REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

Regional CO_2 Transport Infrastructure

for US Midcentury Decarbonization

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Director of Research
Great Plains Institute
July 20, 2020

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Facilitated by GPI:

STATE CARBON CAPTURE WORK GROUP

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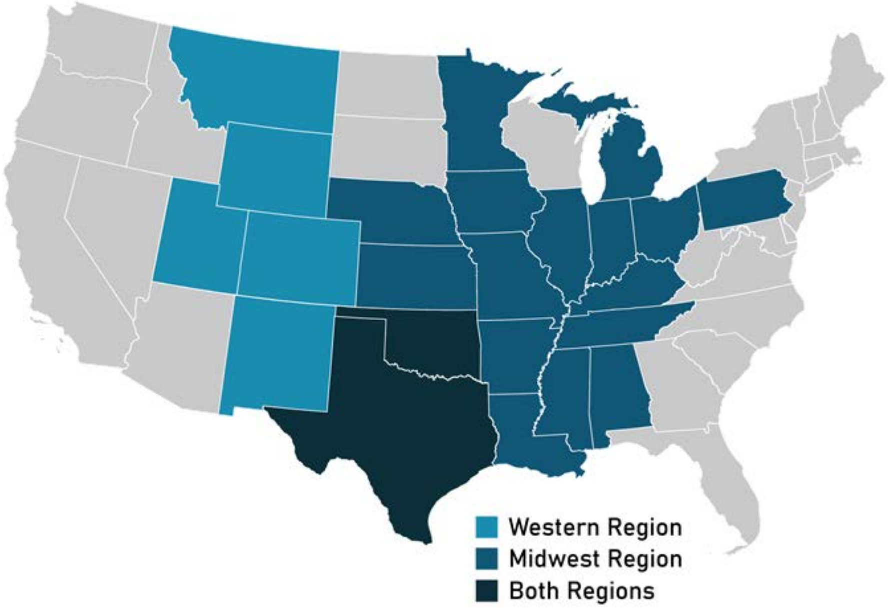
CARBON CAPTURE COALITION



State Participation in the Regional Deployment Initiative

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State & Regional Efforts on Carbon Capture

STATE CARBON CAPTURE WORK GROUP

2015 — State Carbon Capture Work Group led by **Gov. Mead (WY) and Gov. Bullock (MT)**.

2016 — Work Group, comprised of **more than a dozen states**, develops comprehensive policy recommendations on carbon capture.

2017 — Work Group publishes additional papers on CO2 transport infrastructure, electricity market issues and opportunities for carbon capture and ethanol.

Early 2018 — Work Group shifts from learning to action and launches **Regional Carbon Capture Deployment Initiatives in Midwest and Western regions**.

Analytical research initiated.

REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

Fall 2018 — **Regional stakeholders across 25 states** meet to evaluate initial analysis and begin to identify near-to medium-term opportunities for deployment.

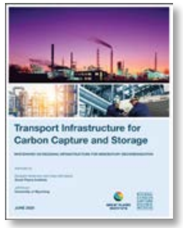
2019 — RDI work broadens to focus **on state policies and other regional efforts that can help close the “cost cap”** for carbon capture deployment.

Winter 2019 — **Carbon Capture Ready website** launched, providing states and stakeholders with best practices and other state-specific information relating to carbon capture.

2020 — **Analytical white paper** is published.

RDI is working with states to prepare for **2021 legislative session**.

States are also cooperating on **regional CO_2 transport infrastructure and hub** development.



CARBON CAPTURE COALITION

Unprecedented National Coalition in U.S. Energy & Climate Policy

Achieve economywide deployment of carbon capture to reduce emissions, foster domestic energy and industrial production, and support high-wage jobs.

Climate, jobs and energy/industrial benefits
unite diverse interests in a common purpose

Over 75 members, including industry, labor and environmental NGOs

To learn more and view our complete membership list, visit www.carboncapturecoalition.org

Participants

- Accelergy
- AFL-CIO
- Air Liquide
- Air Products
- AK Steel
- American Carbon Registry
- ArcelorMittal
- Arch Coal
- Archer Daniels Midland Co.
- Baker Hughes, a GE Company
- Bipartisan Policy Center
- Capital Power
- Carbon180
- Carbon Wrangler LLC
- Center for Climate and Energy Solutions
- Citizens for Responsible Energy Solutions Forum
- Clean Air Task Force
- ClearPath Foundation
- Cloud Peak Energy
- Conestoga Energy Partners
- Core Energy LLC
- DTE Energy
- EBR Development LLC
- EnergyBlue Project
- Energy Innovation Reform Project
- Glenrock Petroleum
- Great River Energy
- Greene Street Capital
- Impact Natural Resources LLC
- ION Engineering LLC
- International Brotherhood of Boilermakers
- International Brotherhood of Electrical Workers
- Jackson Hole Center for Global Affairs
- Jupiter Oxygen Corporation
- Lake Charles Methanol
- LanzaTech
- Linde LLC
- Mitsubishi Heavy Industries America, Inc.
- National Audubon Society
- National Farmers Union
- National Wildlife Federation
- NET Power
- New Steel International, Inc.
- NRG Energy
- Occidental Petroleum Corporation
- Pacific Ethanol
- Peabody
- Prairie State Generating Company
- Praxair Inc.
- Shell
- SMART Transportation Division (of the Sheet, Metal, Air, Rail and Transportation Workers)
- Summit Power Group
- Svante
- Tenaska Energy
- The Nature Conservancy
- Third Way
- Thunderbolt Clean Energy LLC
- United Mine workers of America
- United Steel Workers
- Utility Workers Union of America
- White Energy
- Wyoming Outdoor Council

Observers

- Algae Biomass Organization
- Biomass Power Association
- Carbon Engineering
- Carbon Utilization Research Council
- Chart Industries
- Cornerpost CO2 LLC
- Enhanced Oil Recovery Institute, University of Wyoming
- Environmental Defense Fund
- Growth Energy
- Institute of Clean Air Companies
- Melzer Consulting
- Renewable Fuels Association
- Tellus Operating Group
- World Resources Institute

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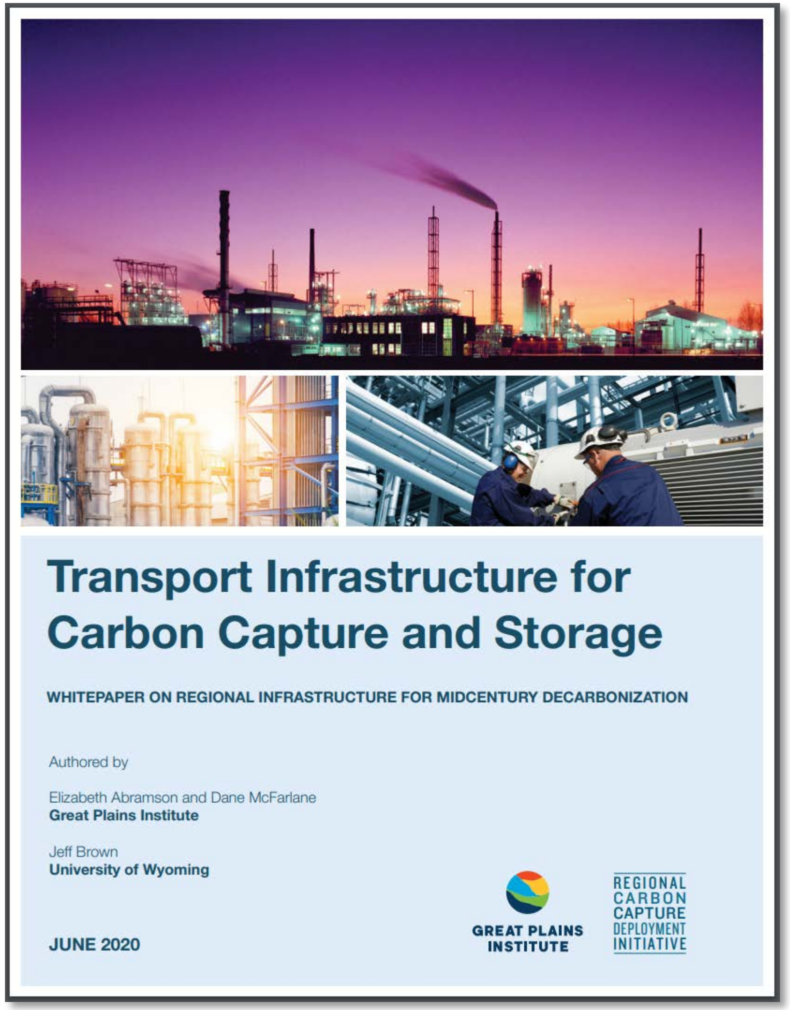
Regional Deployment Initiative
Analytical Report

Published June 30, 2020


Transport Infrastructure for Carbon Capture and Storage

WHITEPAPER ON REGIONAL INFRASTRUCTURE FOR MIDCENTURY DECARBONIZATION

Authored by

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Great Plains Institute

Jeff Brown
University of Wyoming

JUNE 2020

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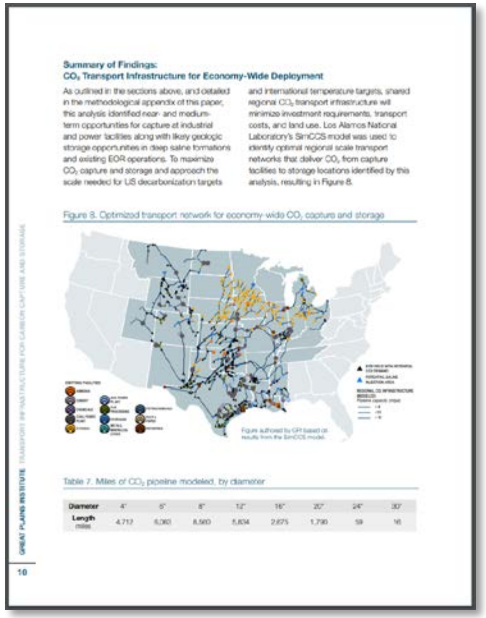
Summary of Findings:
CO_2 Transport Infrastructure for Economy-Wide Deployment

Figure 8. Optimized transport network for economy-wide CO_2 capture and storage

Table 7. Miles of CO_2 pipeline modeled, by diameter

10


Near-term planning and coordination of regional-scale infrastructure will enable significant decarbonization of the industrial and power sectors while creating a marketplace for direct air capture of CO_2 will require.

Economy-wide deployment of carbon capture and storage will help achieve net-zero or negative carbon emissions in the US.

This study has shown clear opportunities for wide-spread capture at low costs throughout the Midwest, Midcontinent, the Rockies, Northern Plains, Gulf Coast, and Texas.

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Download the paper at:

carboncaptureready.org/analysis

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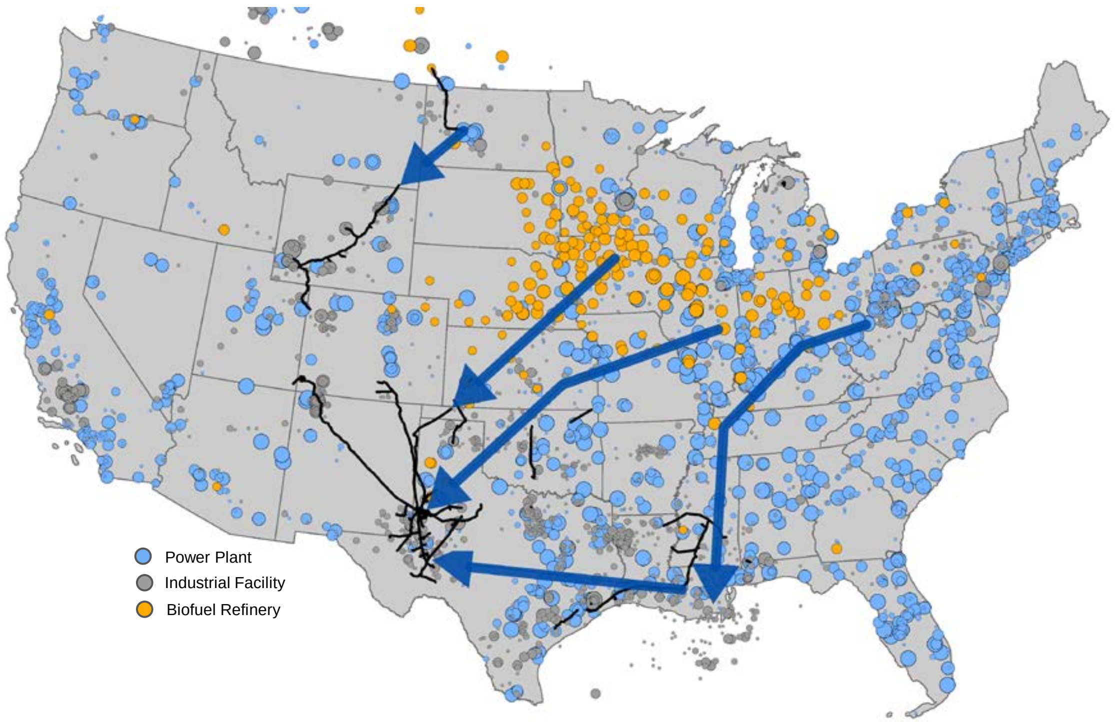
Regional CO_2 Transport Infrastructure Study

Study Components

1. Identify near-term opportunities for CO_2 capture retrofit
2. Locate areas of CO_2 storage and use
3. Model optimized CO_2 transport infrastructure

Initial CO_2 Corridor Scoping



Primary Partners:

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MONTANA STATE UNIVERSITY

B2 E2 BROWN BROTHERS ENERGY & ENVIRONMENT

INDIANA UNIVERSITY

Stanford University

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CO_2 Capture Opportunities: Industrial and Power Facilities

Section 45Q
Tax Credit for CO_2 Storage

Minimum Capture Thresholds

Industrial Facility: 100 thousand tons CO_2
Power Plants: 500 thousand tons CO_2

Near- and Medium-Term Screening Criteria:

- 45Q Eligibility
- Operational patterns
- Expected life
- Right-size capture equipment to specific units within each facility

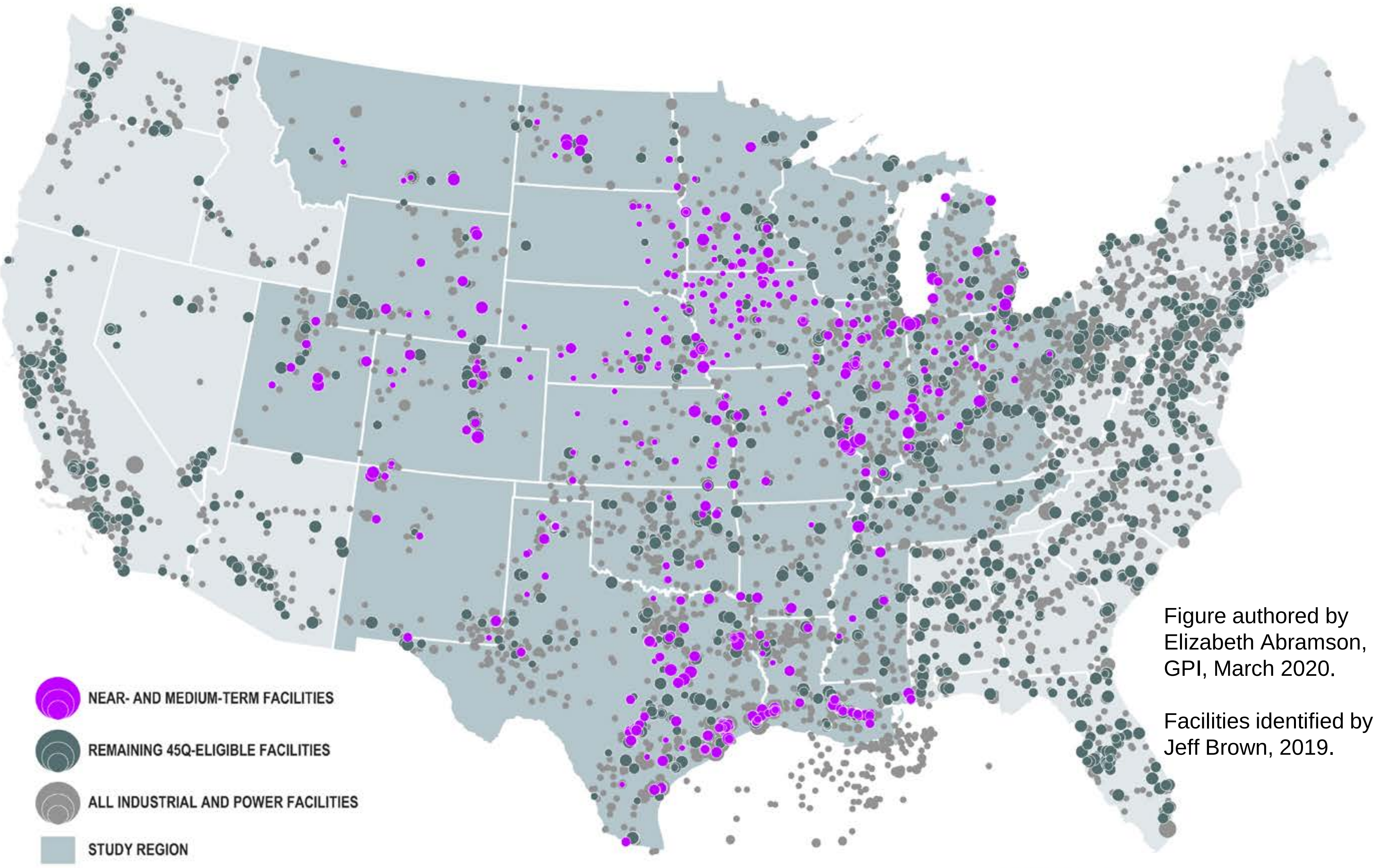

Figure authored by Elizabeth Abramson, GPI, March 2020.

Facilities identified by Jeff Brown, 2019.

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CO_2 Storage in Saline Formations & Petroleum Basins

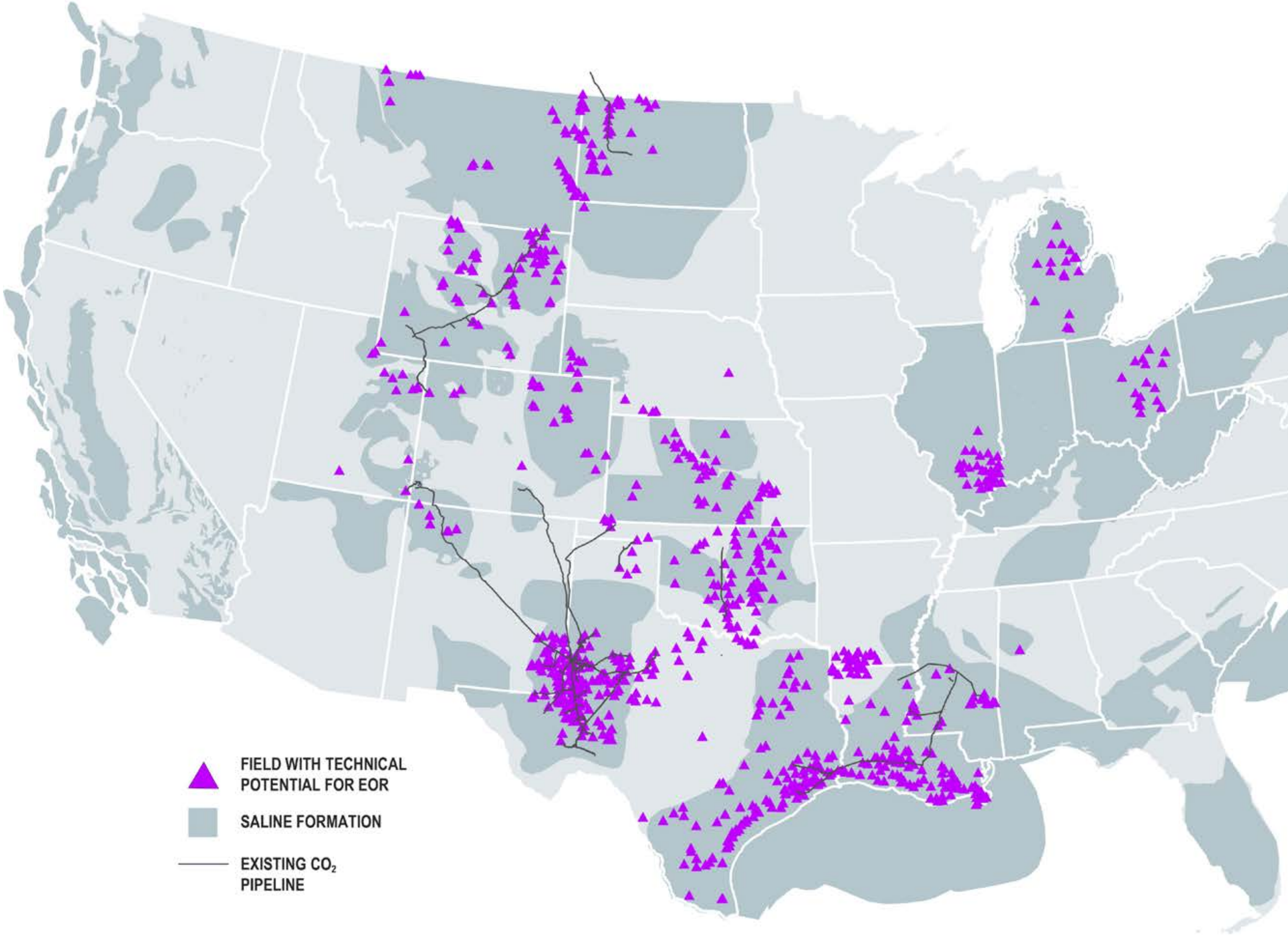
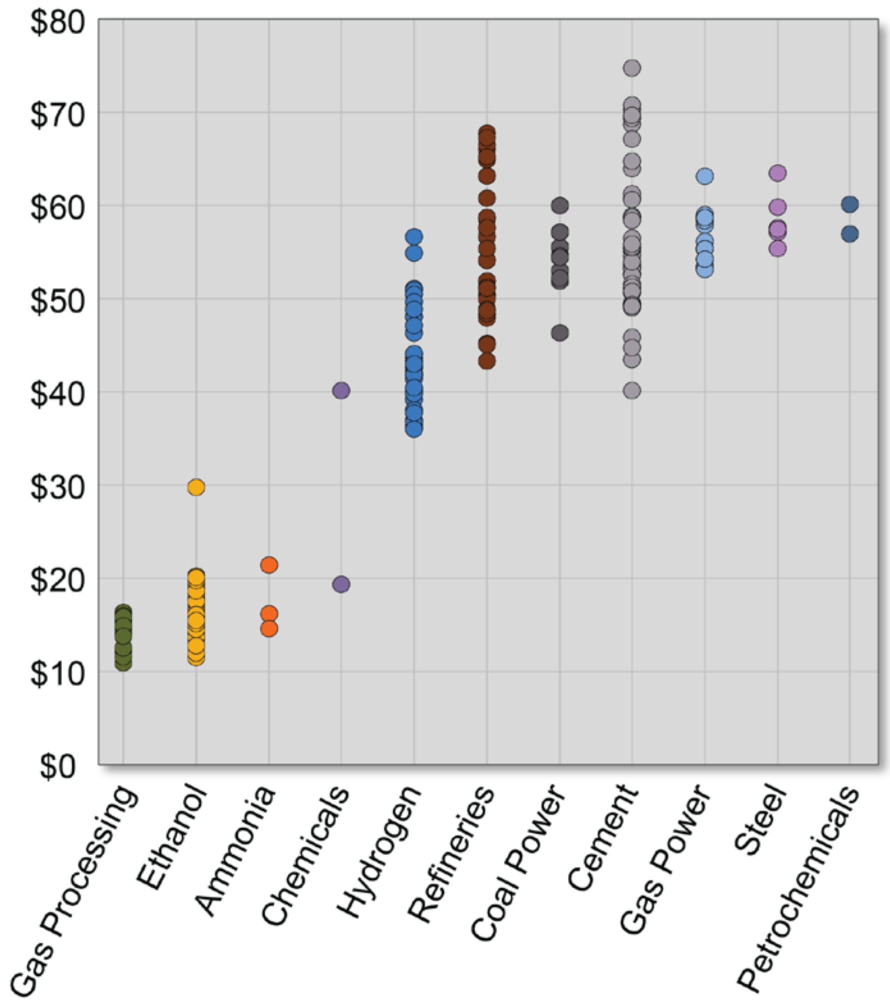


Figure authored by Elizabeth Abramson, GPI, March 2020

Data: DOE NATCARB 2016; ARI 2018.

Estimated Cost of Capture per Industry for Near-Term Facilities in Study Area



Industry	# of Facilities	Optimized Capture (mmt/year)	Average Estimated Cost $/ton
Ethanol	150	50.6	$17
Cement	45	32.7	$56
Refineries	38	26.5	$56
Steel	6	14.6	$59
Hydrogen	34	14.4	$44
Gas Processing	20	4.5	$14
Petrochemicals	2	1.7	$59
Ammonia	3	0.9	$17
Chemicals	2	0.7	$30
Coal Power Plant	58	143.4	$56
Gas Power Plant	60	67.9	$57
Grand Total	**418**	**357.8**	**$39**

Source: Jeff Brown, 2019

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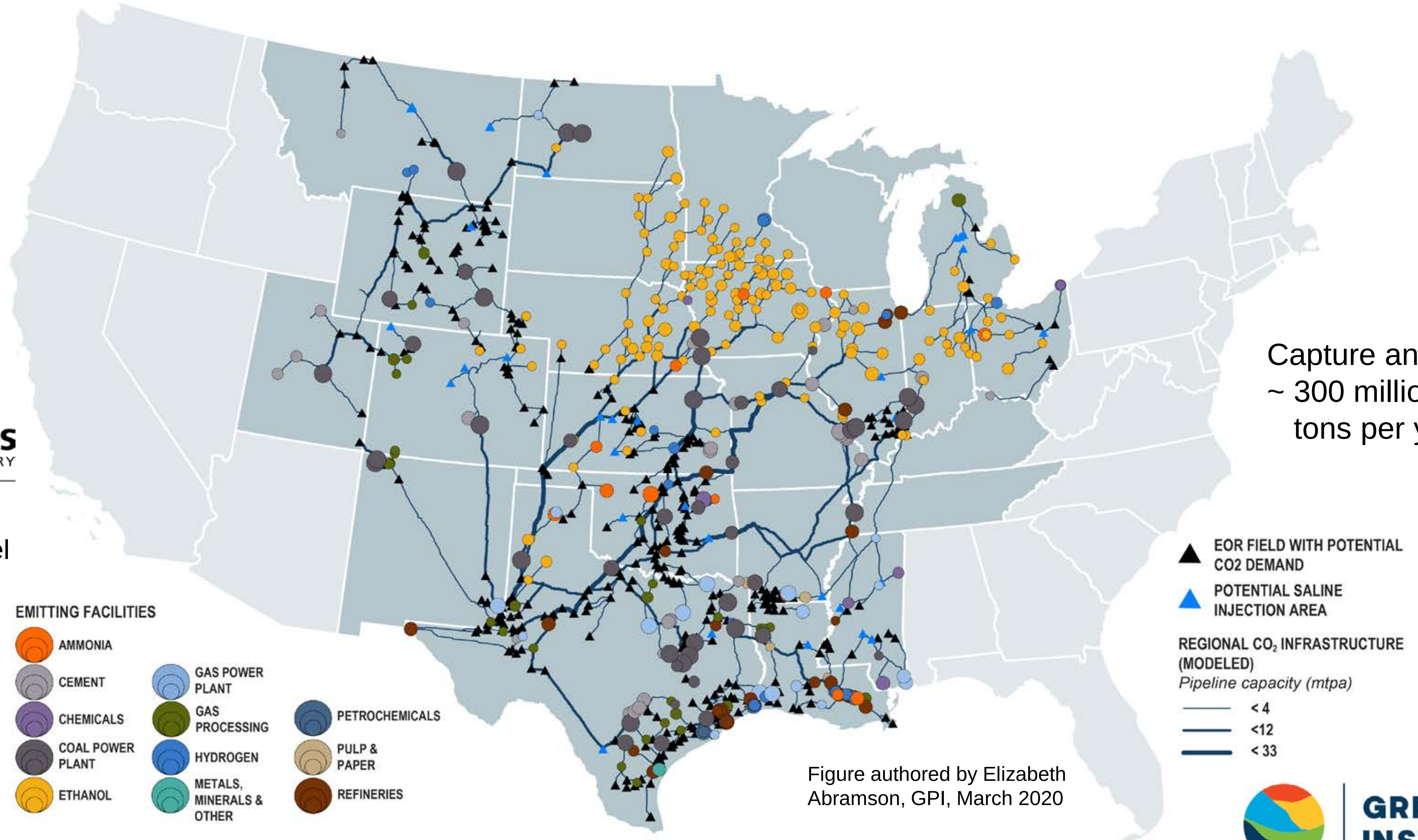
Near- and Medium-Term Scenario:
Optimized transport network for CO_2 capture and storage under 45Q



Capture and storage:
~ 300 million metric tons per year

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SimCCS CO_2 transport model

Figure authored by Elizabeth Abramson, GPI, March 2020

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Near- and Medium-Term Scenario:
Relative transport cost of network segments

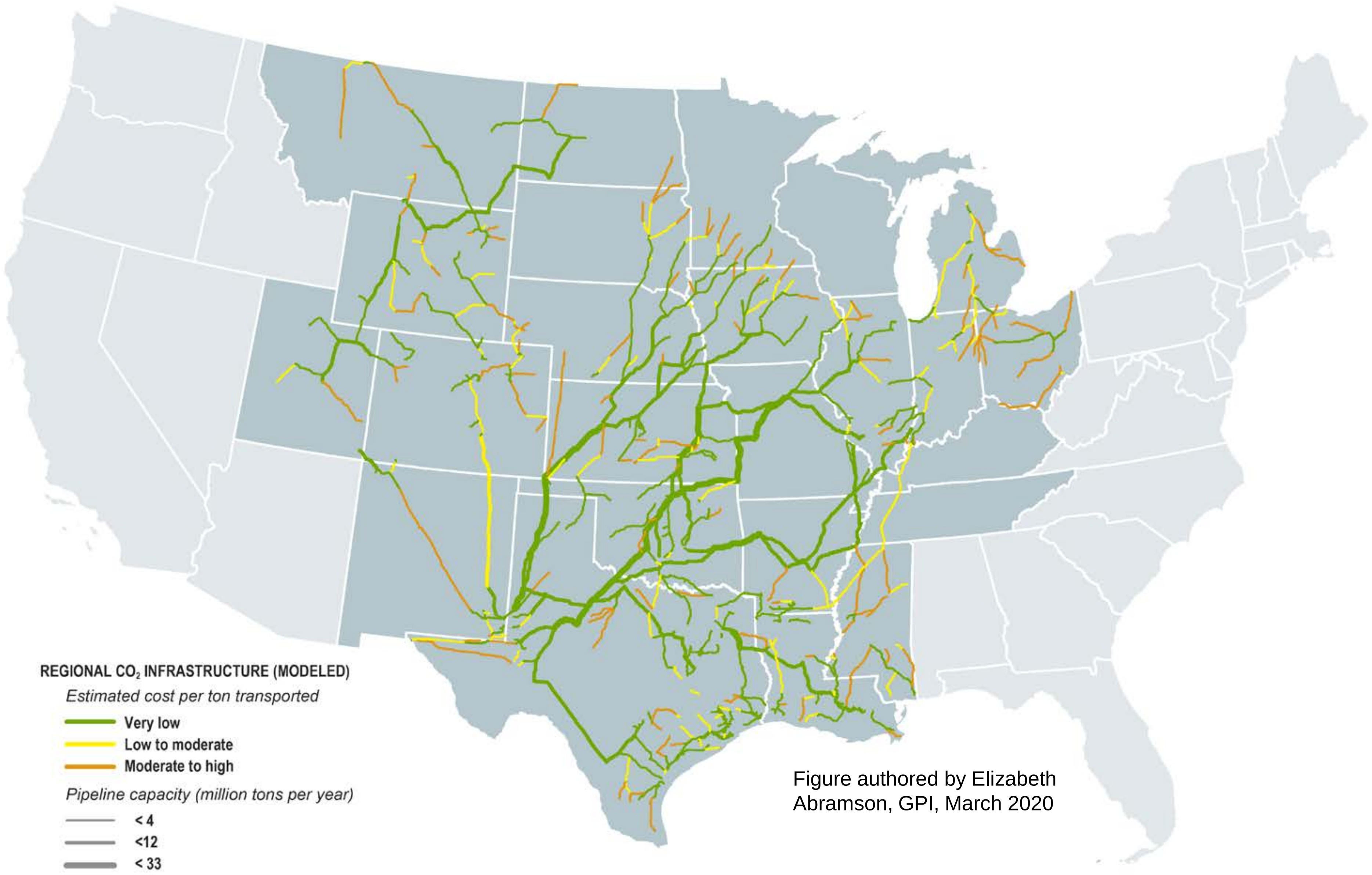

Figure authored by Elizabeth Abramson, GPI, March 2020

Large trunk lines achieve best economies of scale and lowest per-ton transport cost.

Small-feeder lines to individual facilities require less capital but have higher per-ton cost.

Cost Range	Length (miles)
Very Low	18,006
Low to Moderate	4,744
Moderate to High	6,960

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Shared CO_2 Transport Infrastructure: Beneficial Economies of Scale

Higher capacity achieves lower costs per ton

Infrastructure investment by capacity
$ per inch-mile

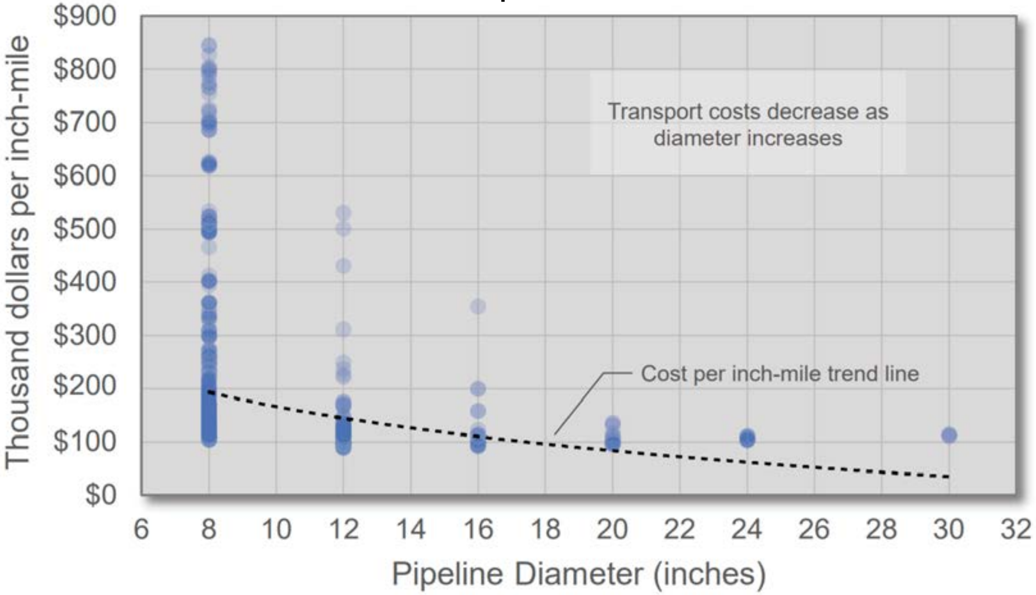

Figure authored by GPI based on calculations performed using the NETL CO_2 Transport Cost Model.

Transport tariff by capacity
$ per ton

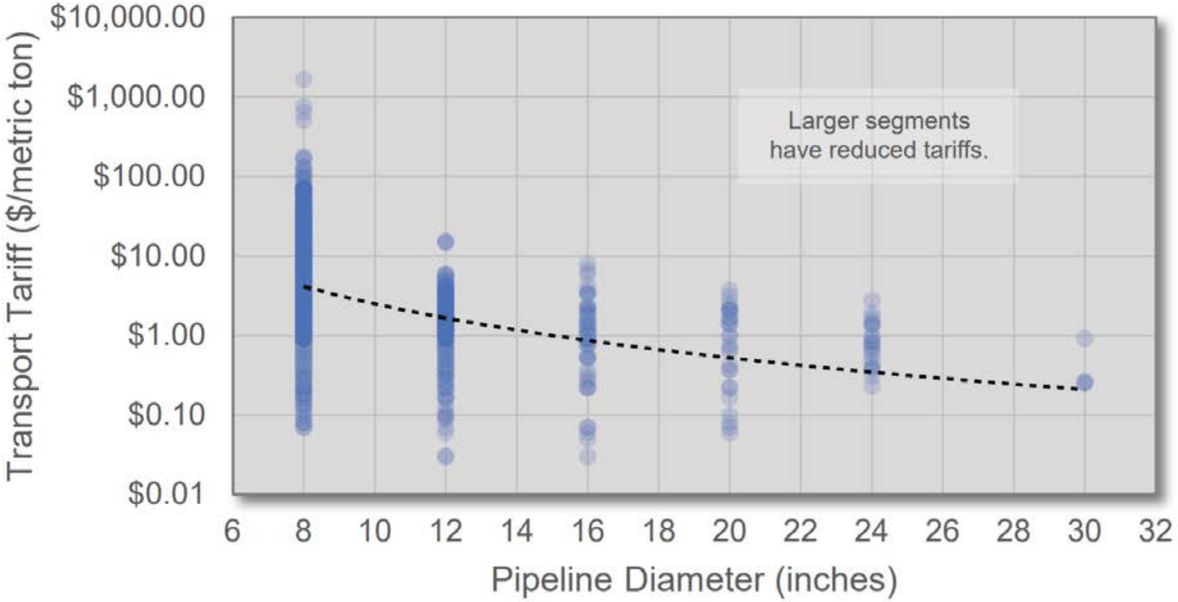

Figure authored by GPI based on calculations performed using the NETL CO_2 Transport Cost Model, as modified by McFarlane, Dubois, and Edwards, 2018.

Investment by owner/operator → **Cost to user/customer**

Calculated with:

NATIONAL ENERGY TECHNOLOGY LABORATORY CO_2 Transport Cost Model

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Midcentury: Long-term Economy-Wide Deployment

Expanded storage in saline formations and petroleum basins

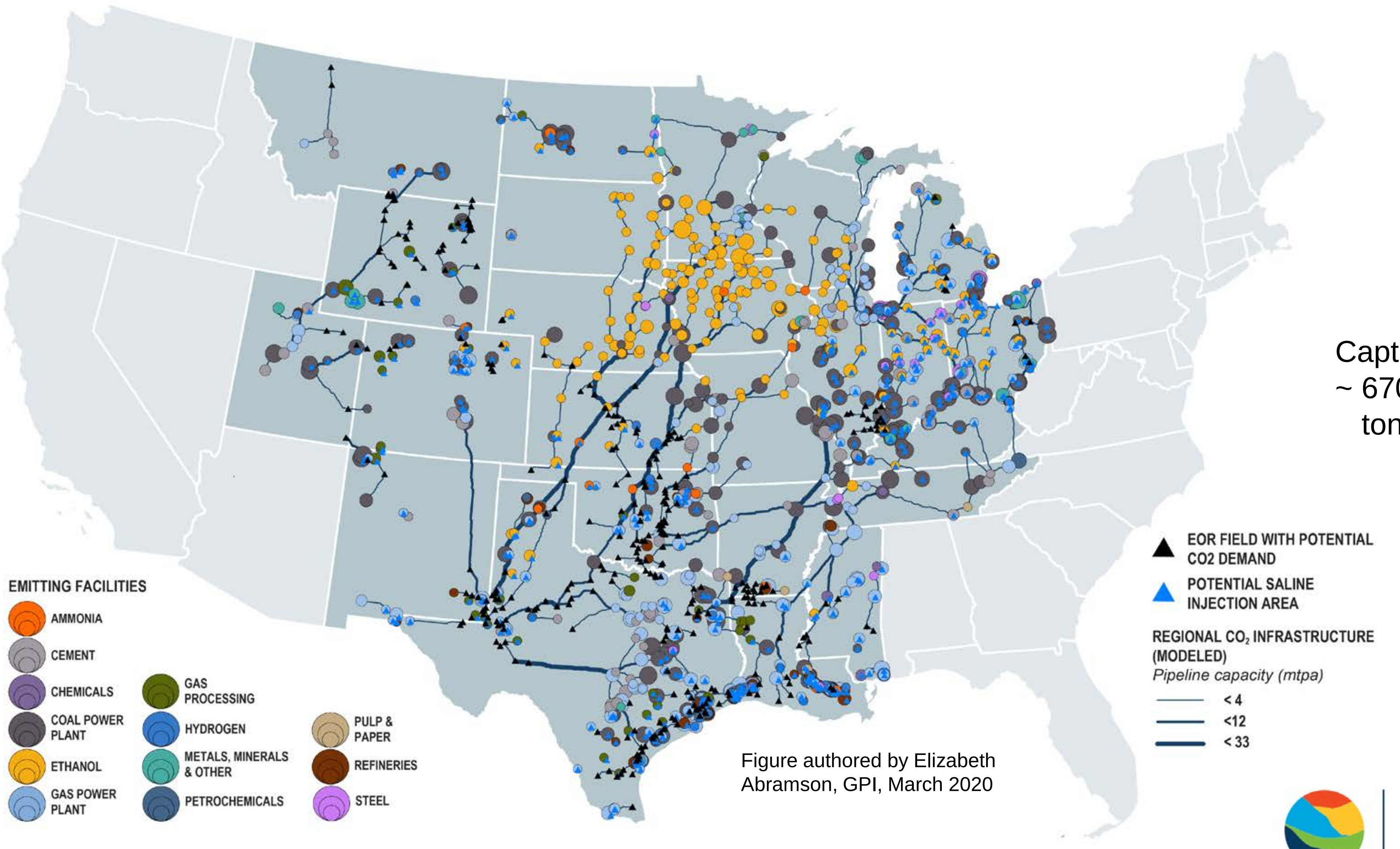

Figure authored by Elizabeth Abramson, GPI, March 2020

Capture and storage:
~ 670 million metric tons per year

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Planning for Near-Term versus Long-term Economy-Wide Deployment

Economies of scale benefit higher capacity for CO_2 delivery

Regional infrastructure can store more CO_2 at a lower cost

Long term planning results in more CO_2 stored, smaller land use, and lower marginal cost

Scenario	CO_2 Stored	Land Use	Capital Investment	Project Labor Investment	Annual O&M Spending
Near- and Medium-Term	**281** million metric tons	**29,710** miles	**$16.6** billion	**$14.3** billion	**$252** million
Midcentury	**669** million metric tons	**29,922** miles	**$19.3** billion	**$15.3** billion	**$254** million
Midcentury scenario **increase over Near- and Medium-Term** scenario	**x 2.38** more CO_2 stored	**+0.7%**	**16.3%**	**7.0%**	**0.8%**

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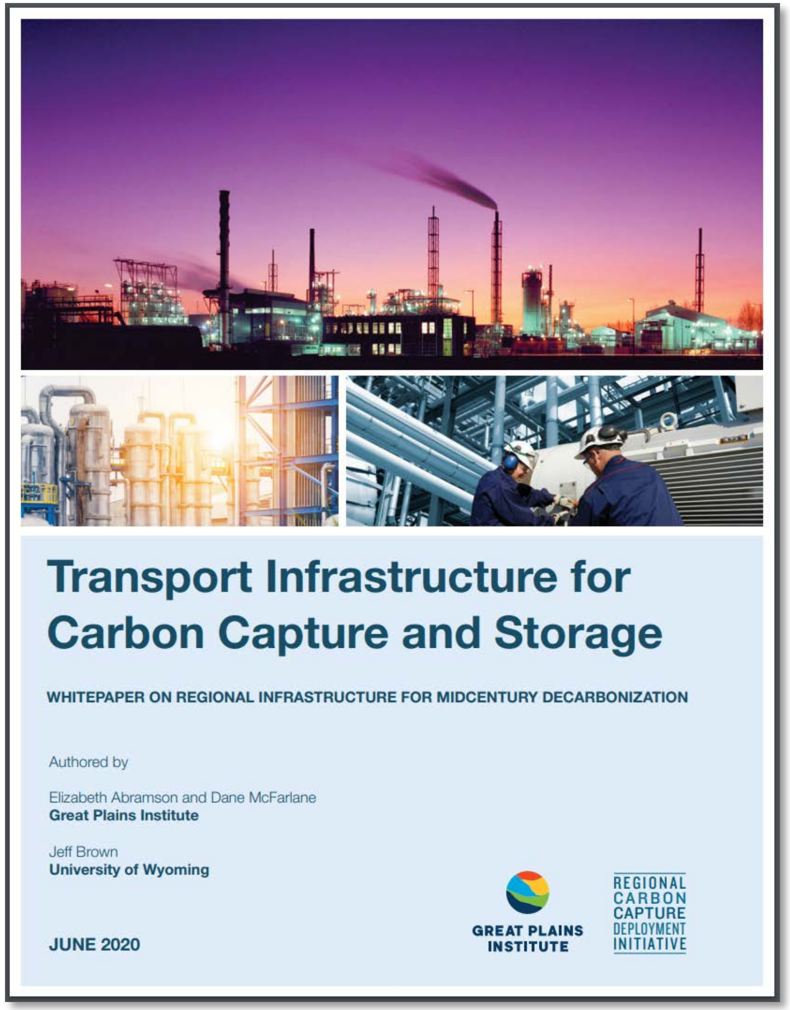
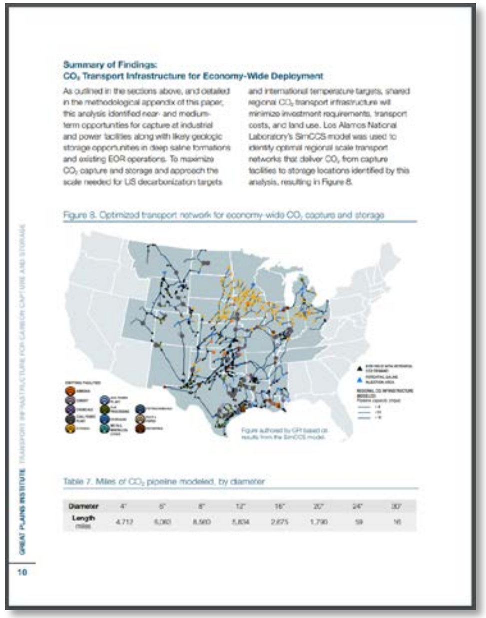
Analytical Report

Published June 30, 2020





Download the paper at:

carboncaptureready.org/analysis

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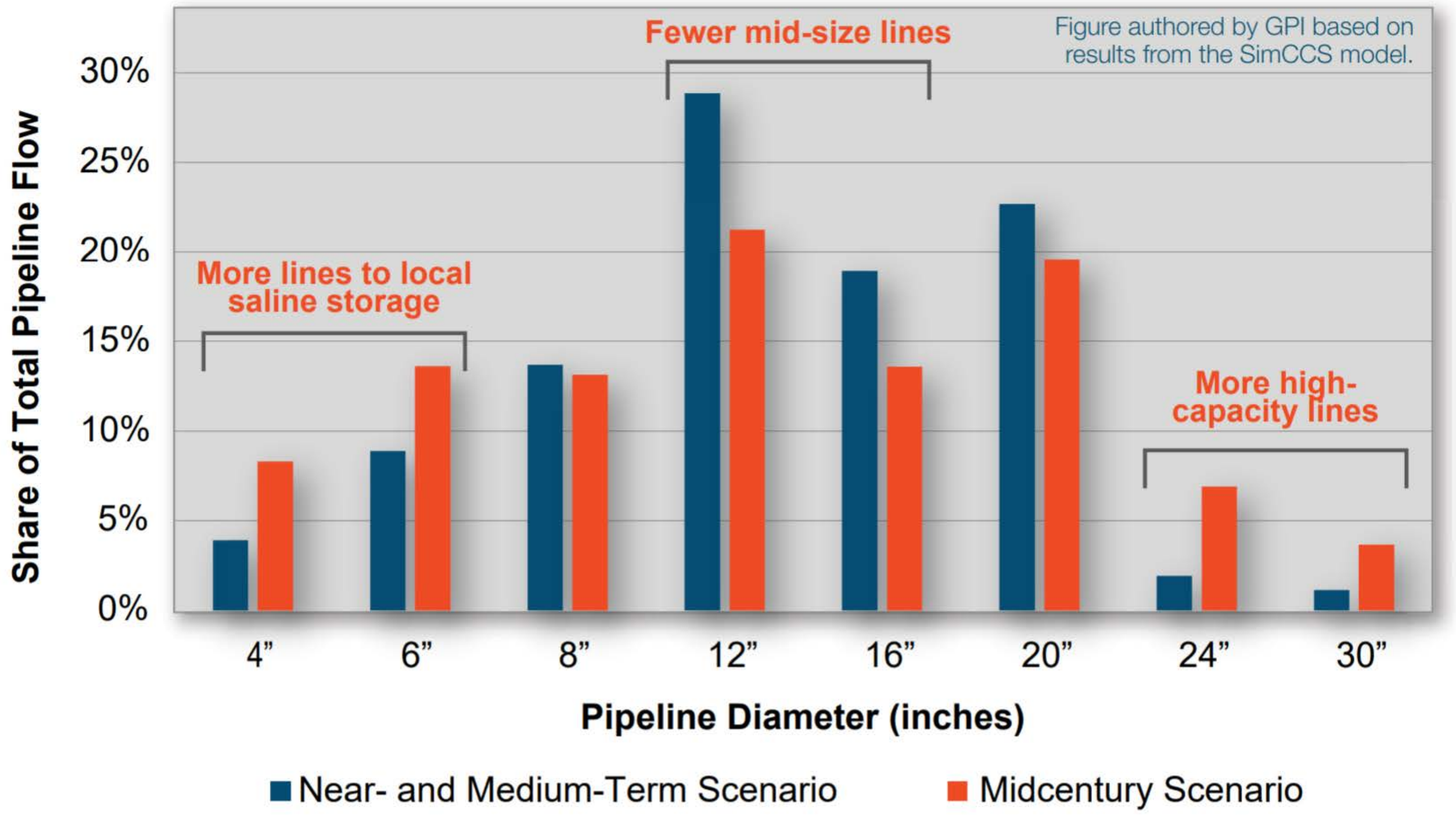
End of presentation.

Appendix: Additional slides below.

Achieving lower costs through shared high capacity infrastructure

Type of infrastructure built in each scenario



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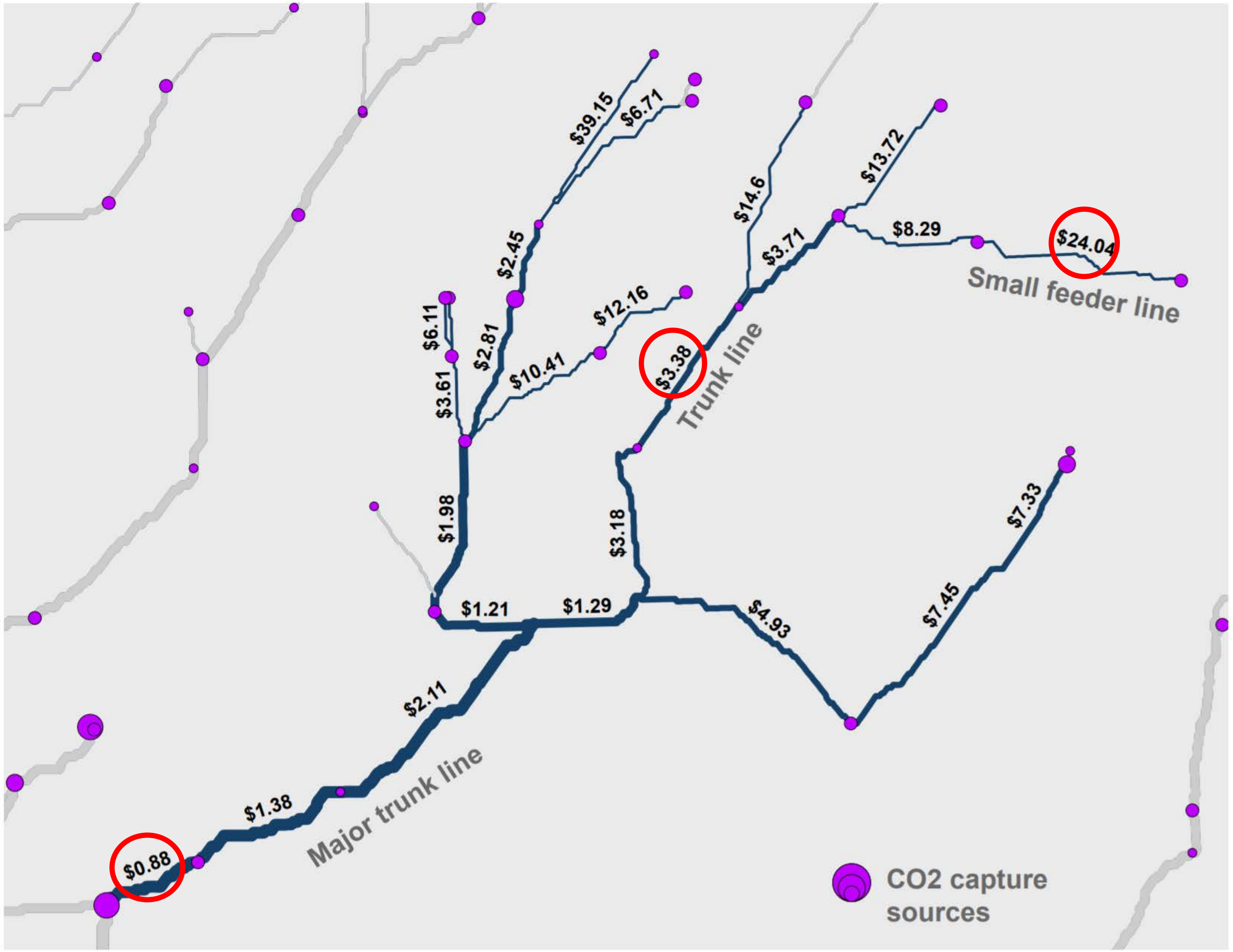
Shared CO_2 Transport Infrastructure: Beneficial Economies of Scale



Example network section from the Near- and Medium-Term Scenario. Figure authored by GPI based on results from the SimCCS model, with cost estimates calculated by the NETL CO_2 Transport Cost model.

Small feeder lines have a higher per-ton cost because they deliver less CO_2.

Shared high-capacity transport segments achieve beneficial economies of scale.

Customers generally pay a transport tariff ($/ton) based on the route their CO_2 product takes through the transport network.

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SCO_2T Model: Nation-wide geologic storage potential

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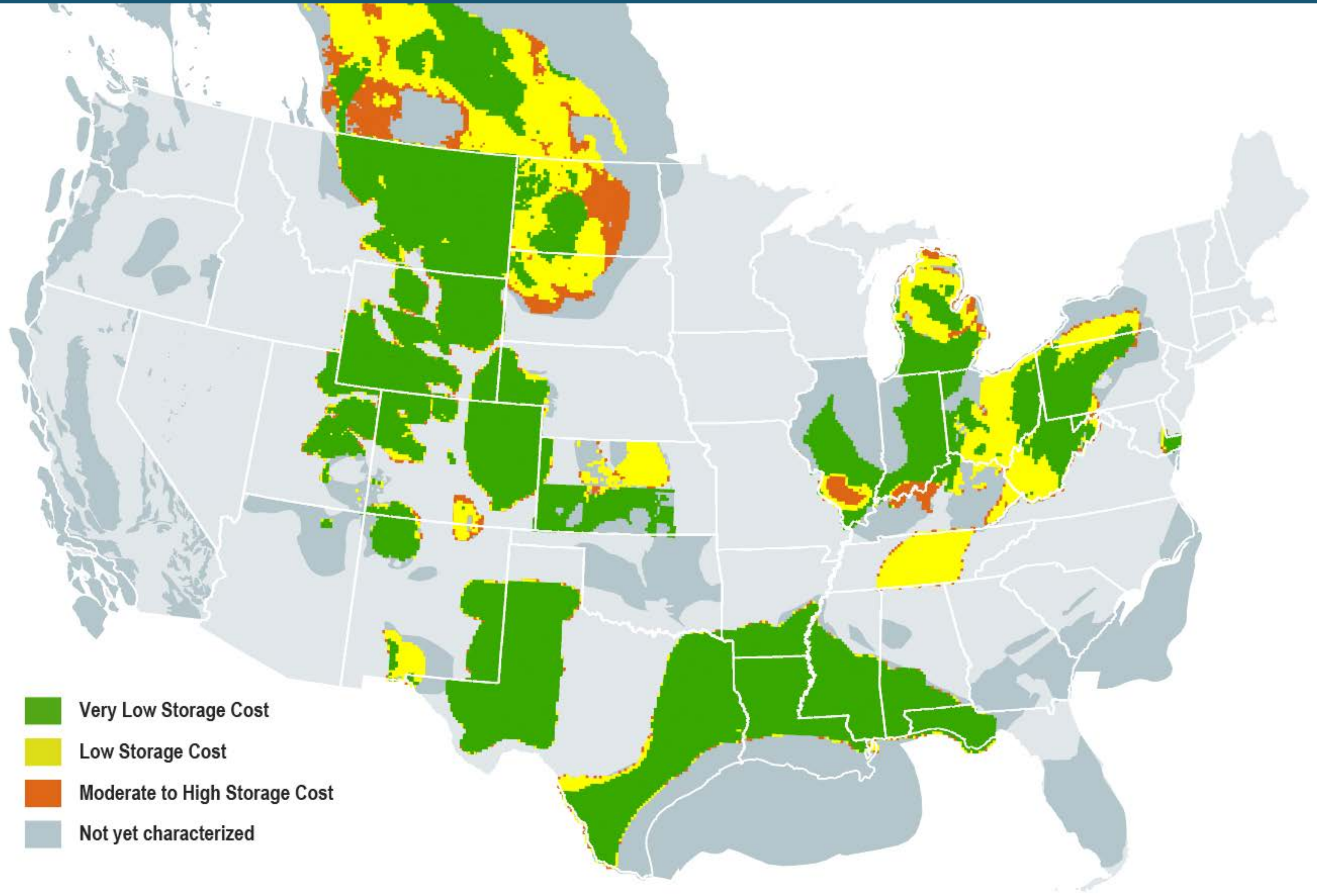
Los Alamos
NATIONAL LABORATORY
EST. 1943



Sensitivity Analysis:
High-cost sensitivity with economic break-even required

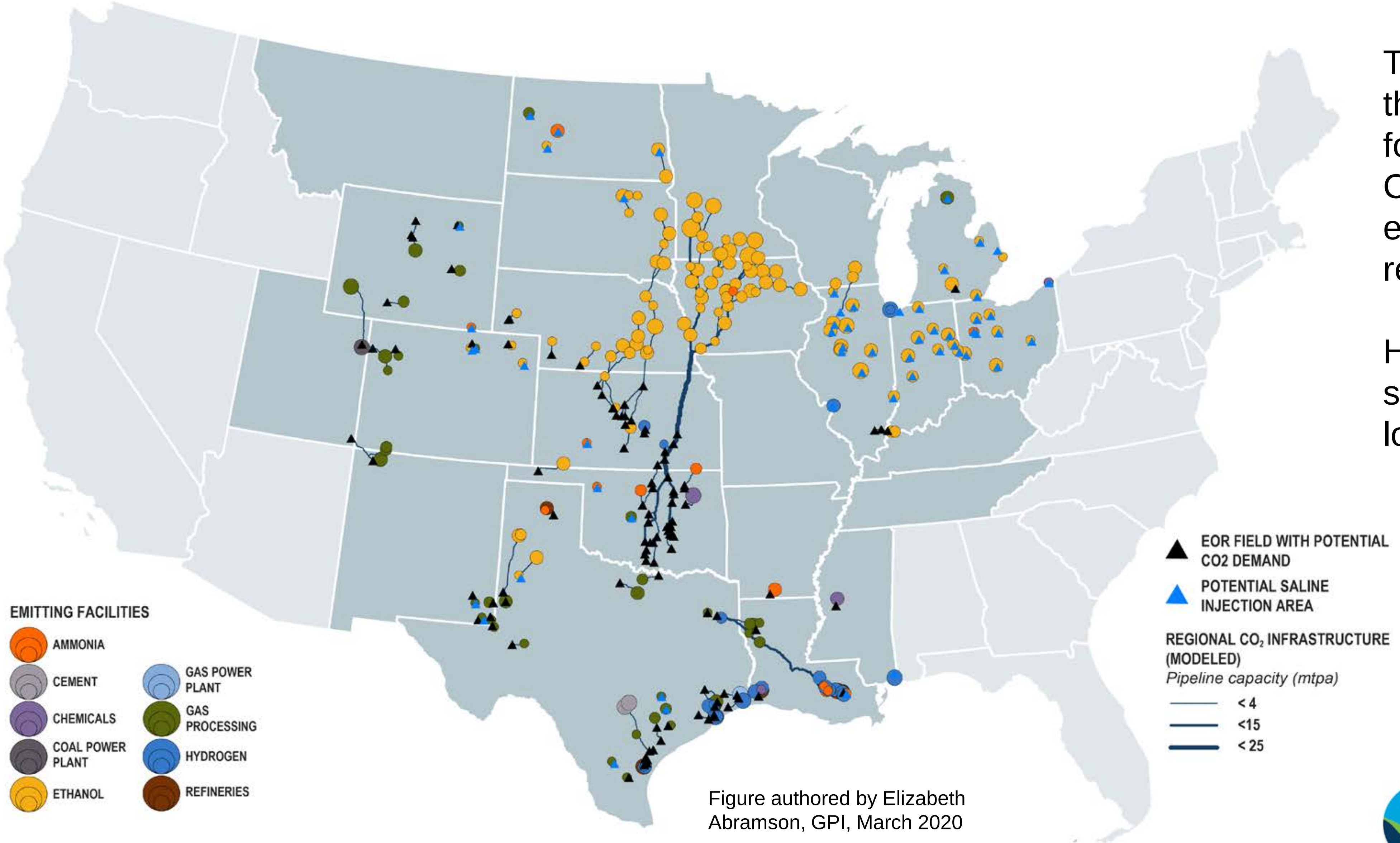


Figure authored by Elizabeth Abramson, GPI, March 2020

Transport segments that essentially “pay for themselves”. Capital investment easily paid for by revenue.

High-purity industrial sources choose local saline storage.

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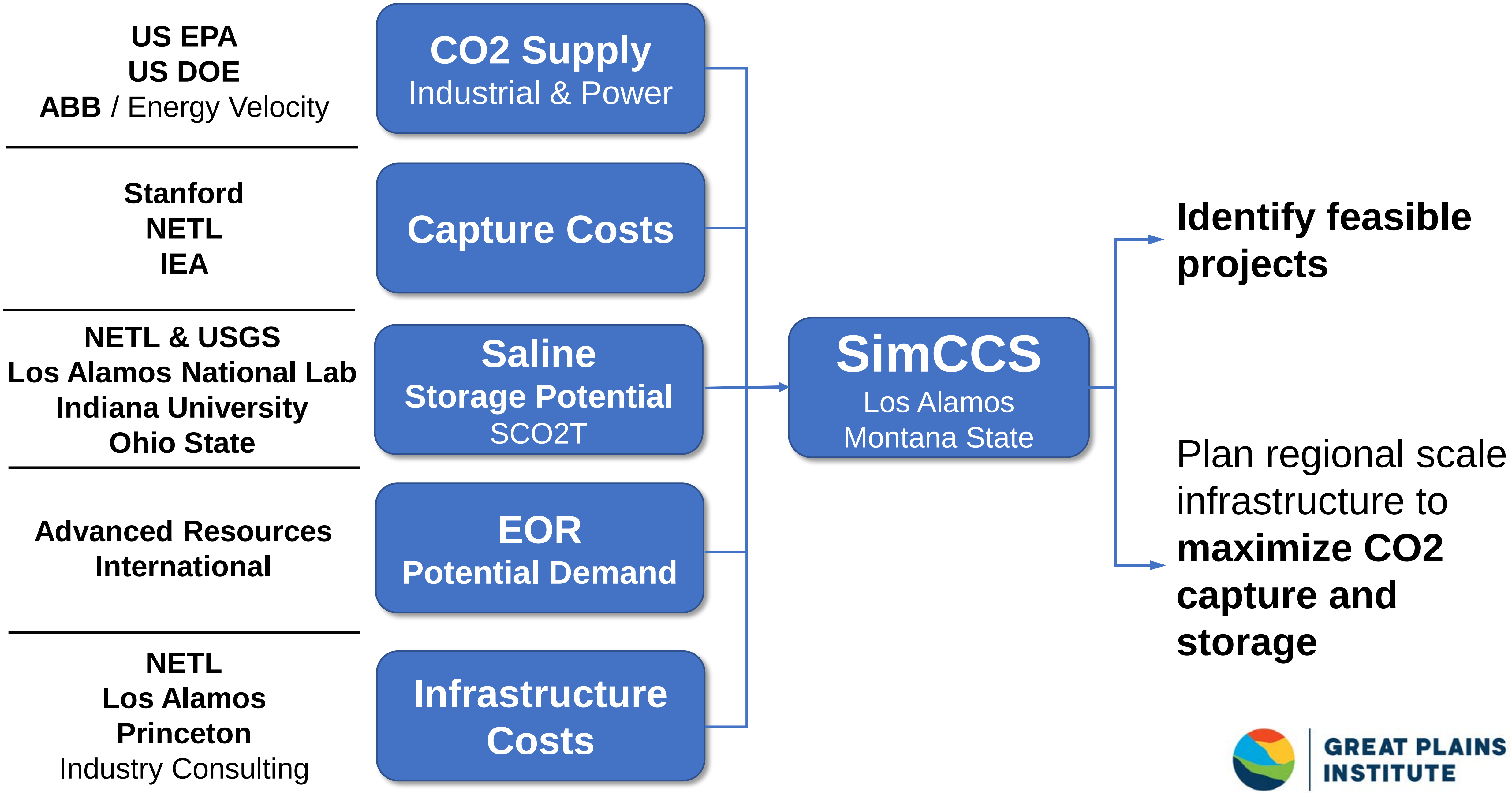

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