.045	0.10	1.03	4.53	4.64	4.96	5.42	6.00	6.71	7.55	12.23	16.53	20.64	25.31	30.54
0.04	0.10	1.03	4.40	4.49	4.76	5.16	5.69	6.35	7.14	11.61	15.54	19.45	23.92	28.96
0.035	0.10	1.03	4.27	4.33	4.55	4.90	5.38	5.99	6.73	10.99	14.56	18.26	22.54	27.37
0.03	0.10	1.03	4.14	4.17	4.34	4.64	5.06	5.62	6.31	10.37	13.57	17.08	21.15	25.78
0.025	0.10	1.03	4.01	4.02	4.13	4.38	4.75	5.26	5.90	9.75	12.58	15.89	19.76	24.20
0.02	0.10	1.03	3.88	3.86	3.92	4.12	4.44	4.90	5.48	9.04	11.59	14.70	18.38	22.61
0.015	0.10	1.03	3.75	3.71	3.72	3.86	4.13	4.54	5.07	8.26	10.60	13.52	16.99	21.03
0.01	0.10	1.03	3.62	3.55	3.51	3.60	3.82	4.17	4.66	7.47	9.62	12.33	15.60	19.44
Km	1	10	50	100	200	300	400	500	600	1,000	1,500	2,000	2,500	3,000

Pipeline
Rail Intermodal
Rail Tanker
Truk Intermodal
Truck Tanker

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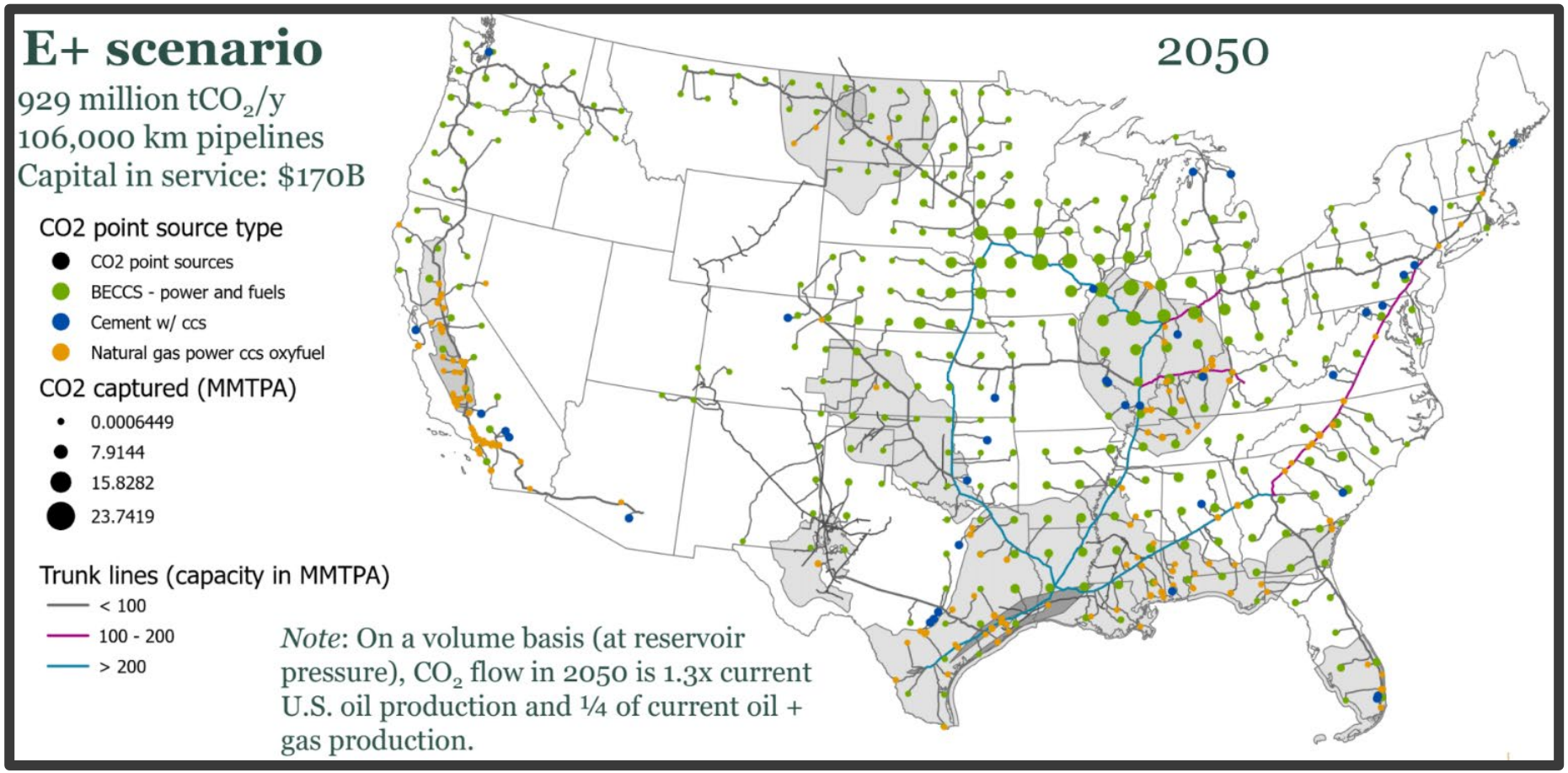
The U.S. may need 66,000 miles of new CO_2 pipelines by 2050 to support CCS demand.



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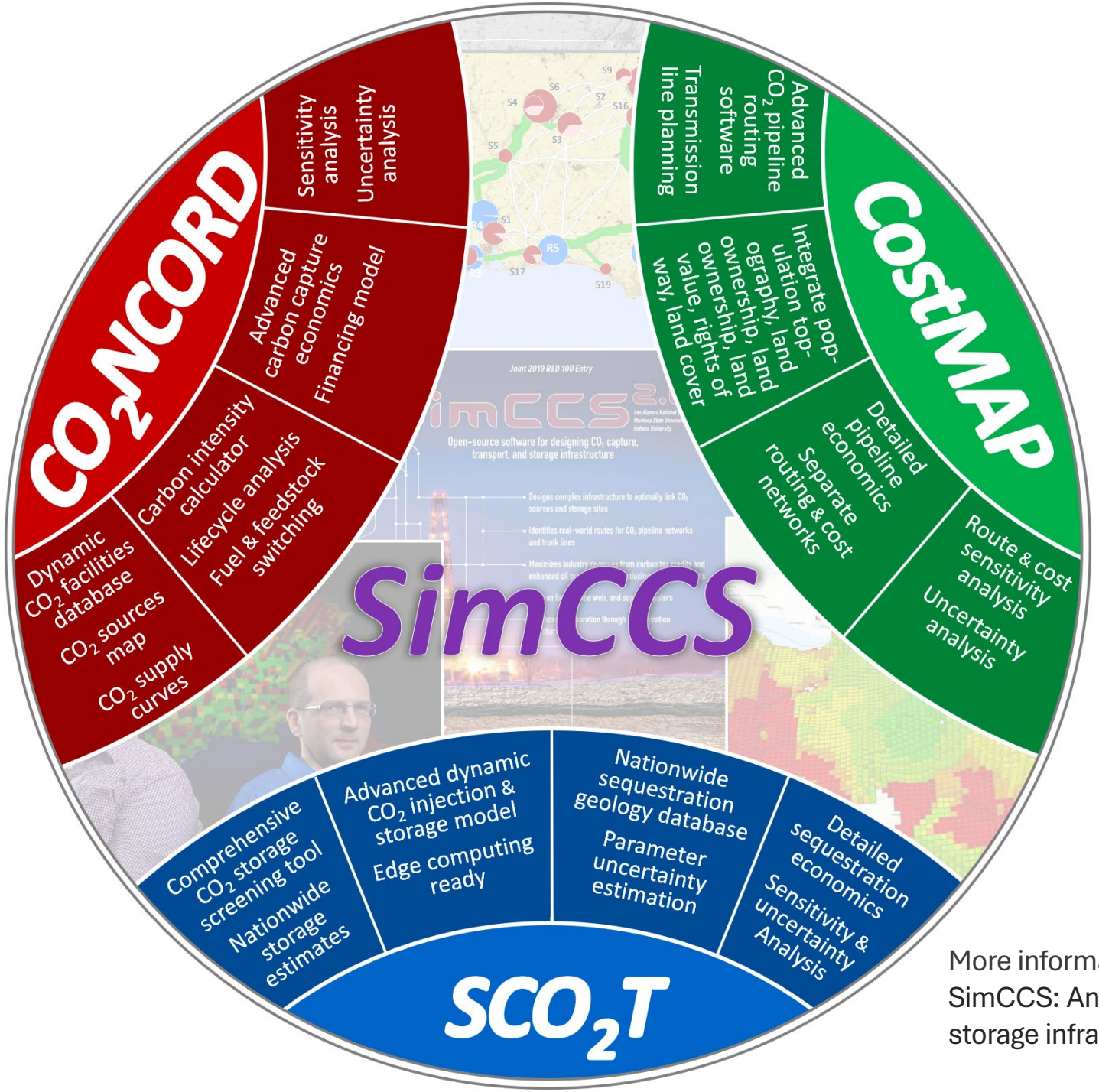
CARBON SOLUTIONS leverages our award-winning software and interdisciplinary experts to drive CO_2 transportation solutions.



SimCCS^{PRO} Software

SimCCS^{PRO} (system analysis)

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

CO_2NCORD (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).

While CO_2 transportation is a critical piece of the carbon management value chain, it presents both technical, economic, regulatory, and social challenges.

Addressing unique properties of CO_2 and impurities in CO_2 streams requires careful materials selection.

- CO_2 is transported at high pressure to maintain dense phase (liquid or supercritical).
- CO_2 system is subjected to rapid cooling and very low temperatures during depressurization.
- Pipelines are susceptible to fracture propagation
- Non-metallic components can be susceptible to damage from rapid gas depressurization
- In presence of impurities such as water, CO_2 is highly corrosive.
- Rapid gas depressurization

Composition of CO_2 streams vary from source to source; these components can affect pipeline performance.

- Some components such as N_2 can substantially change compression requirements.
- Some components such as water combined with CO_2 to are highly corrosive
- Some components, such as H_2S can affect permit conditions for geologic storage wells.

Repurposing existing pipelines for CO_2 service can be possible, but has limitations.

- Existing lines are often rated for lower pressures than required for dense phase CO_2 service.
- Condition assessment and review of construction/maintenance records is important to evaluate suitability for CO_2.
- Upgrades for service conversion can be cost prohibitive/

Lack of clarity and inconsistencies in siting and permitting requirements lead to delays in CO_2 pipeline projects.

- There is no federal authority for permitting/siting interstate CO_2 pipelines.
- Permitting regimes at the state levels vary; not all states have clearly delineated regulations governing pipeline CO_2 siting.
- Some state and local jurisdictions may have additional permitting or other statutory/regulatory requirements.

Regulatory uncertainty adds financial risk to projects and can lead to project delays.

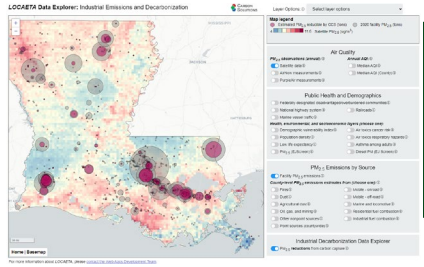
- DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA) is currently undertaking a rulemaking in response to 2020 Satartia, MS CO_2 pipeline rupture.
- 45Q tax credit currently expires after 12 years; currently there are no announced plans to extend the credit.
- EPA regulations pertaining to CO_2 emissions control are contested.
- Some states and localities have on going efforts to promote or restrict CCS activities.

Community engagement can make or break a project.

- Public opposition to CO2 pipeline projects can be significant in some areas and can lead to permitting delays and project cancellations.
- Proactive, early engagement with stakeholders is critical to managing reception to the project in communities.
- Evaluation of environmental , economic, and social impacts of CO2 is needed to address stakeholder concerns.
- Delivering benefits to communities is critical to project success.

CARBON SOLUTIONS provides innovative support and approached for community engagement.

- Interactive community maps enable identification and exploration of information stakeholders are interested in around project areas.
- The Local Air Quality Emissions Tracking Atlas, *LOCAETA* is a tool to **identify community impacts from industrial emissions** and to help **estimate the air quality health benefits from decarbonizing** these facilities to specific communities.



LOCAETA Data Explorer

Co-benefits analysis

GHGRP → NEI → co-benefits

Lives saved
$ saved
Policy

Air quality, public health, economic modeling

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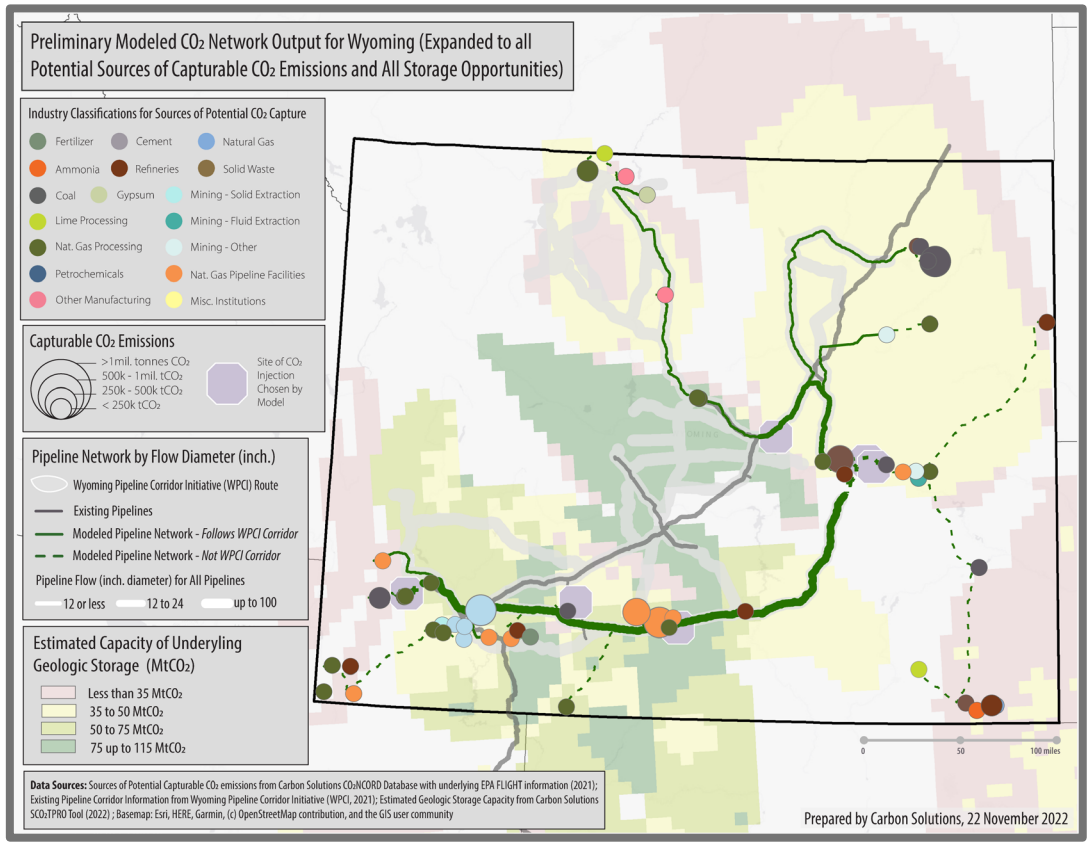
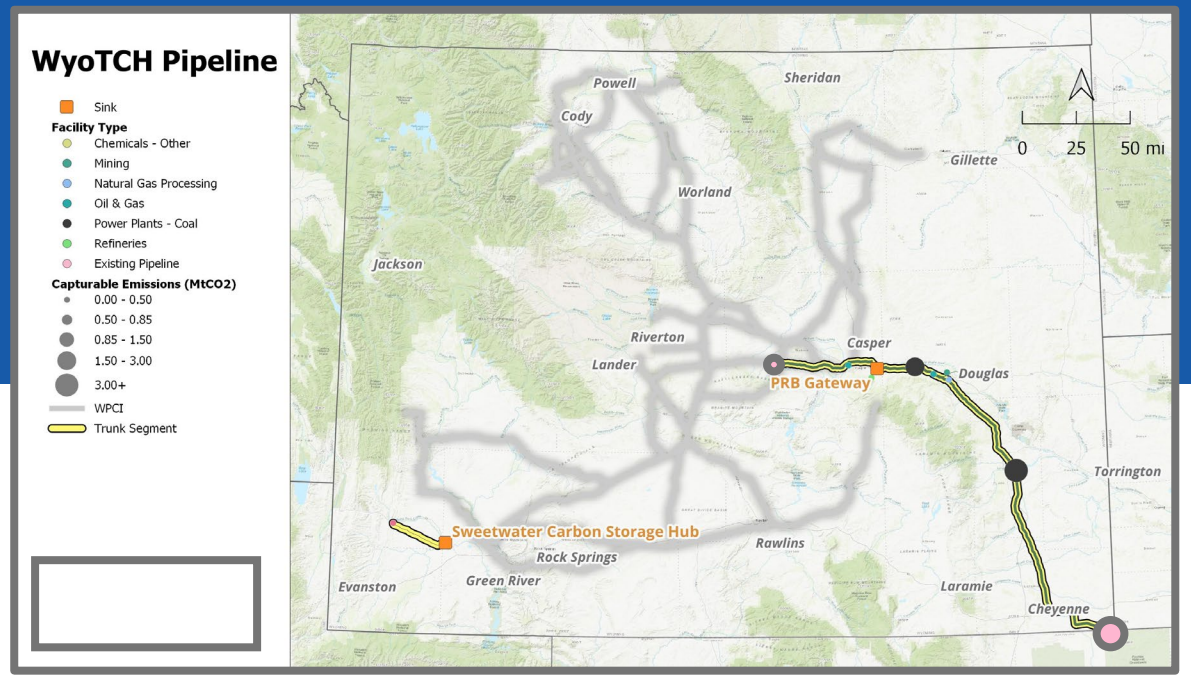
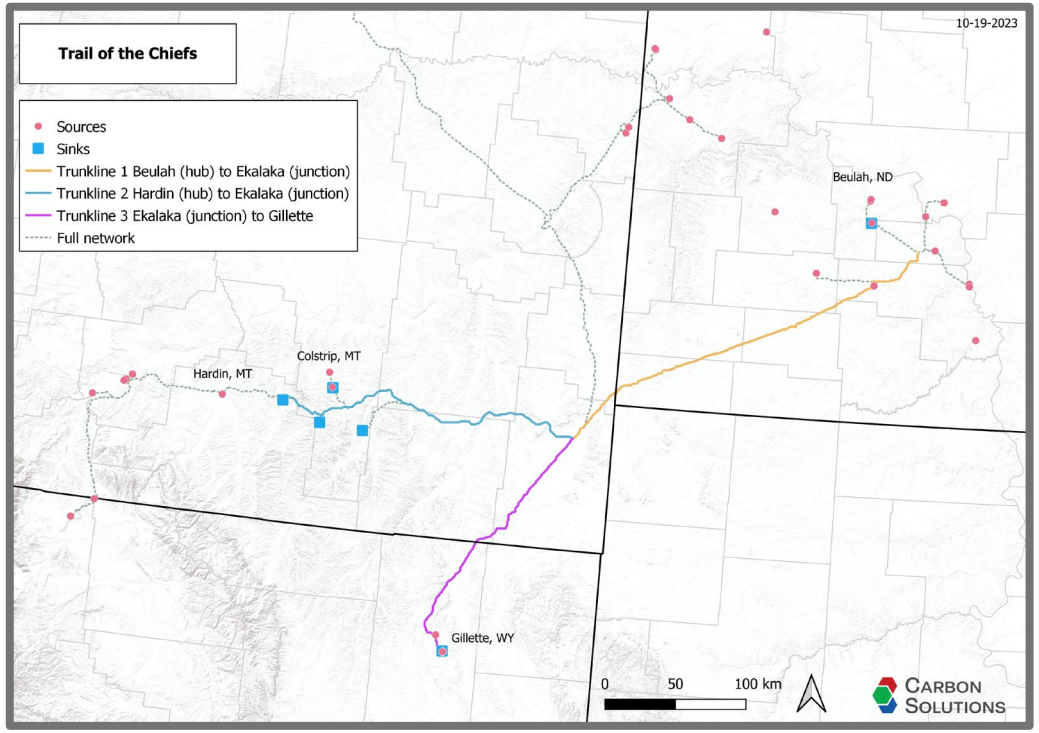
The CO_2 transportation sector is evolving to seize opportunities and tackle challenges in connecting CO_2 sources and sinks.

- Federal funding via DOE grant and loan programs
- PHMSA CO_2 transportation rulemaking
- DOE CO2 Transport Research, Development & Demonstration Consortium
- Congressional research service reports
- Industry standards and initiatives

CARBON SOLUTIONS is at the forefront of tackling CO2 transportation challenges.







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Questions?

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