



Regional Carbon Capture and Transport Opportunities for Storage in Texas, the Permian Basin, and the Gulf

December 9, 2020

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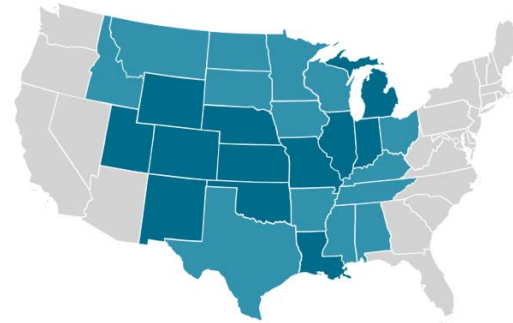


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REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE



Objectives:

- Prioritize key carbon capture and CO₂ pipeline project opportunities revealed in modeling
- Determine cost gaps, where applicable, for priority projects after accounting for federal 45Q tax credit
- Identify state policies to help close cost gaps
- Engage stakeholders, policymakers and media to marshal support for projects to meet 45Q timeline of beginning construction by end of 2023
- Prepare for 2020-21 state legislative sessions



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Regional CO₂ Transport Infrastructure Study

Study Components

1. Identify near-term opportunities for CO₂ capture retrofit
2. Locate areas of CO₂ storage and use
3. Model optimized CO₂ transport infrastructure to maximize capture and storage

Primary Partners:



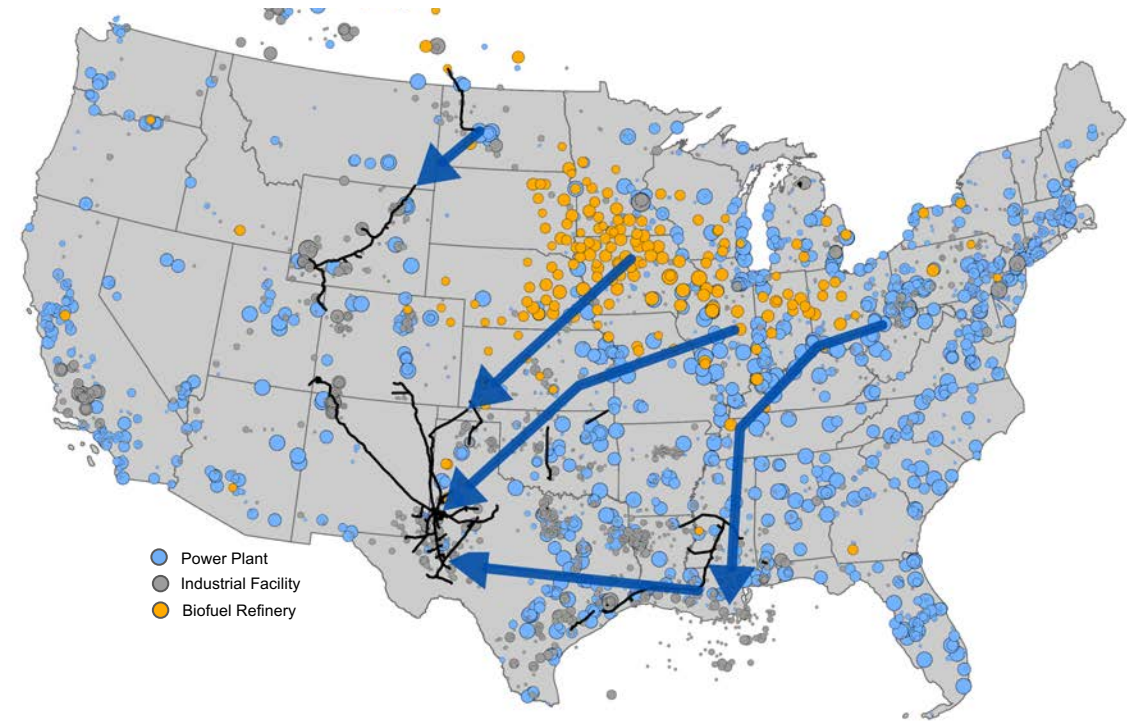
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Initial CO₂ Corridor Scoping



Analytical Report

Published June 30, 2020




Transport Infrastructure for Carbon Capture and Storage


WHITEPAPER ON REGIONAL INFRASTRUCTURE FOR MIDCENTURY DECARBONIZATION

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JUNE 2020

Summary of Findings:
CO₂ Transport Infrastructure for Economy-Wide Deployment

As outlined in the sections above, and detailed in the methodological appendix of this paper, this analysis identified near- and medium-term opportunities for capture at industrial and power facilities along with likely geologic storage opportunities in deep saline formations and existing EOR operations. To maximize CO₂ capture and storage and approach the scale needed for US decarbonization targets and international temperature targets, shared regional CO₂ transport infrastructure will minimize investment requirements, transport costs, and land use. Los Alamos National Laboratory's SIMCCS model was used to identify optimal regional scale transport networks that deliver CO₂ from capture facilities to storage locations identified by the analysis, resulting in Figure 8.

Figure 8. Optimized transport network for economy-wide CO₂ capture and storage




Figure 8 is a map of the United States showing an optimized transport network for economy-wide CO₂ capture and storage. The map displays a dense network of lines representing transport routes, primarily concentrated in the Midwest, Rocky Mountain, and Gulf Coast regions. Nodes on the map represent capture facilities and storage locations. A legend indicates different types of infrastructure: EOR-based storage, Dedicated storage, and Dedicated infrastructure. A note states: 'Map is shown as EOR-based nodes from the SIMCCS model.'

Table 7. Miles of CO₂ pipeline modeled, by diameter

Diameter	4"	8"	12"	16"	20"	24"	30"
Length (miles)	4,712	6,063	6,560	5,824	2,675	1,700	59

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The difference in build-out of CO₂ transport infrastructure in the Near- to Medium-Term Scenario and the High-Cost Sensitivity Scenario shows that there is still a gap in pure break-even economic equilibrium: a regional scale CO₂ transport network will require capital investment that will not necessarily be paid simply through the sale of CO₂ at \$20 per ton combined with the value of tax credits in the current 45Q program. The transport networks modeled here maximize the rate of CO₂ capture and storage across the power and industrial sectors while minimizing the cost and land use of transport infrastructure. In reality, CO₂ transport infrastructure may more likely be built out in a piecemeal fashion, linking single facilities or a small group of projects to a single storage location. This may result in CO₂ infrastructure that is not of sufficient capacity to meet the scale of CO₂ capture and storage required by midcentury decarbonization targets. This infrastructure would need to be replaced in the future or an abundance of additional infrastructure would need to be built, costing more and having a greater land use impact than a regional system built through coordinated planning.

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

If the US is to significantly decarbonize the industrial and power sectors, as well as create a marketplace that allows for direct air capture facilities to help achieve net zero or negative carbon emissions, then planning and coordination must occur in the near term to begin building regional-scale transport

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 CO₂ will require.

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

networks for economy-wide deployment of carbon capture and storage. By midcentury, local, national, and international climate action and the need to drive down the societal costs of carbon emissions will likely create natural economic incentives that enable CO₂ capture at industrial and power facilities, in addition to direct air capture facilities, that today seem relatively expensive.

Developing solutions in the near term to address logistical issues such as inter-state CO₂ transportation corridors, interconnected pipeline networks operated or shared by multiple private entities, and state and federal support for future-proofing pipeline capacity through "super-sizing" will drastically reduce costs as well as land use and environmental impact of CO₂ transport infrastructure. Achieving national goals will require broad scale coordinated vision and action. This analysis provides a framework for coordinated regional infrastructure that can help define that vision.

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Download the paper at:

carboncaptureready.org/analysis



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CO₂ Capture Opportunities: Industrial and Power Facilities

Section 45Q Tax Credit for CO₂ Storage

Geologic Saline: \$50 / ton
EOR Storage: \$35 / ton

Minimum Capture Thresholds

Industrial Facility: 100 thousand tons CO₂
Power Plants: 500 thousand tons CO₂

Near- and Medium-Term Screening Criteria:

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

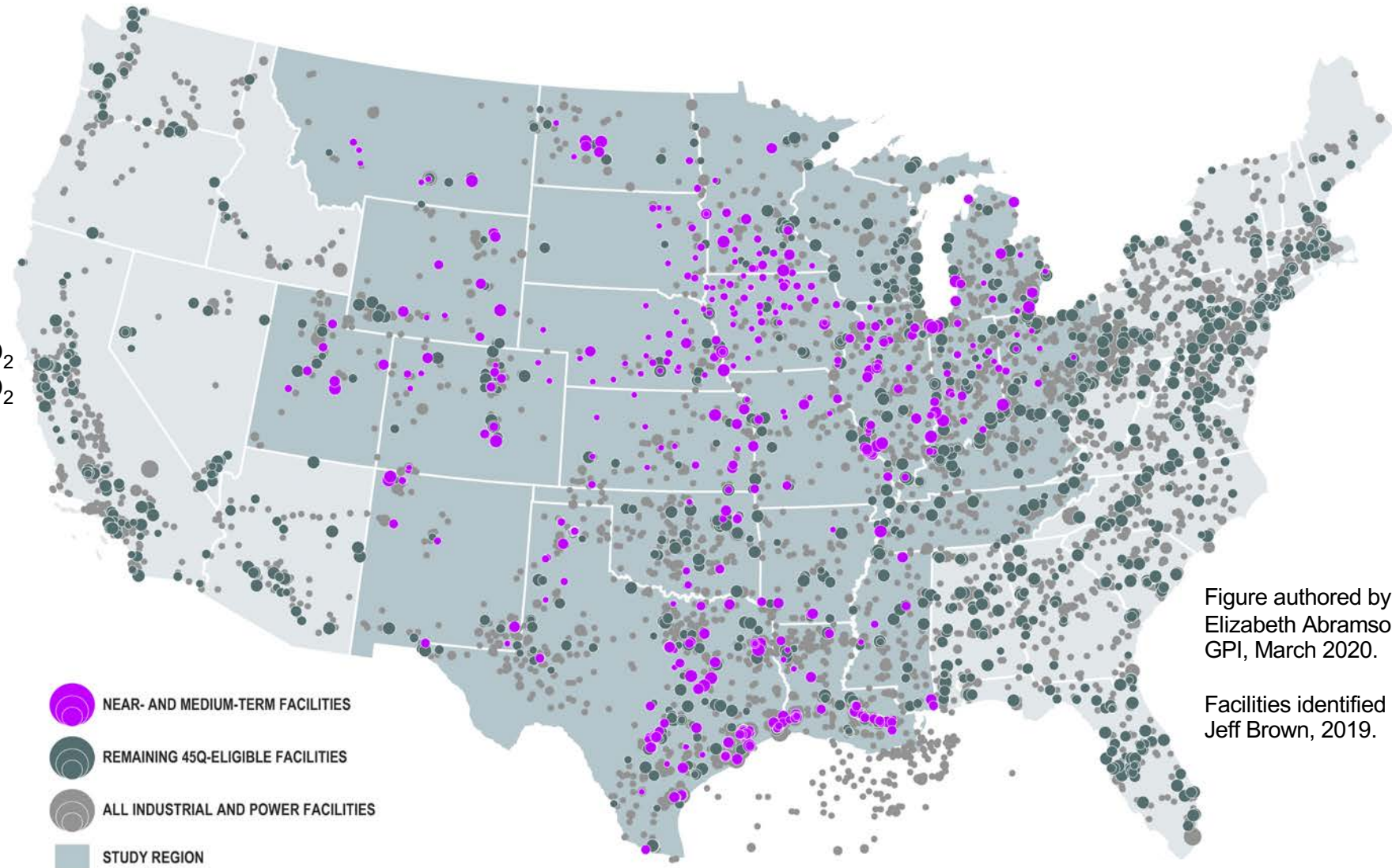


Figure authored by
Elizabeth Abramson,
GPI, March 2020.

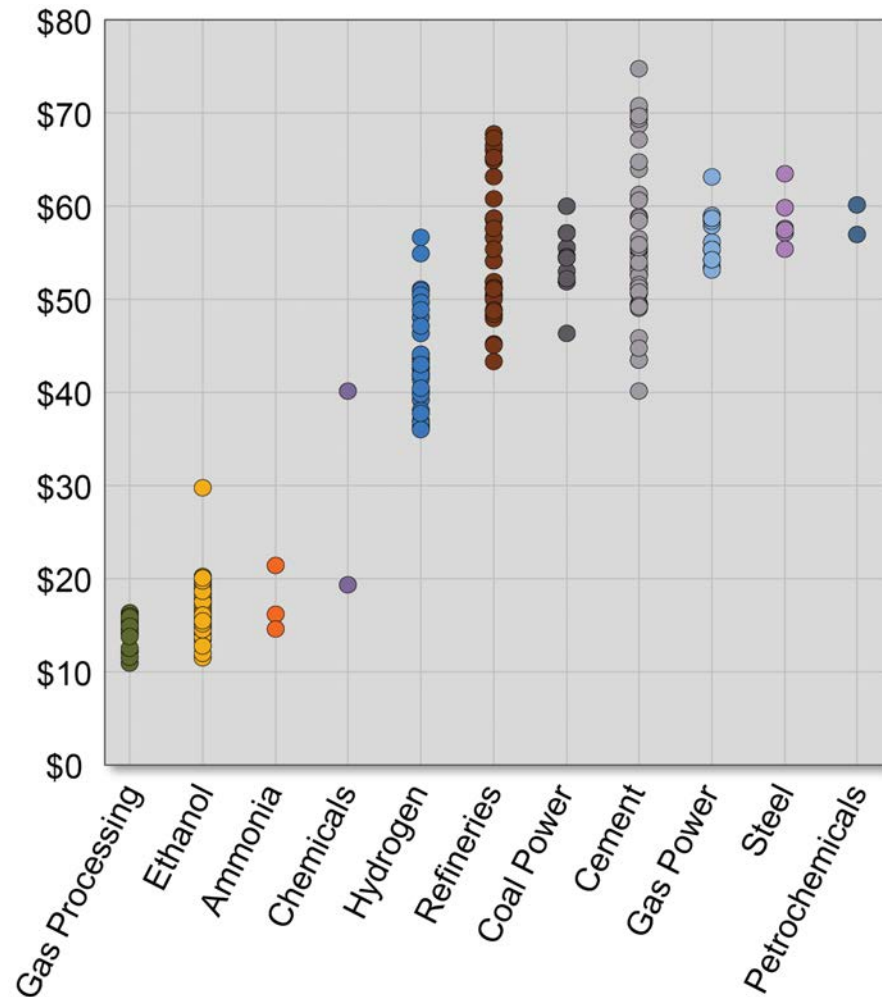
Facilities identified by
Jeff Brown, 2019.



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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

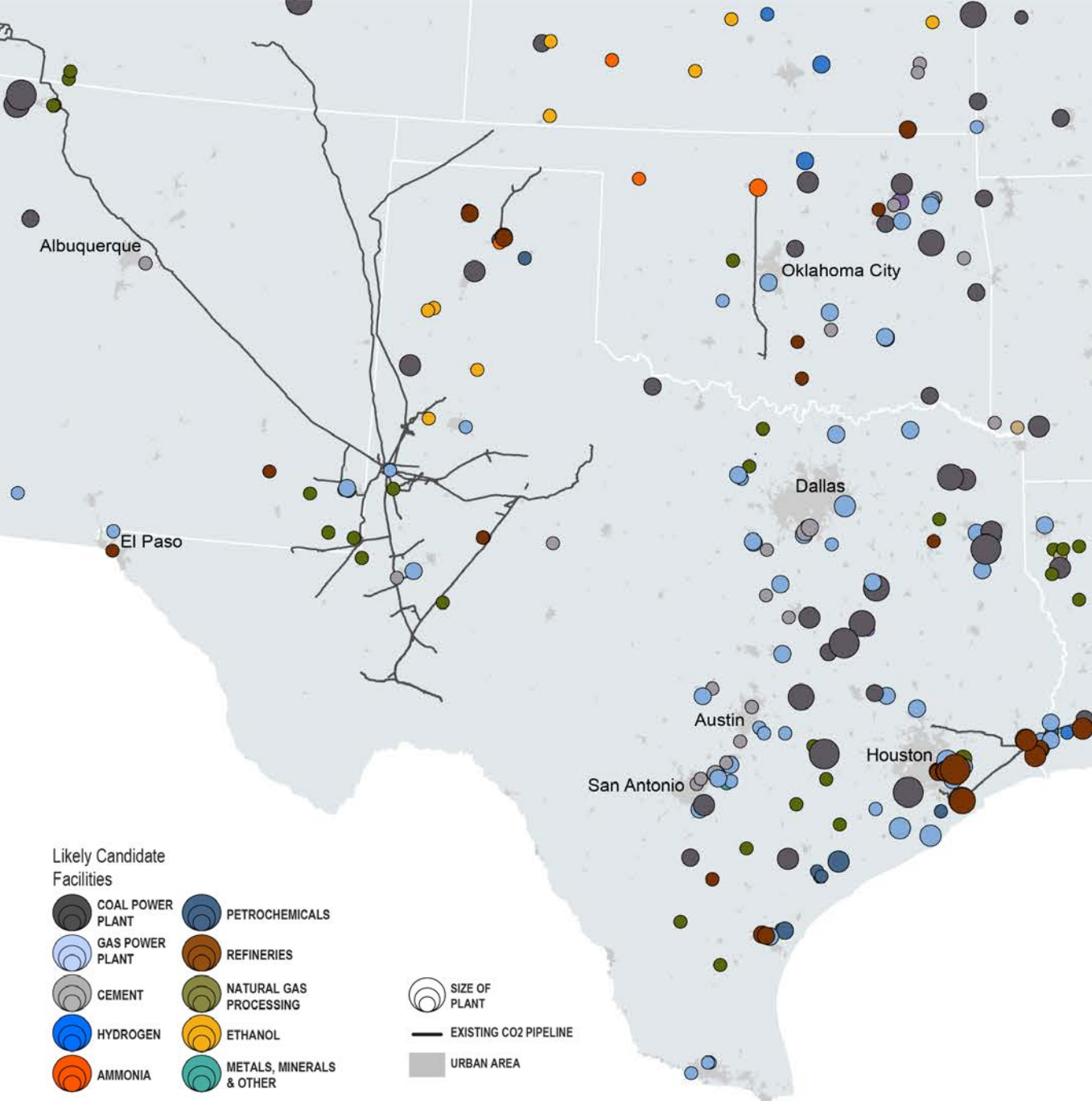
Source: Jeff Brown, 2019



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45Q-Qualifying Power and Industrial Sources of CO2 in Texas



Industry	# of 45Q Qualifying Facilities	45Q Qualifying Emissions (million metric tons CO2)	Total # of Facilities in Texas	Total Facility Emissions in Texas (million metric tons CO2)
Coal Power Plant	20	127.4	20	127.4
Gas Power Plant	56	100.6	111	109
Refineries	25	61.9	34	78
Petrochemicals	14	10.9	31	25.5
Gas Processing	12	4.9	264	21
Hydrogen	16	12.5	16	12.5
Cement	16	10.4	16	10.4
Chemicals	-	-	52	7.4
Metal & Minerals	2	0.4	97	4.8
Ethanol	4	1.2	4	1.2
Ammonia	1	0.7	1	0.7
Pulp & Paper	-	-	5	0.7
Steel	1	0.2	5	0.6
Grand Total	167	331.1 MMT	656	399.2 MMT

MMT: million metric tons CO2

Source: EPA GHGRP 2018

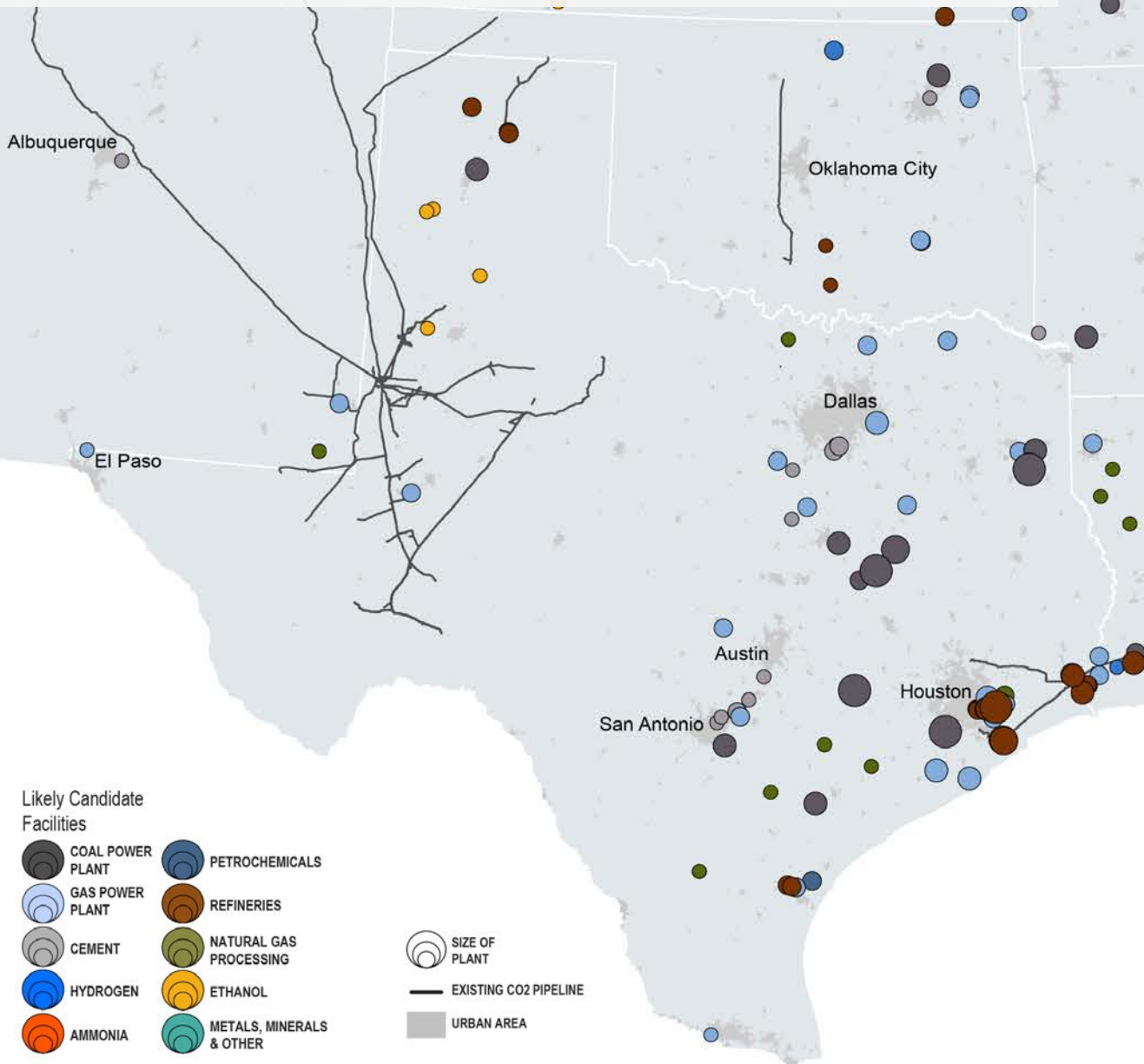


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Texas

Identified near- and medium-term capture opportunities



Industry	CO2 Captured Target (million metric tons CO2)	Total Texas Facility CO2 Emissions (million metric tons CO2)	Facility Capture Rate	Share of Industry Emissions Captured
Ammonia	-	0.7	-	-
Cement	7.7	10.4	83%	74%
Chemicals	-	7.4	-	-
Coal Power Plant	24.0	127.4	29%	19%
Ethanol	1.0	1.2	287%	89%
Gas Power Plant	31.5	109.0	48%	29%
Gas Processing	1.1	21.0	43%	5%
Hydrogen	5.0	12.5	54%	40%
Metals & Minerals	-	4.8	-	-
Petrochemicals	1.7	25.5	65%	7%
Pulp & Paper	0.0	0.7	-	0%
Refineries	14.8	78.0	25%	19%
Steel	-	0.6	-	-
Grand Total	87 MMT	399.2 MMT	N/A	22%

Source: EPA GHGRP 2018; GPI 2019

Near- and Medium-Term Opportunities

Economically feasible with today's technology, 45Q tax credit, and assumed \$10-\$15 / ton pipeline transport tariff, for sale to EOR at \$20 / ton.

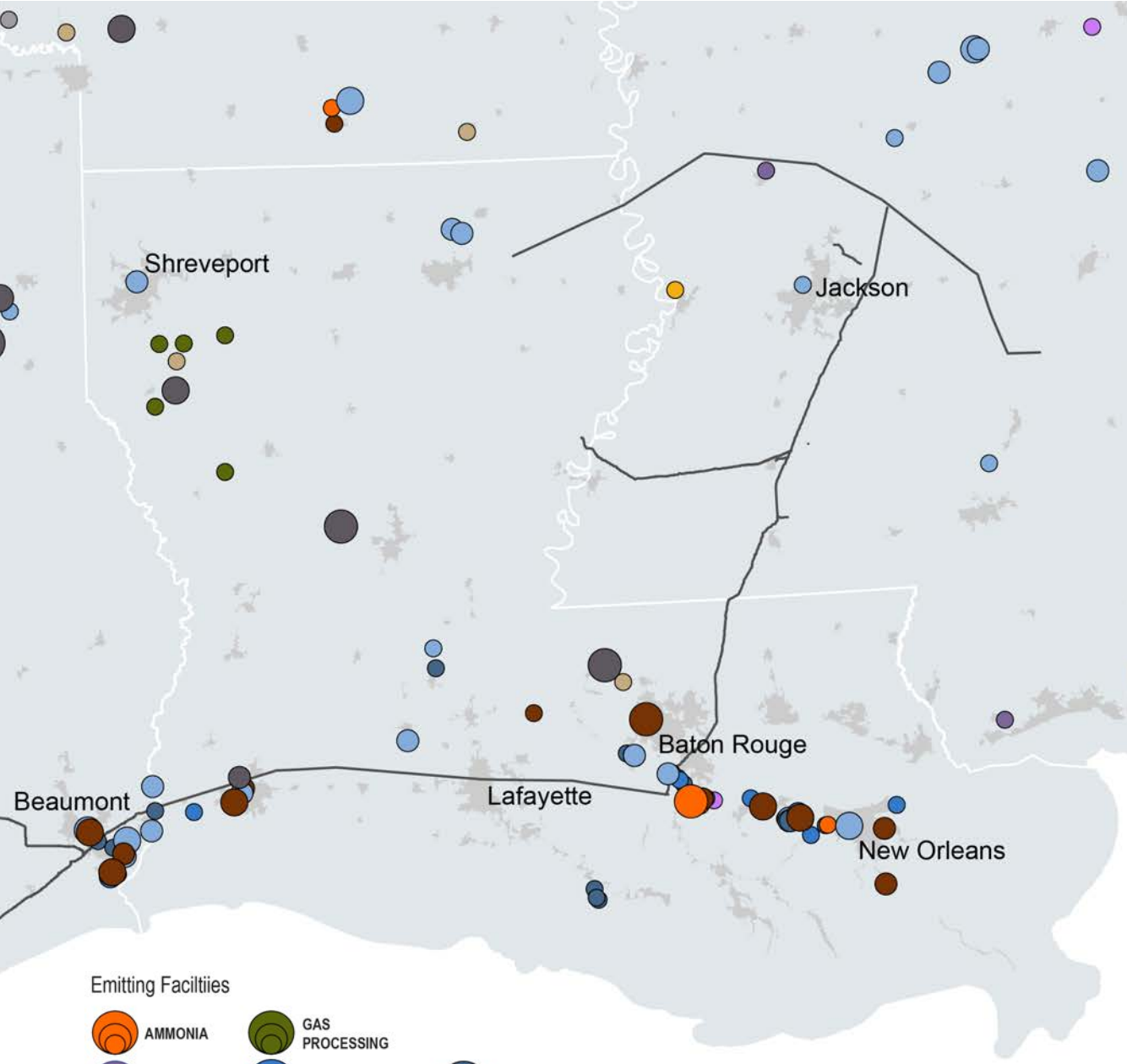
Source: Regional Carbon Capture Deployment Initiative, GPI, and Jeff Brown. 2019.



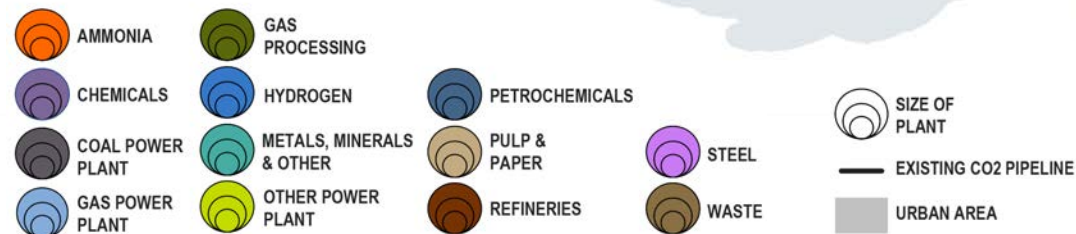
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45Q-Qualifying Power and Industrial Sources of CO2 in Louisiana



Emitting Facilities



Industry	# of 45Q Qualifying Facilities	45Q Qualifying Emissions (million metric tons CO2)	Total # of Facilities in Louisiana	Total Facility Emissions in Louisiana (million metric tons CO2)
Ammonia	4	8.9	4	8.9
Chemicals	1	0.3	31	3.8
Coal Power Plant	4	18.5	4	18.5
Gas Power Plant	12	23.2	26	26.0
Gas Processing	4	0.8	227	11.9
Hydrogen	10	7.4	13	7.6
Metals & Minerals	-	-	25	2.4
Other Power Plant	-	-	1	2.1
Petrochemicals	12	10.2	20	14.2
Pulp & Paper	2	1.4	9	2.8
Refineries	11	30.7	15	32.1
Steel	1	0.1	1	0.1
Waste	-	-	25	-
Grand Total	61	101.4 MMT	401	130.5 MMT

MMT: million metric tons CO2

Source: EPA GHGRP 2018

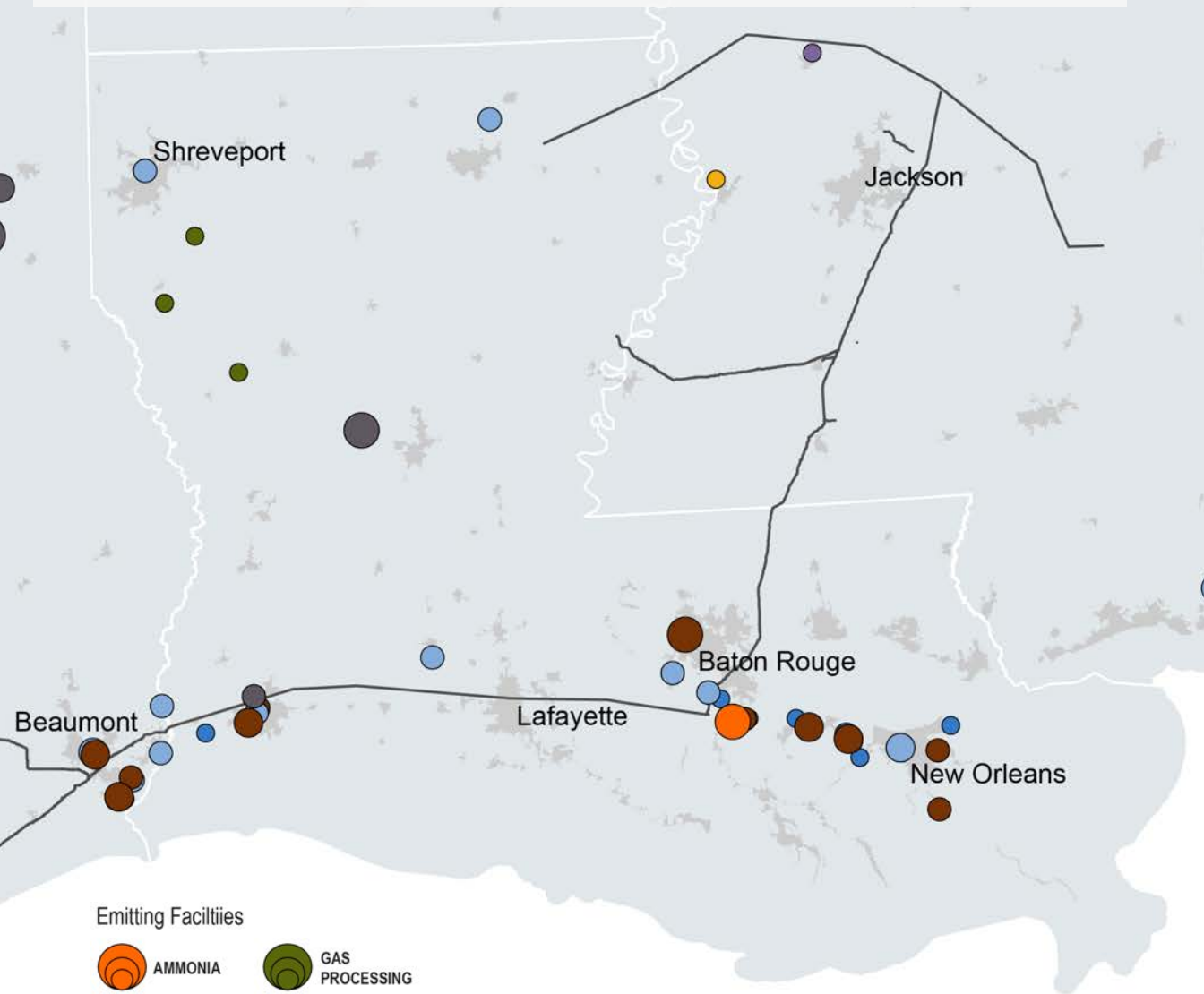


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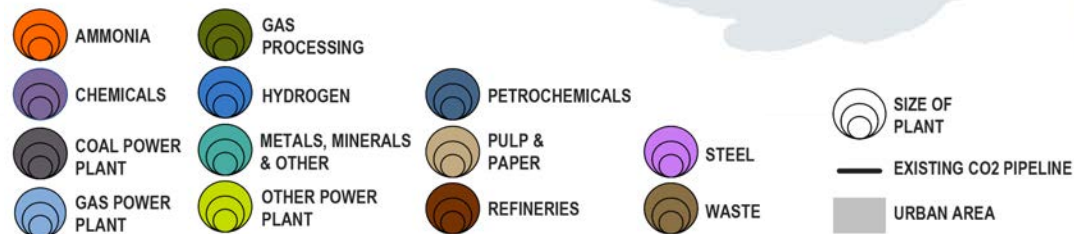


Louisiana

Identified near- and medium-term capture opportunities



Emitting Facilities



Industry	CO2 Captured Target (million metric tons CO2)	Total Louisiana Facility CO2 Emissions (million metric tons CO2)	Share of Industry Emissions Captured
Ammonia	0.5	8.9	5.5%
Chemicals	-	3.8	-
Coal Power Plant	3.2	18.5	17.3%
Gas Power Plant	8.0	26.0	30.8%
Gas Processing	0.5	11.9	4.0%
Hydrogen	4.2	7.6	55.1%
Metals & Minerals	-	2.4	-
Other Power Plant	-	2.1	-
Petrochemicals	-	14.2	-
Pulp & Paper	0.0	2.8	-
Refineries	7.0	32.1	21.7%
Steel	-	0.1	-
Waste	-	0.0	-
Grand Total	23.3 MMT	130.5 MMT	18%

Source: EPA GHGRP 2018; GPI 2019

Near- and Medium-Term Opportunities

Economically feasible with today's technology, 45Q tax credit, and assumed \$10-\$15 / ton pipeline transport tariff, for sale to EOR at \$20 / ton.

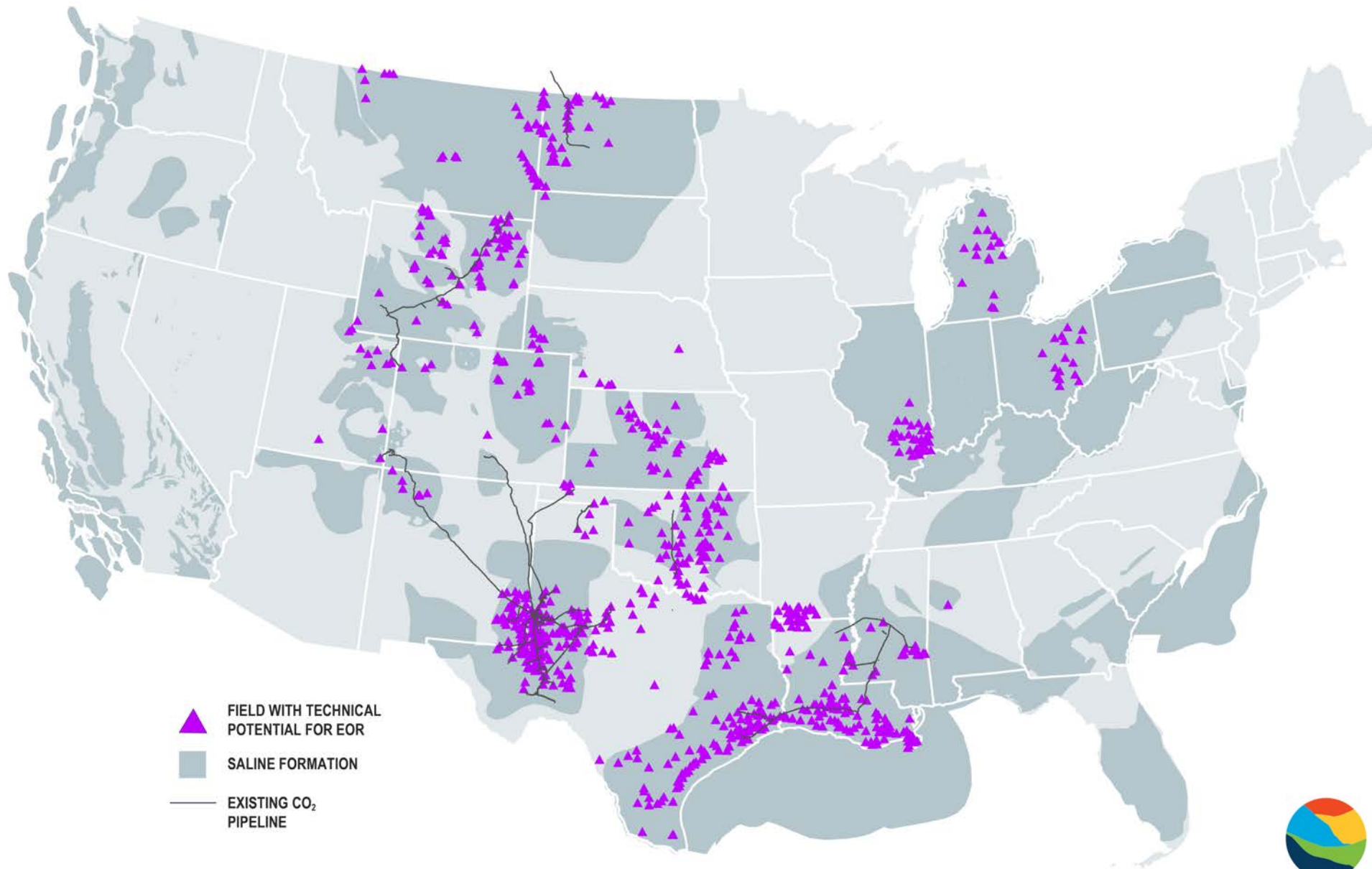
Source: Regional Carbon Capture Deployment Initiative, GPI, and Jeff Brown. 2019.



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CO₂ Storage in Saline Formations & Petroleum Basins



Saline data via
**The Sequestration of
CO₂ Tool (SCO₂T)**



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Figure authored by Elizabeth
Abramson, GPI, March 2020

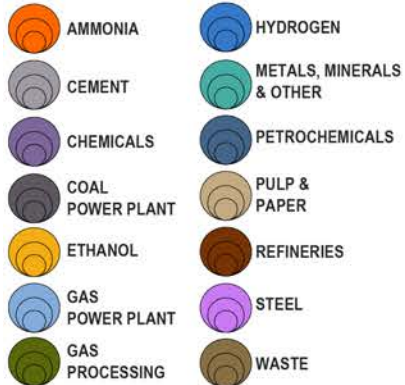


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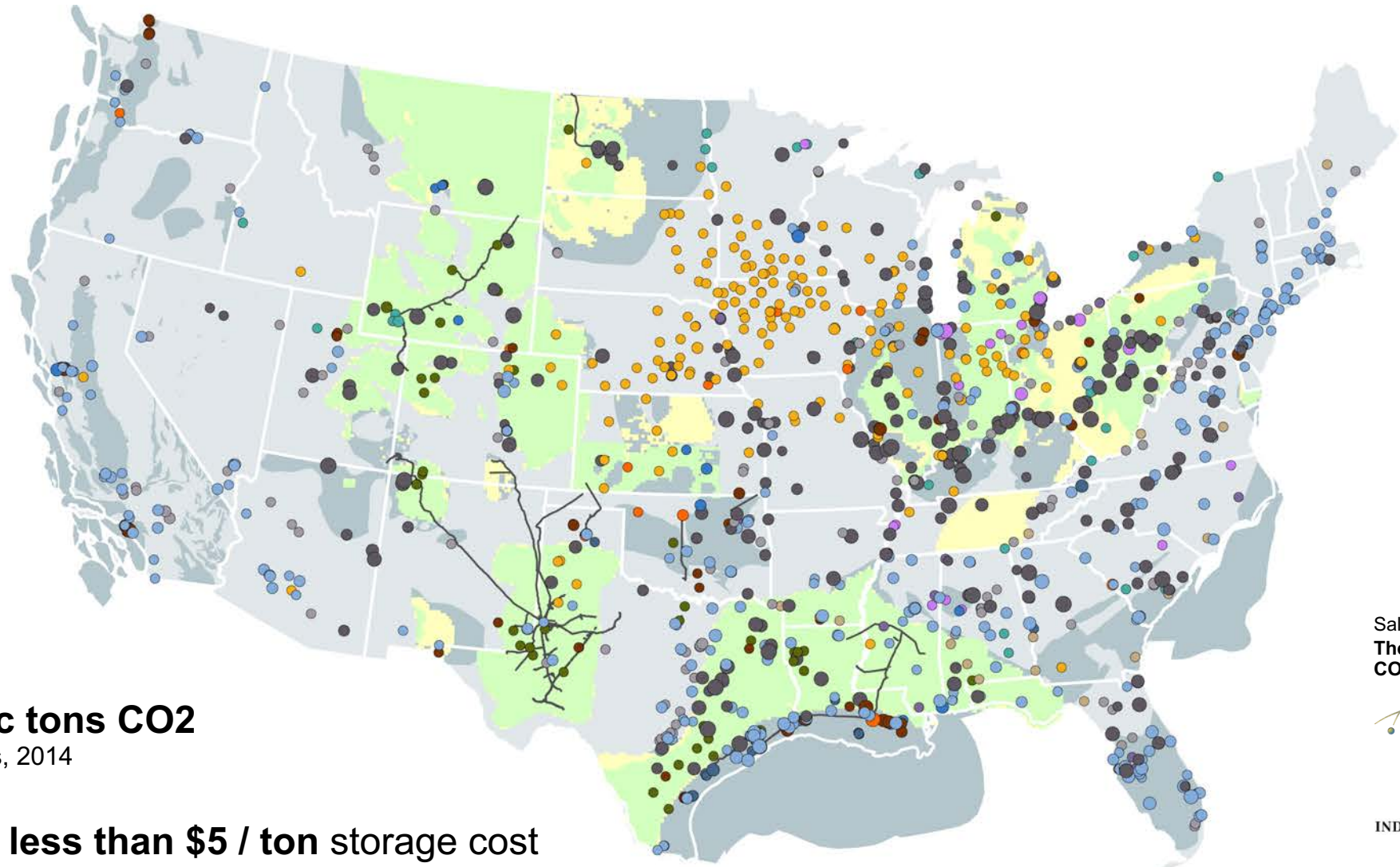
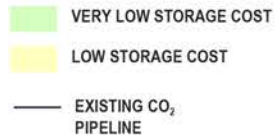
CO₂ Storage in Saline Formations & Petroleum Basins

45Q-ELIGIBLE INDUSTRIAL EMITTERS



SALINE FORMATION

CHARACTERIZED BY CO₂T:



US Saline Storage Potential
8.3 to 21.6 trillion metric tons CO₂

U.S. DOE, U.S. Carbon Storage Atlas, 2014

1.8 trillion metric tons at less than \$5 / ton storage cost

[Conservative estimate based on *partial* coverage of data. National estimate forthcoming.]

Los Alamos National Lab and Indiana Geological Survey, SCO2T Model, 2020

Saline data via
**The Sequestration of
 CO₂ Tool (SCO2T)**



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Figure authored by Elizabeth
 Abramson, GPI, March 2020



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2020 CO₂ Conference
 December 8-10

Near- and Medium-Term Scenario: Optimized transport network for CO₂ capture and storage under 45Q

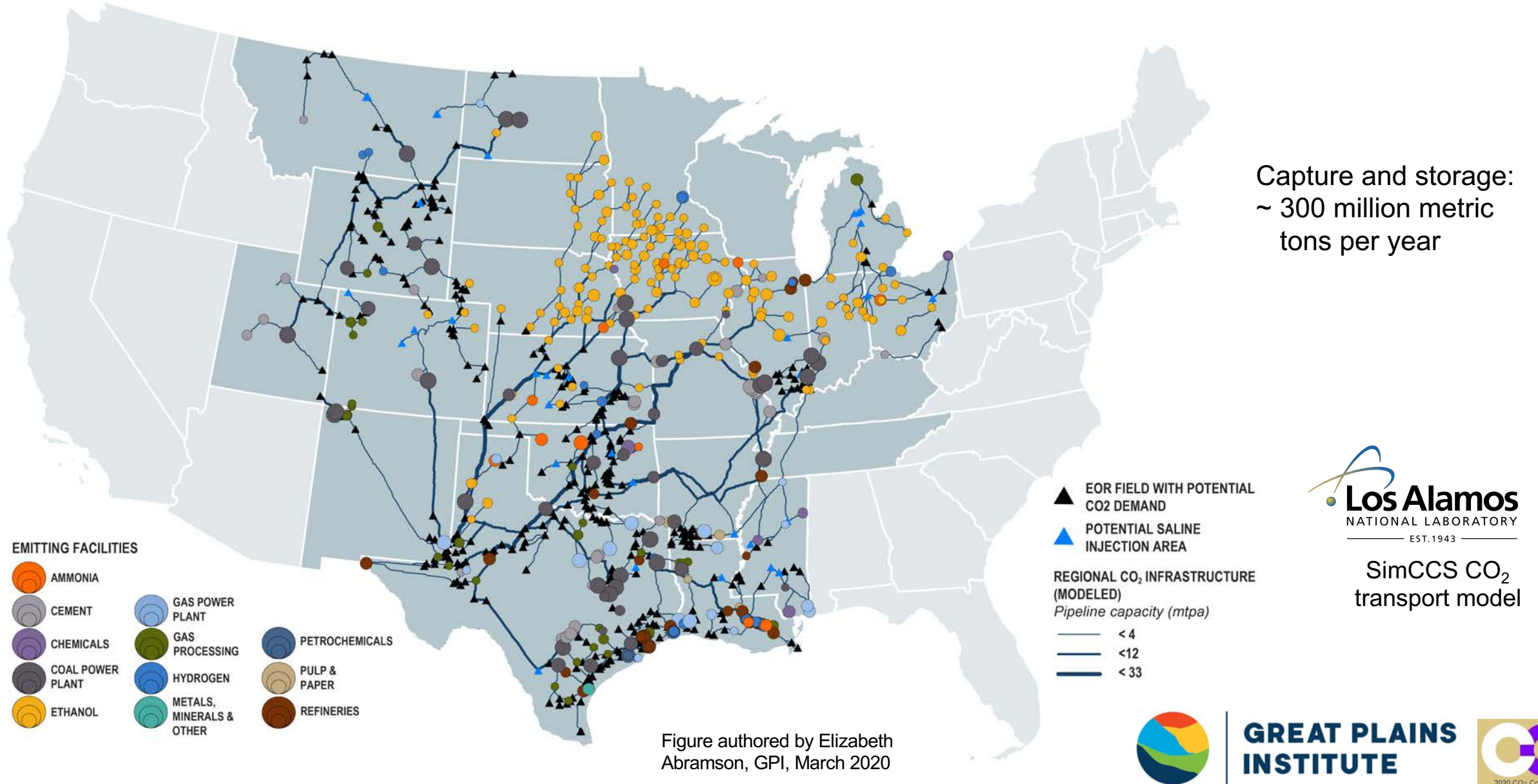


Figure authored by Elizabeth
Abramson, GPI, March 2020

Near- and Medium-Term Scenario: Optimized transport network for CO₂ capture and storage under 45Q

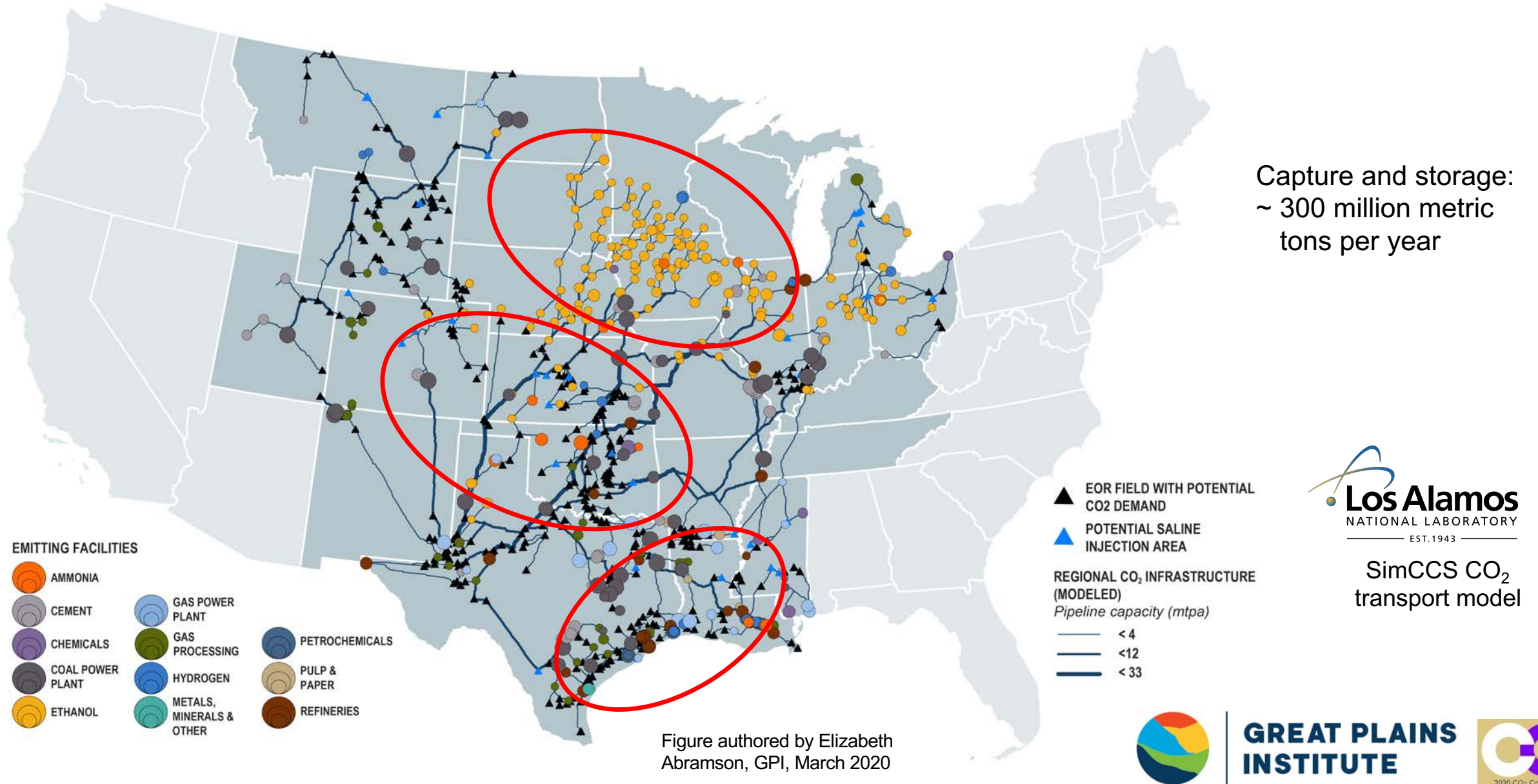


Figure authored by Elizabeth Abramson, GPI, March 2020

Shared CO₂ Transport Infrastructure: Beneficial Economies of Scale

Higher capacity achieves lower costs per ton

Infrastructure investment by capacity
\$ per inch-mile

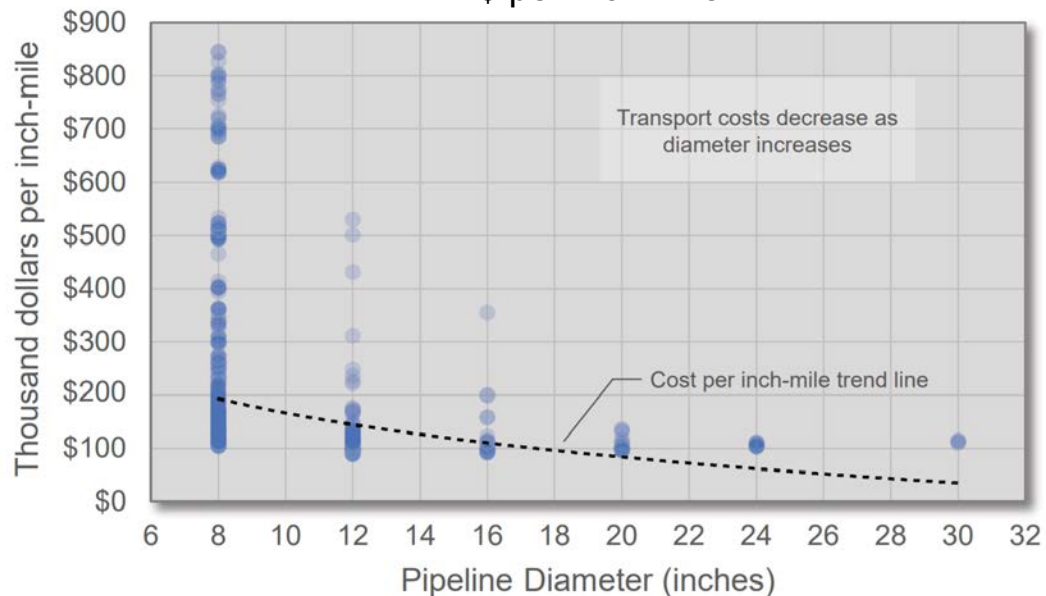


Figure authored by GPI based on calculations performed using the NETL CO₂ Transport Cost Model.

Transport tariff by capacity
\$ per ton

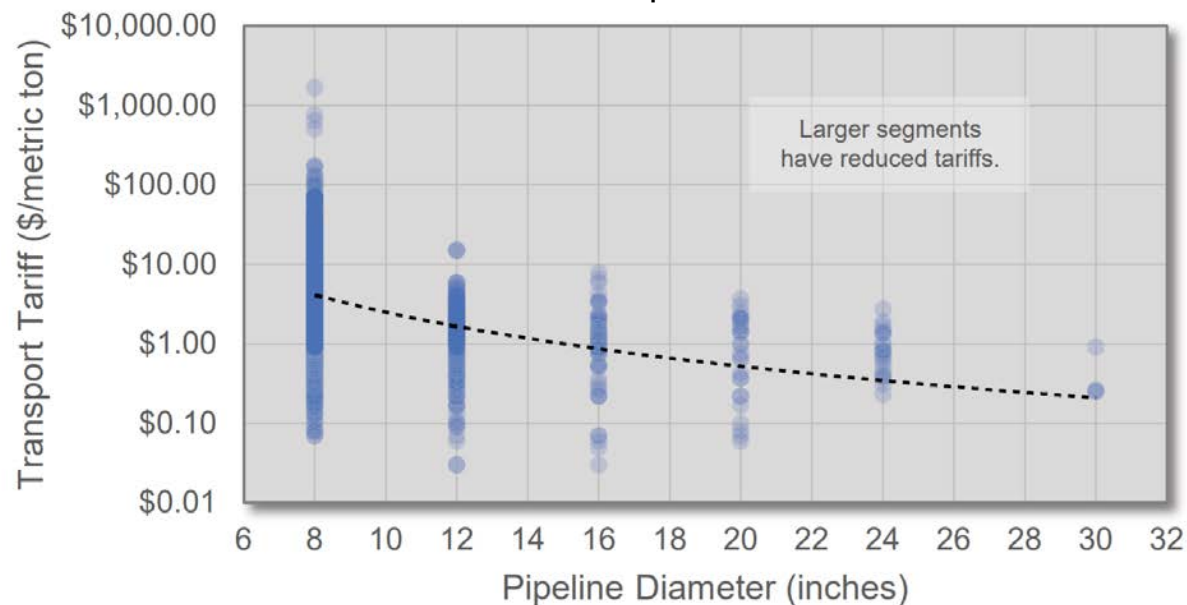


Figure authored by GPI based on calculations performed using the NETL CO₂ Transport Cost Model, as modified by McFarlane, Dubois, and Edwards, 2018.

Investment by owner/operator



Cost to user/customer

Calculated with:



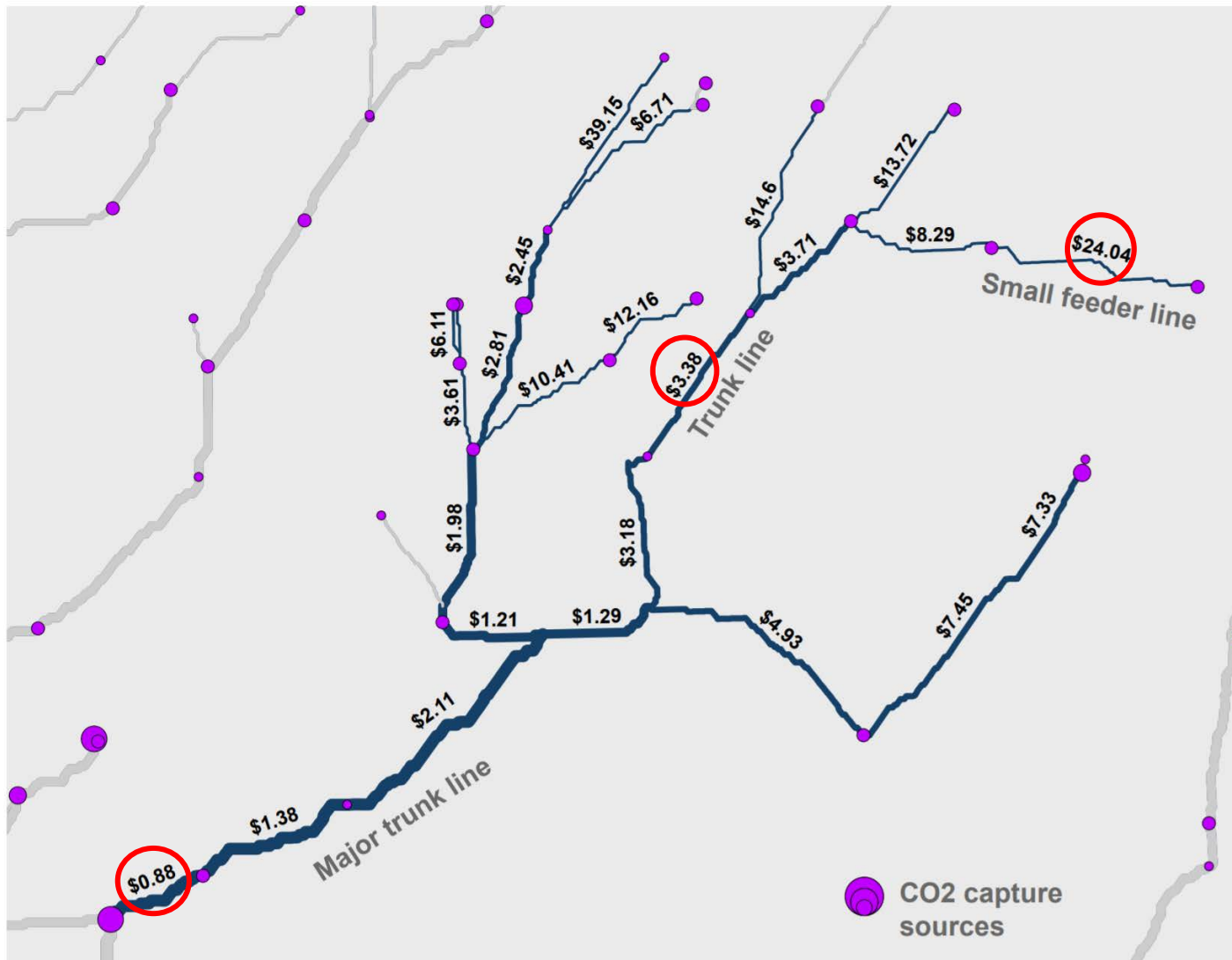
CO₂ Transport Cost Model



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Shared CO₂ Transport Infrastructure: Beneficial Economies of Scale



Small feeder lines have a higher per-ton cost because they deliver less CO₂.

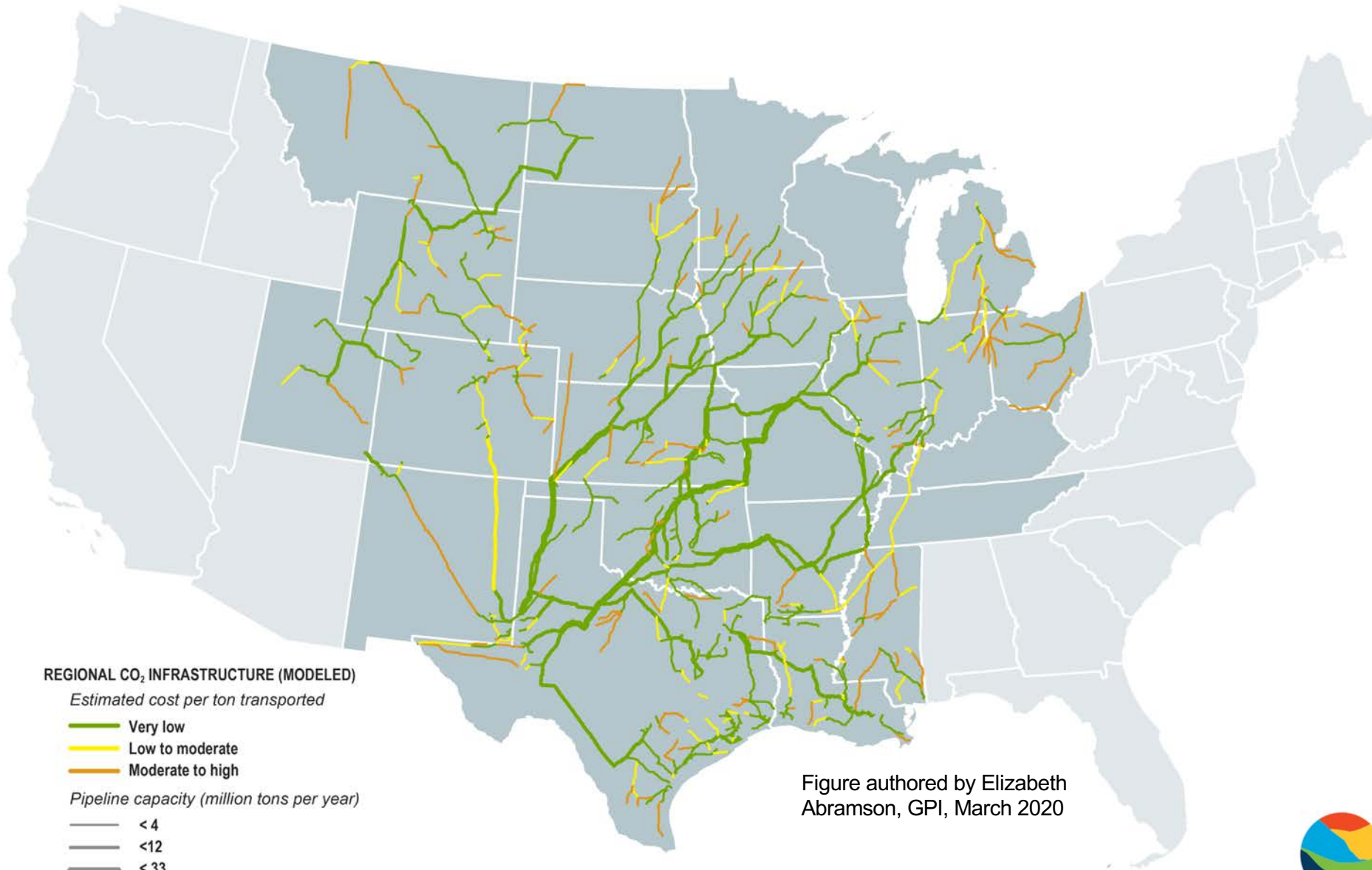
Shared high-capacity transport segments achieve beneficial economies of scale.

Customers generally pay a transport tariff (\$/ton) based on the route their CO₂ product takes through the transport network.

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 CO₂ Transport Cost model.



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



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.

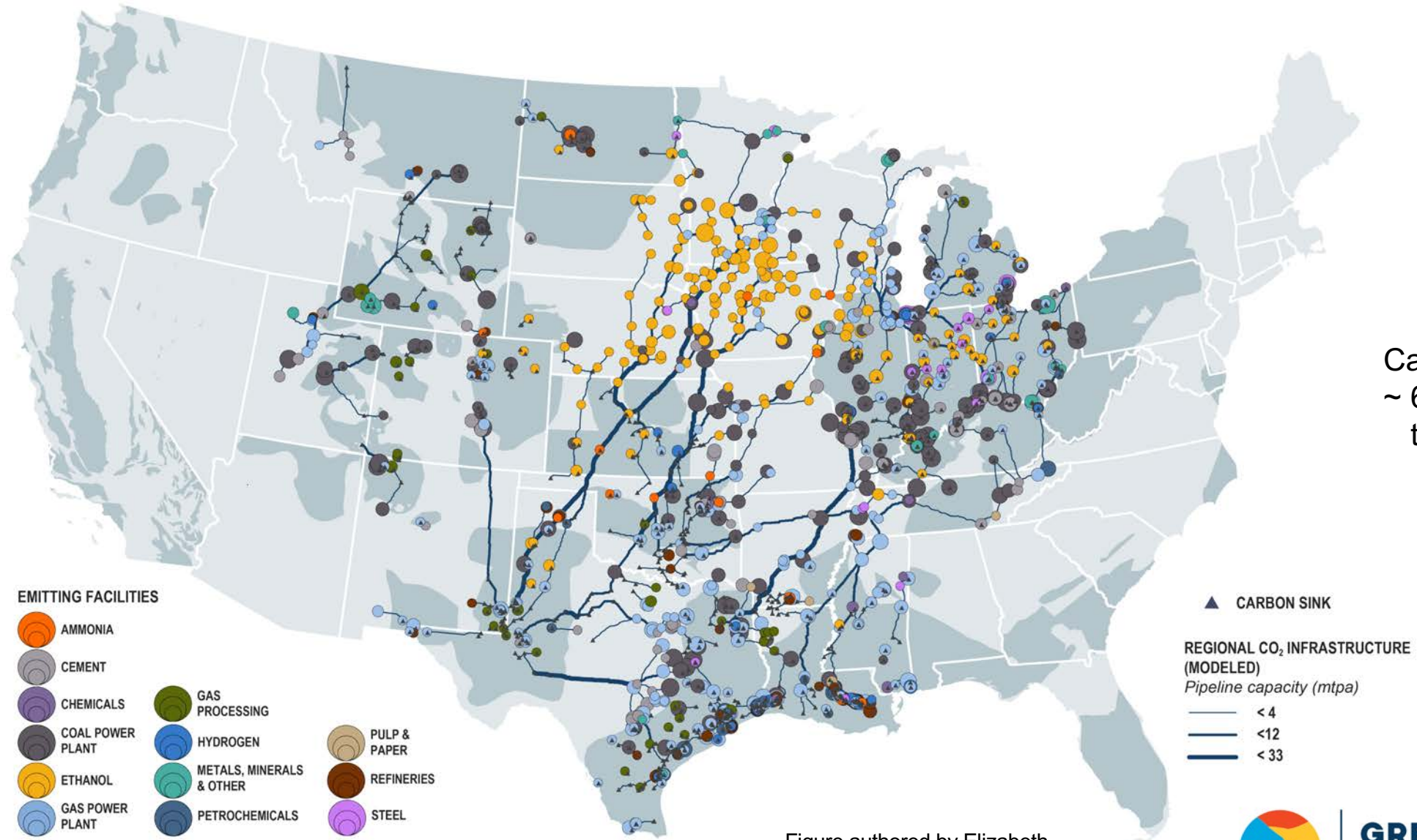
Cost Range	Length (miles)
Very Low	18,006
Low to Moderate	4,744
Moderate to High	6,960

Figure authored by Elizabeth Abramson, GPI, March 2020



Midcentury: Long-term Economy-Wide Deployment

Expanded storage in saline formations and petroleum basins



Capture and storage:
~ 670 million metric
tons per year

Figure authored by Elizabeth Abramson, GPI, March 2020



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2020 CO₂ Conference
December 8-10

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

Economies of scale benefit higher capacity for CO₂ delivery

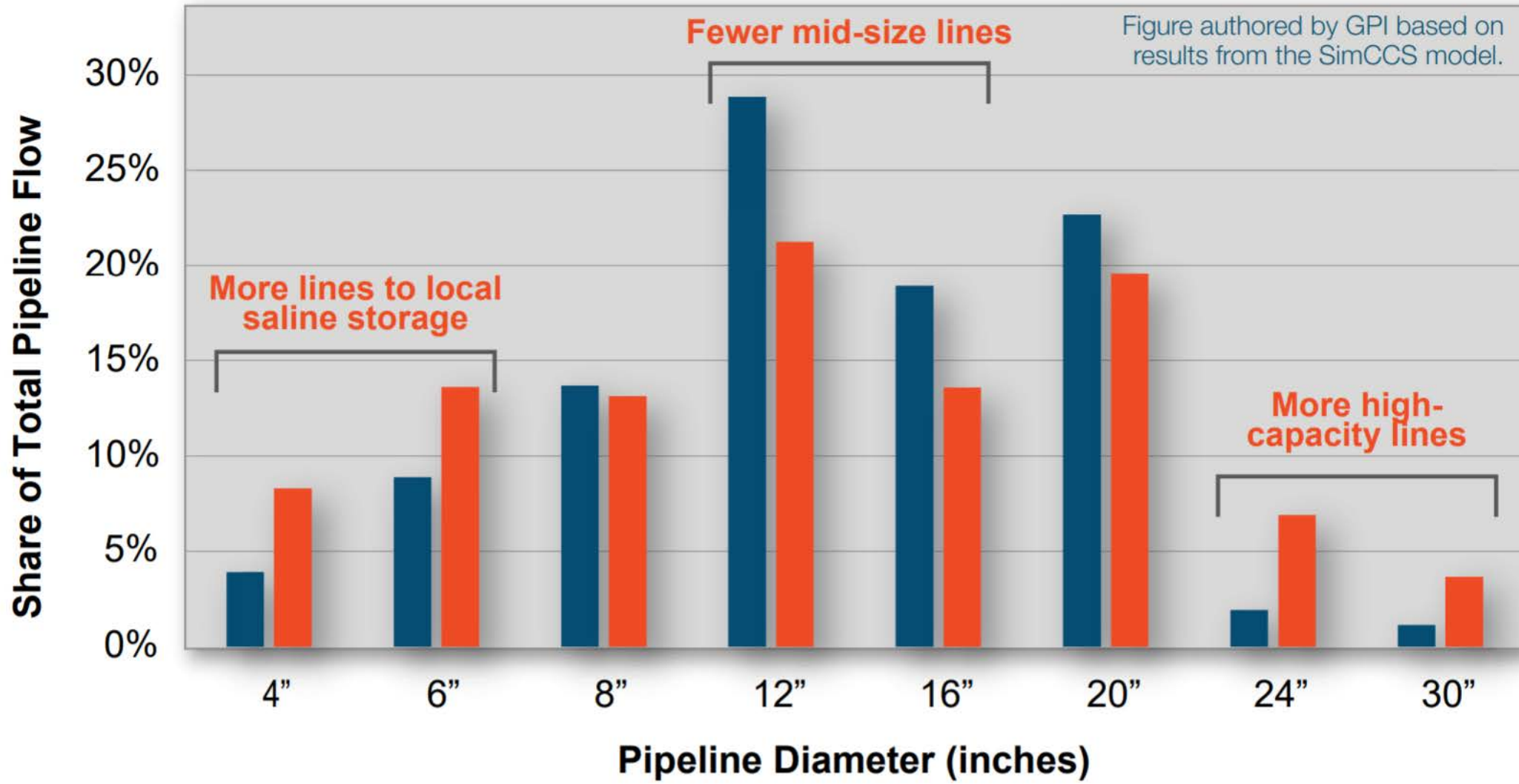
Regional infrastructure can store more CO₂ at a lower cost

Long term planning results in more CO₂ 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%



Transport Network Size for Near- and Medium-Term versus Midcentury Scenario



Carbon Capture Ready Website

RDI Homepage

- State fact sheets
- Jobs fact sheets
- Analytical white paper
- Policy briefs
- Resources on carbon capture



REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

JOBS AND ECONOMIC IMPACT OF CARBON CAPTURE DEPLOYMENT Texas

TOTAL JOBS POTENTIAL

Project Jobs	Operations Jobs	Infrastructure Jobs
15,010	9,230	2,850

Texas has the opportunity to create an annual average of up to 17,860 project jobs over a 15-year period and 9,230 ongoing operations jobs through the deployment of carbon capture at 95 industrial and power facilities. The retrofit of equipment at these facilities has the potential to capture nearly 161 million metric tons of carbon dioxide (CO₂) per year. Along with the development of CO₂ transport infrastructure, this would generate up to over \$69 billion in private investment.

CREATING JOBS & CAPTURING CARBON

Carbon capture is essential to meeting mid-century emissions reduction goals while retaining and growing a domestic base of high-wage energy, industrial, and manufacturing jobs. Carbon capture retrofits require facilities to be outfitted with capture technologies such as amine scrubbers to remove CO₂ from exhaust gas and compressors to make the CO₂ transport-ready, that are dependent upon the type of industrial plant and vary across industries and facilities. There are jobs associated with the equipment, materials (e.g. cement and steel), engineering, and labor required to install the capture technology, as well as ongoing jobs to operate and maintain the retrofits. These are referred to as project jobs and operations jobs.

Rhodium Group performed an economic analysis based on the Regional Carbon Capture Deployment Initiative's near- and medium-term capture potential scenario.¹ The Rhodium analysis quantifies the economic impact and employment opportunities of carbon capture retrofit projects by deploying state-specific data in the IMPLAN economic model. The analytical results measure the impact of project investment and operation costs through expected annual jobs. Average annual project jobs were calculated assuming deployment of all projects within the 15-year period from 2021-2035. The jobs reported are in-state jobs, directly associated with carbon capture retrofits. They do not include other jobs at the facilities, nor indirect and induced jobs.

CARBON CAPTURE JOBS AND ECONOMIC IMPACT SUMMARY

Industry	Number of Facilities	Total Capture Target Metric Tons	Private Investment Million Dollars	Annual Average Project Jobs 2021-2035	Annual Operations Jobs
Cement	11	8,000,000	\$1,200 - \$1,800	350 - 520	310 - 430
Coal Power	11	70,000,000	\$14,000 - \$20,000	3,870 - 5,800	2,360 - 3,540
Ethanol	4	1,000,000	\$60 - \$90	15 - 25	20 - 30
Gas Power	28	53,000,000	\$15,000 - \$25,000	4,400 - 6,600	2,570 - 3,850
Gas Processing	6	900,000	\$70 - \$100	20 - 25	20 - 30
Hydrogen	14	9,000,000	\$900 - \$1,300	260 - 380	270 - 370
Petrochemicals	2	2,000,000	\$500 - \$700	150 - 220	110 - 160
Refineries	19	17,000,000	\$2,600 - \$3,900	960 - 1,440	690 - 820
CO ₂ Transport Infrastructure	-	-	\$7,000,000,000	2,850	-

1 Rhodium Group analytical results: rhg.com/research/ For more information, visit carboncaptureready.org

REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

Carbon Capture and Storage Infrastructure for Midcentury Decarbonization

TOTAL JOBS POTENTIAL

Project Jobs	Operations Jobs	Infrastructure Jobs
15,010	9,230	2,850

This report provides data sources, details the analytical methodology, and identifies potential capture facilities throughout the Western and Midwestern regions, as well as primary modeling scenarios and conclusions on regional CO₂/front capture, transport, and storage opportunities.

Download the report below.

[Download Whitepaper](#)

Jobs and Economic Growth Fact Sheets

The Regional Deployment Initiative has released a series of state fact sheets on potential jobs creation and economic impact of carbon capture deployment, based on collaborative analysis by Rhodium Group. The Rhodium analysis quantifies the economic impact and employment opportunities of carbon capture retrofit projects by deploying state-specific data in the IMPLAN economic model.

Download each state fact sheet below:

Midcontinent Region --

Arkansas	Louisiana	Montana	Oklahoma
Colorado	Michigan	North Dakota	South Dakota
Iowa	Minnesota	Nebraska	Texas
Illinois	Missouri	New Mexico	Utah
Indiana	Mississippi	Ohio	Wisconsin

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Thank You

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