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

December 9, 2020

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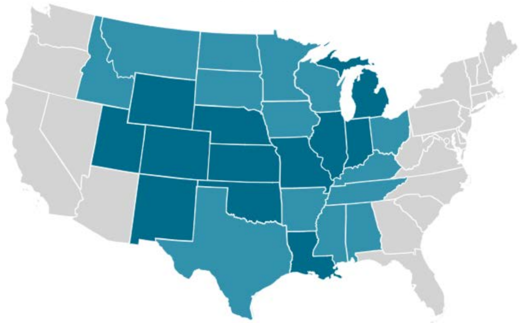
2020 CO_2 Conference
December 8-10

REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE



Objectives:

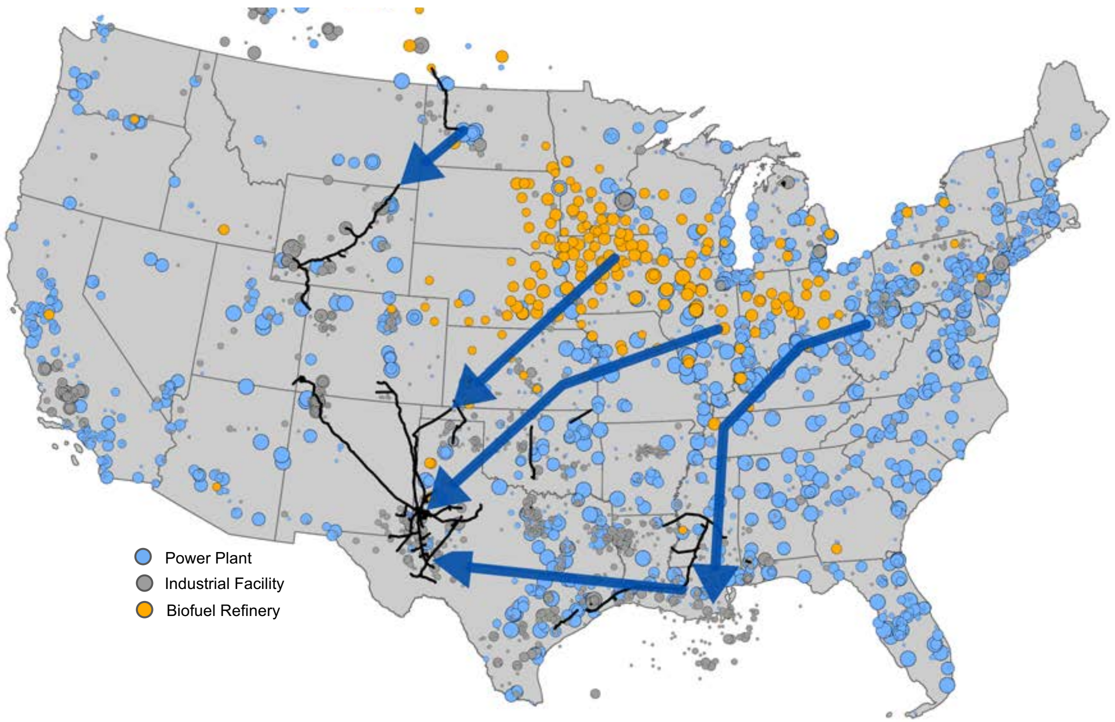
- Prioritize key carbon capture and CO2 pipeline project opportunities revealed in modeling
- Determine cost gaps, where applicable, for priority projects after accounting for federal 45Q tax credit
- Identify state policies to help close cost gaps
- Engage stakeholders, policymakers and media to marshal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

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 to maximize capture and storage

Initial CO_2 Corridor Scoping



Primary Partners:

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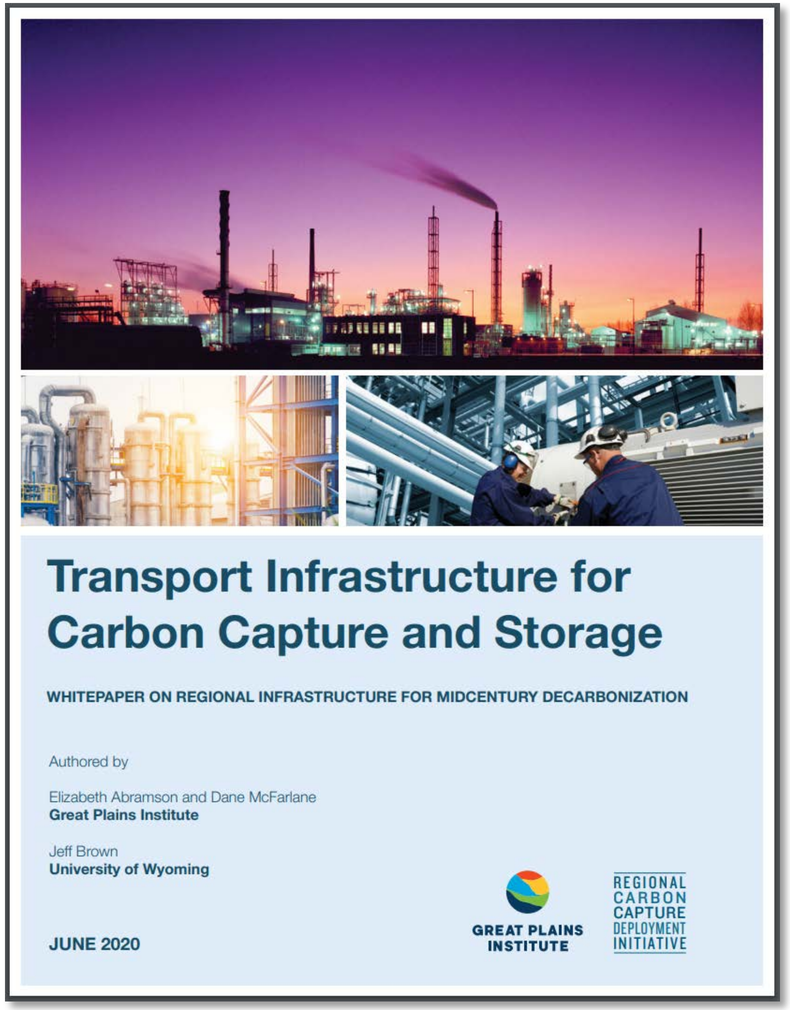
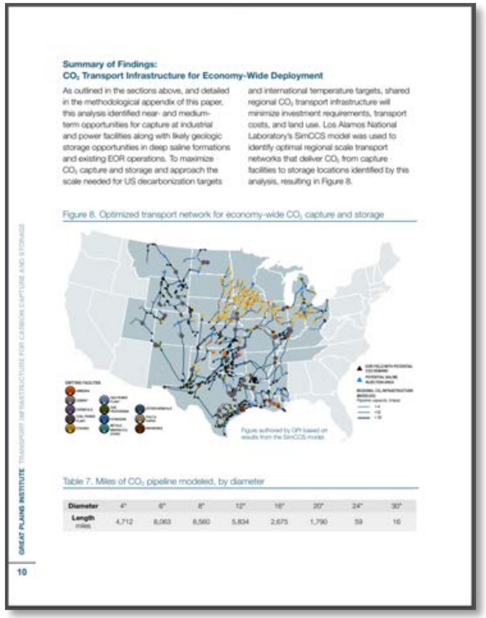
Analytical Report

Published June 30, 2020





Download the paper at:

carboncaptureready.org/analysis

CO_2 Capture Opportunities: Industrial and Power Facilities

Section 45Q
Tax Credit for CO_2 Storage

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

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

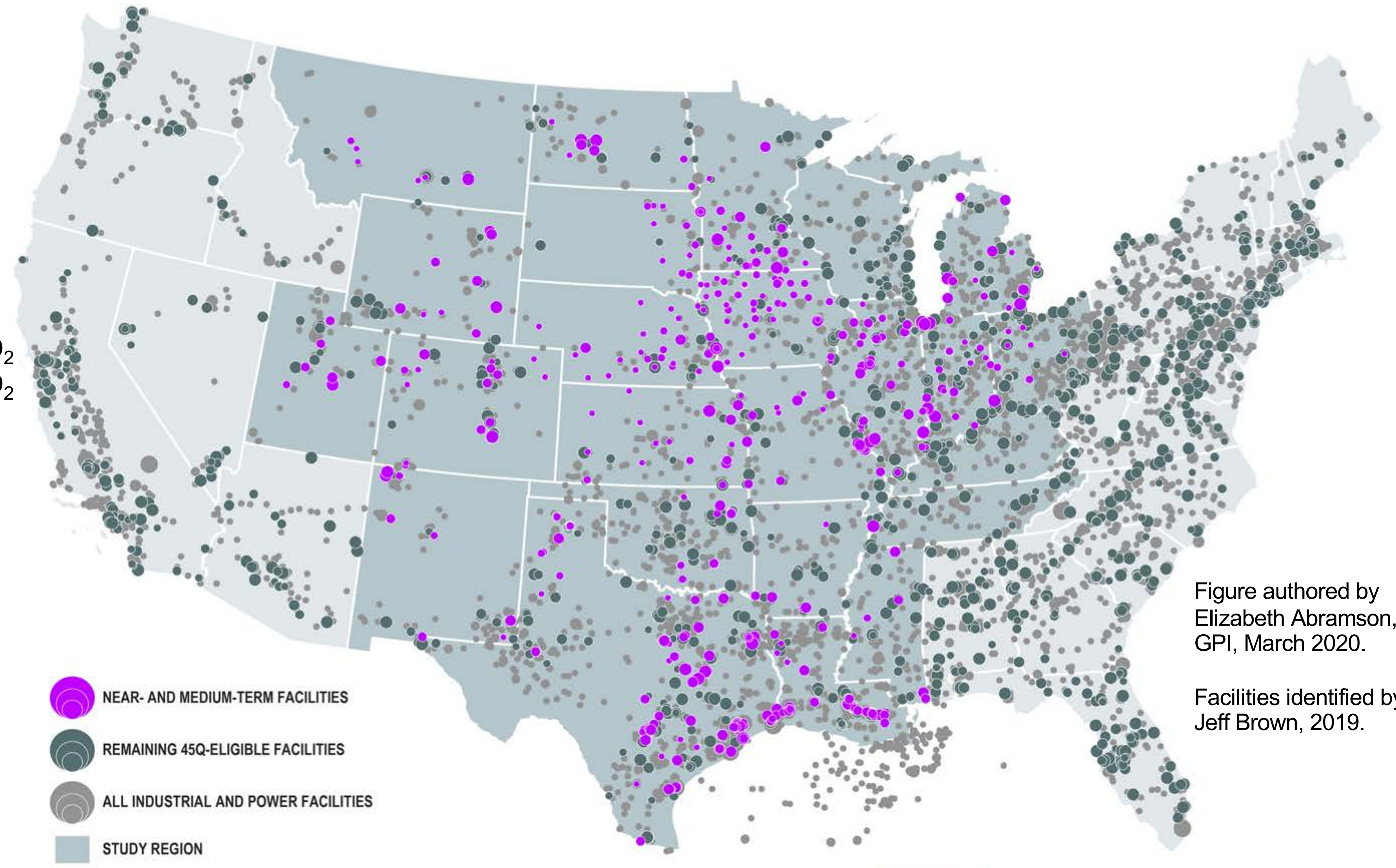


Figure authored by Elizabeth Abramson, GPI, March 2020.

Facilities identified by Jeff Brown, 2019.

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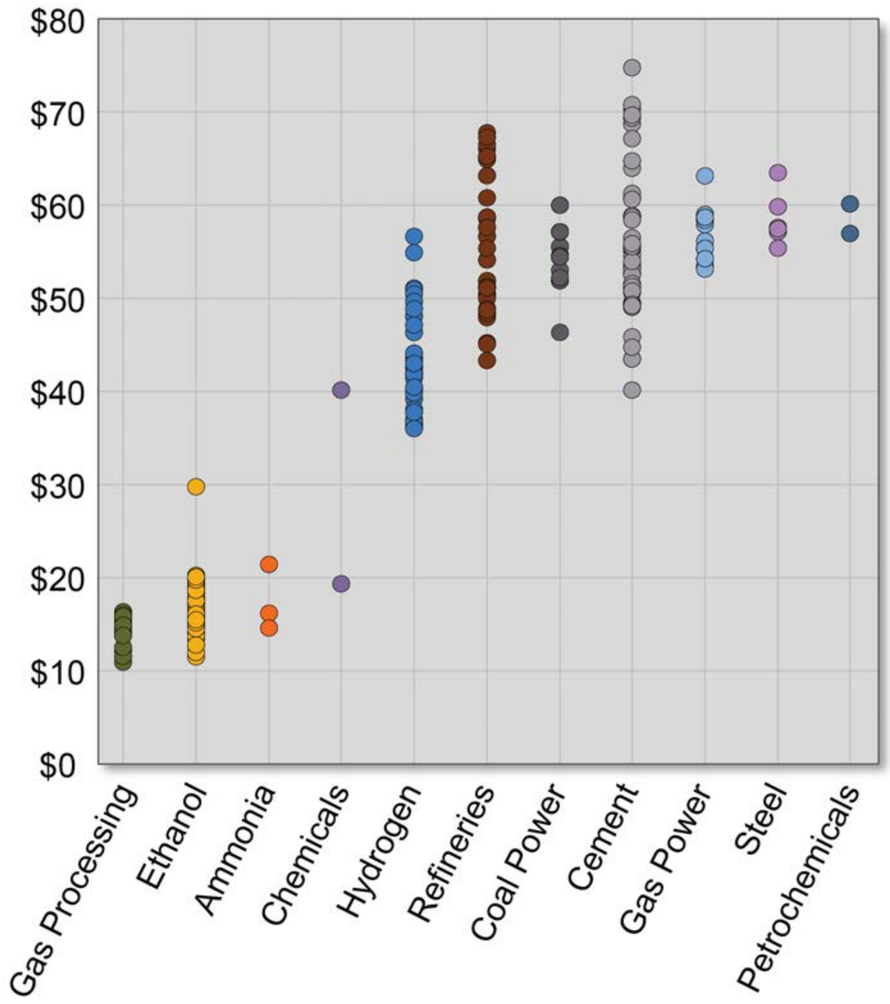
Estimated Cost of Capture per Industry for Near-Term Facilities in Study Area



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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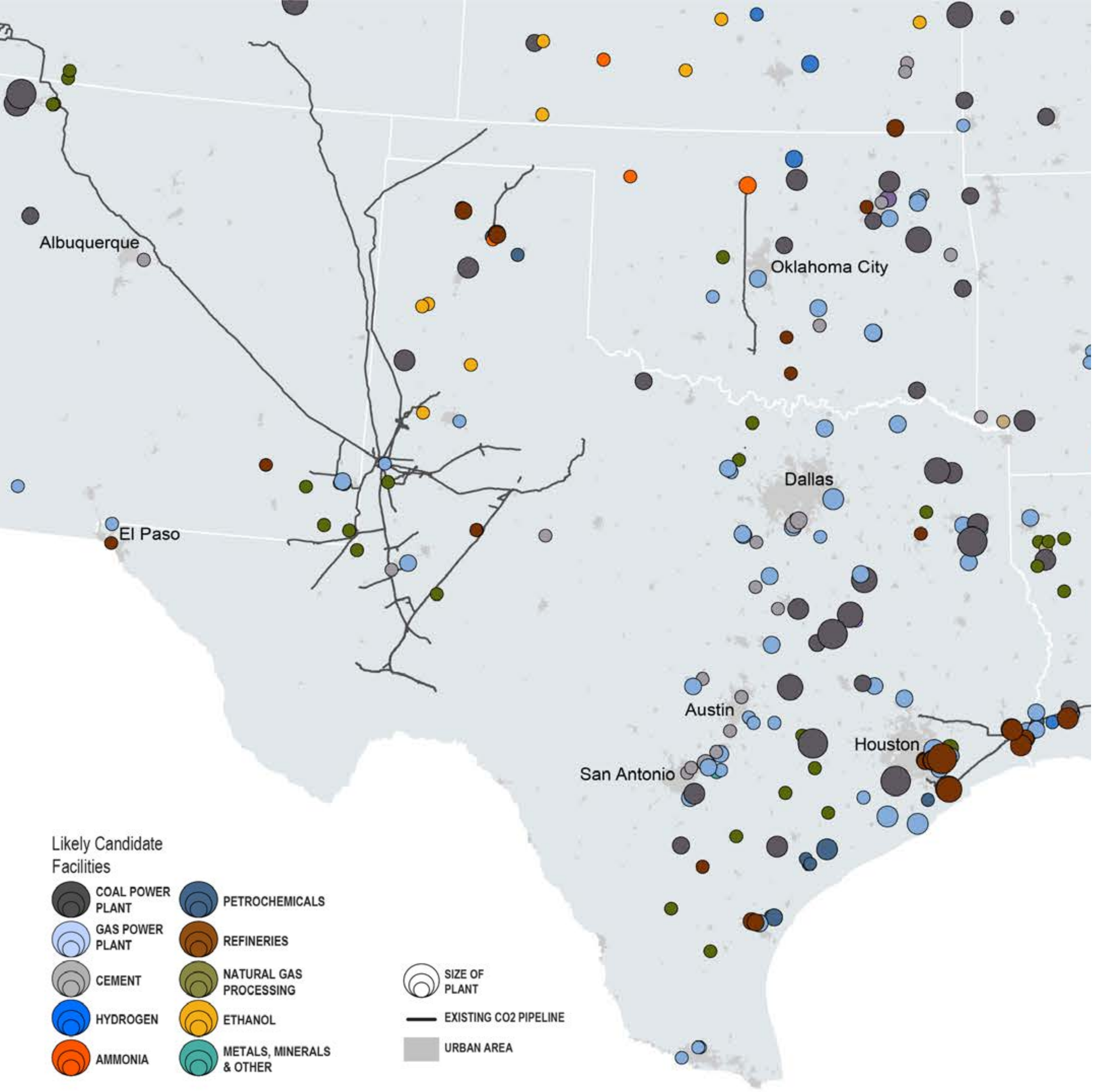

45Q-Qualifying Power and Industrial Sources of CO2 in Texas

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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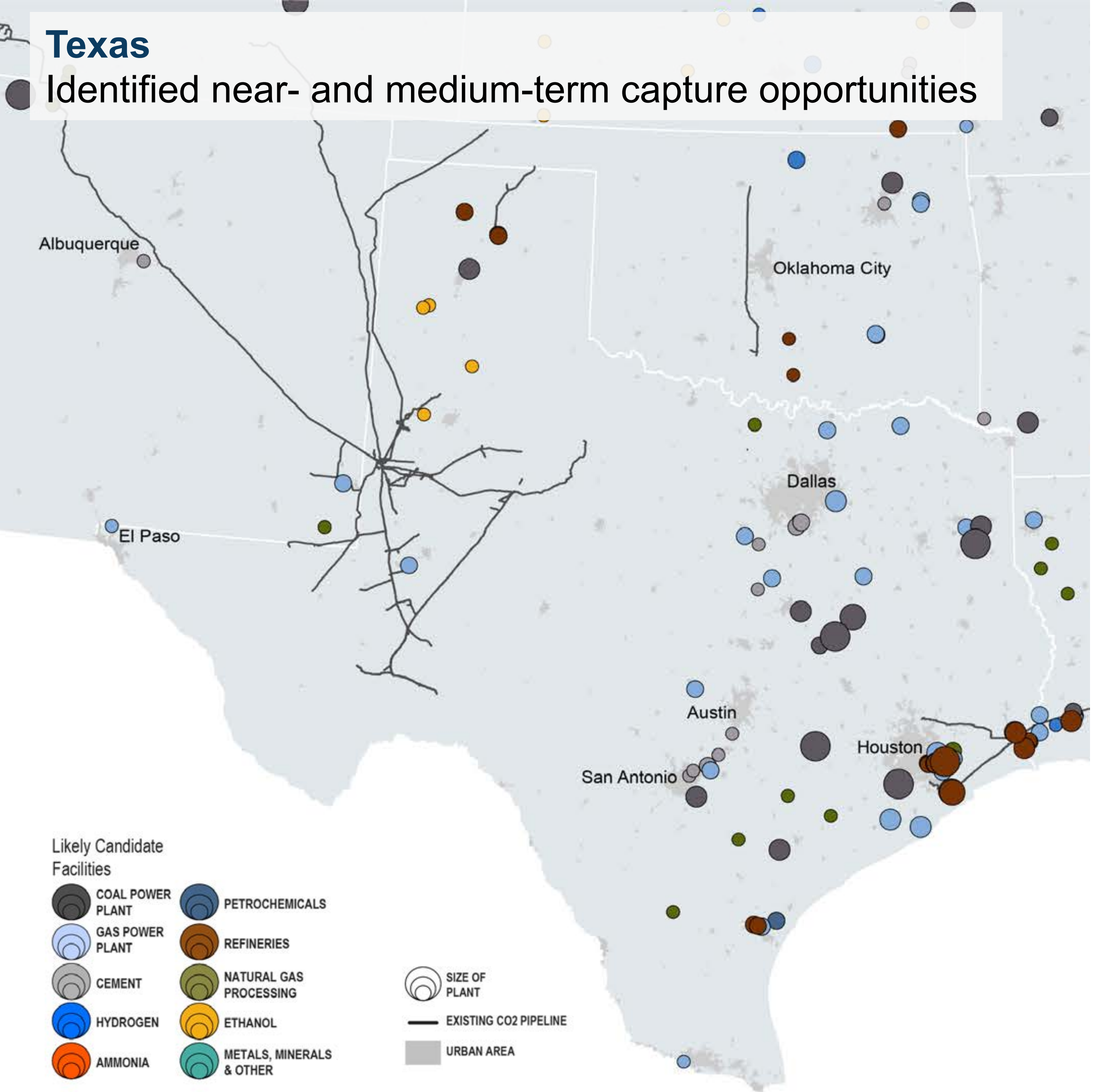
Texas

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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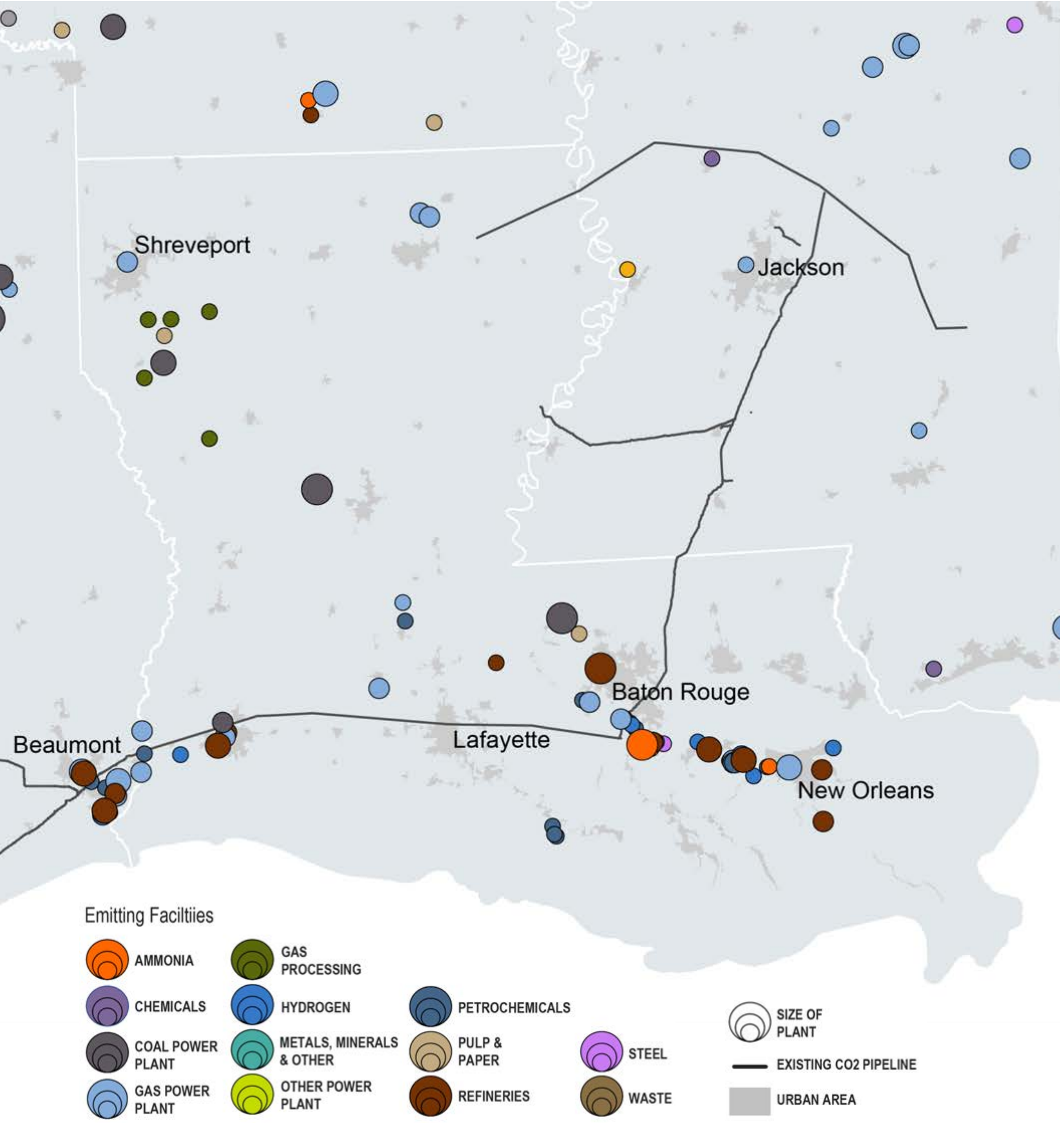

45Q-Qualifying Power and Industrial Sources of CO2 in Louisiana

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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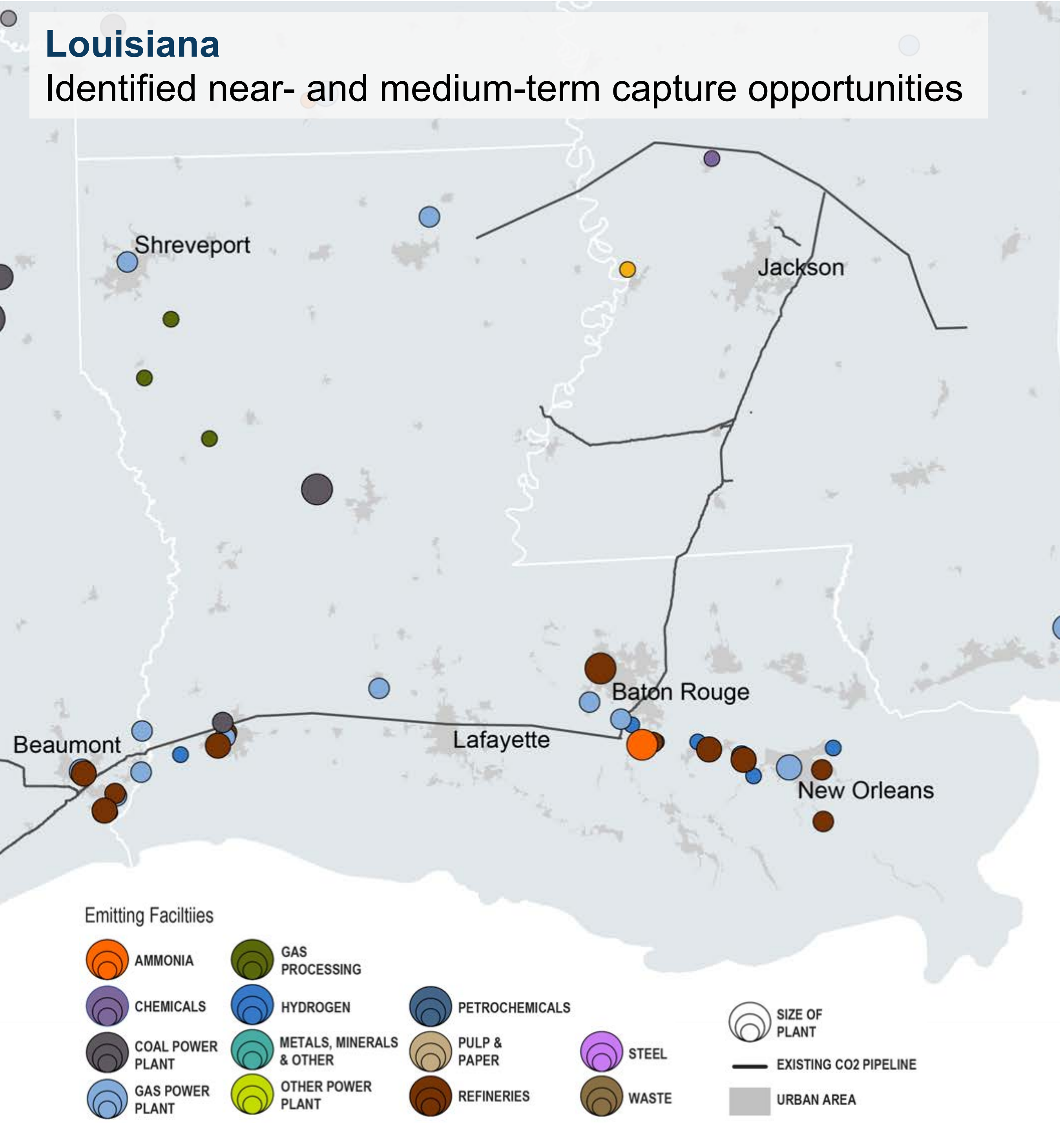
Louisiana
Identified near- and medium-term capture opportunities



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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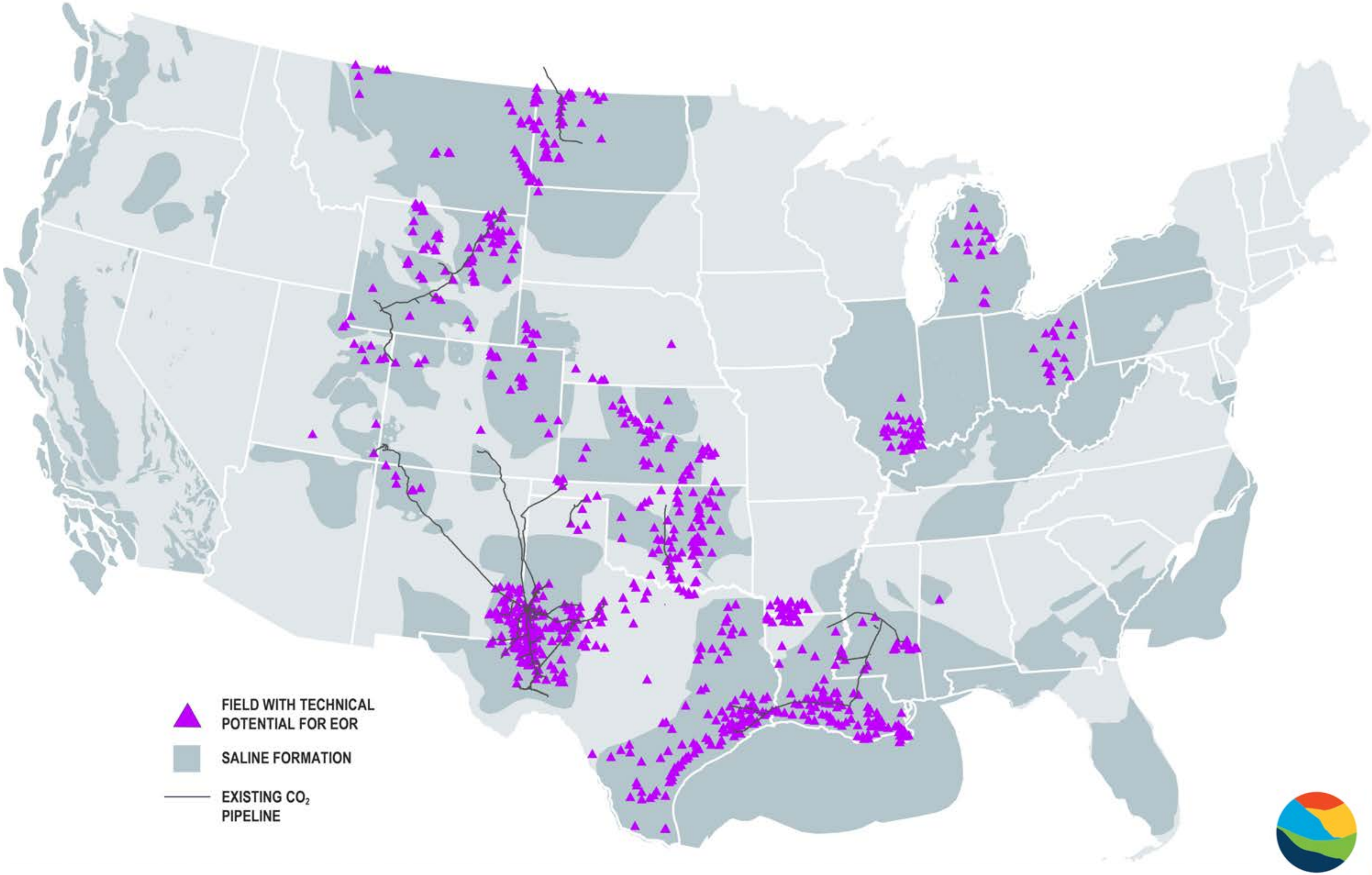
CO_2 Storage in Saline Formations & Petroleum Basins



Saline data via
The Sequestration of CO2 Tool (SCO2T)

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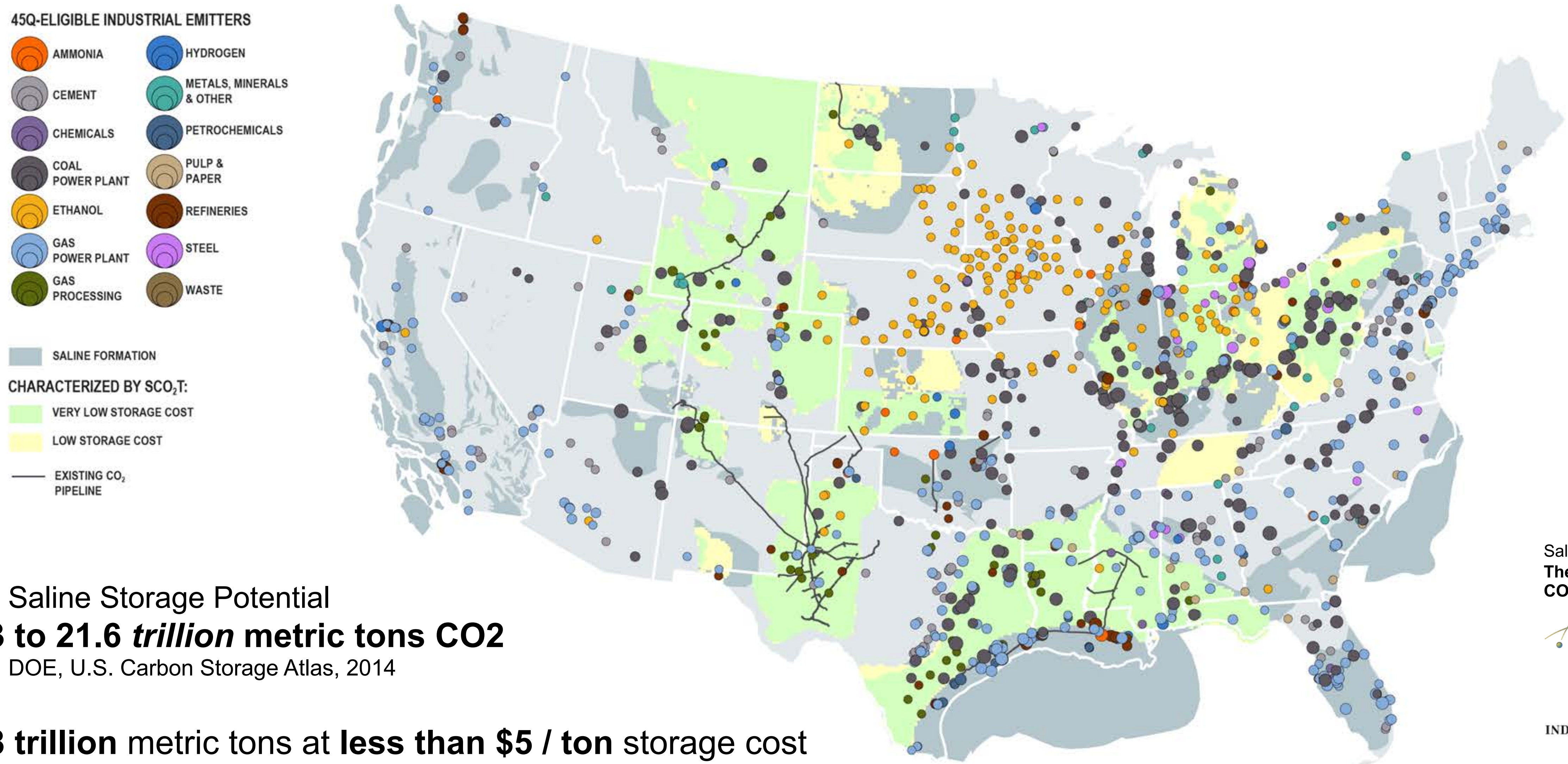
CO_2 Storage in Saline Formations & Petroleum Basins



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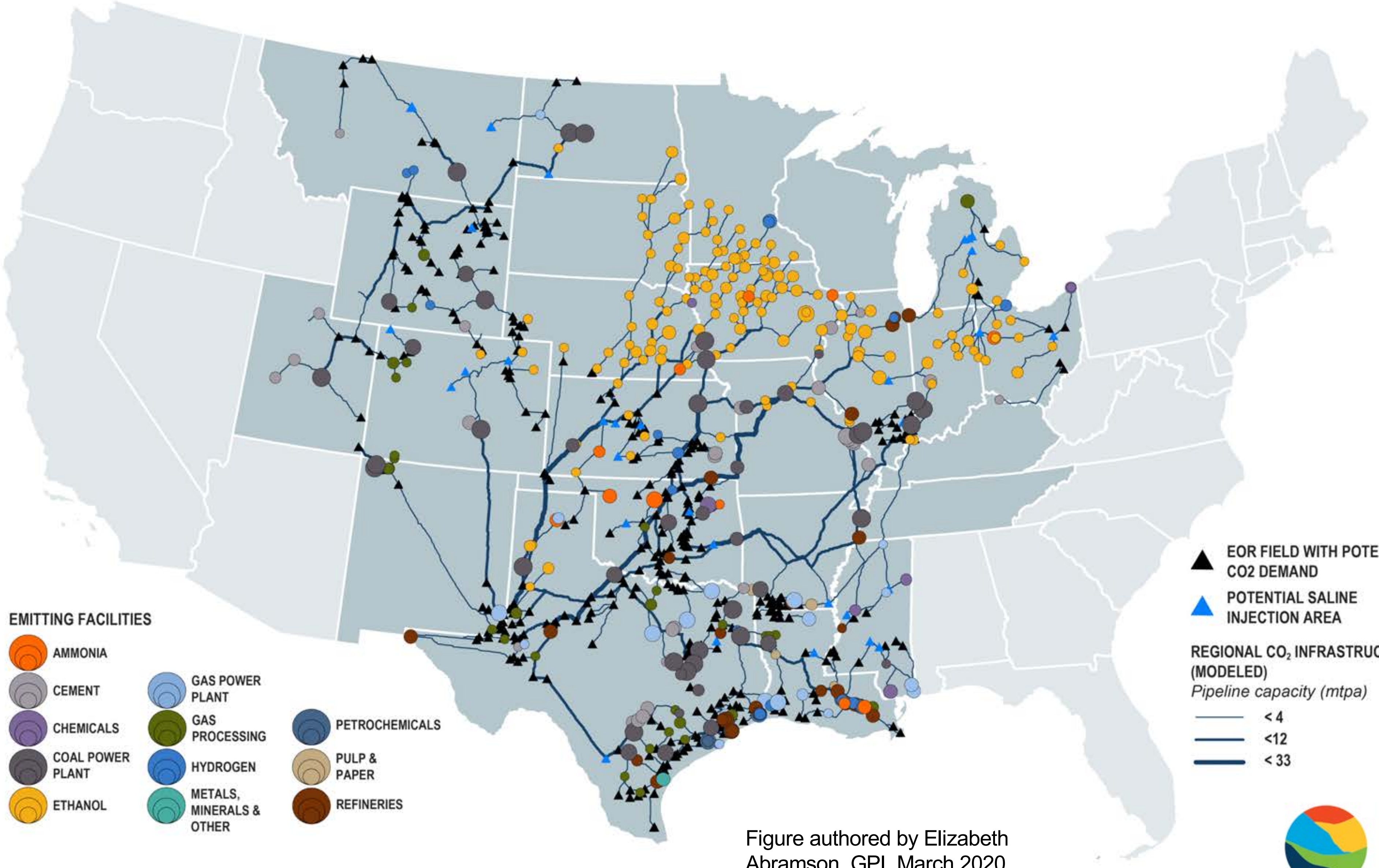
Near- and Medium-Term Scenario:
Optimized transport network for CO_2 capture and storage under 45Q



Capture and storage:
~ 300 million metric tons per year

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SimCCS CO_2 transport model

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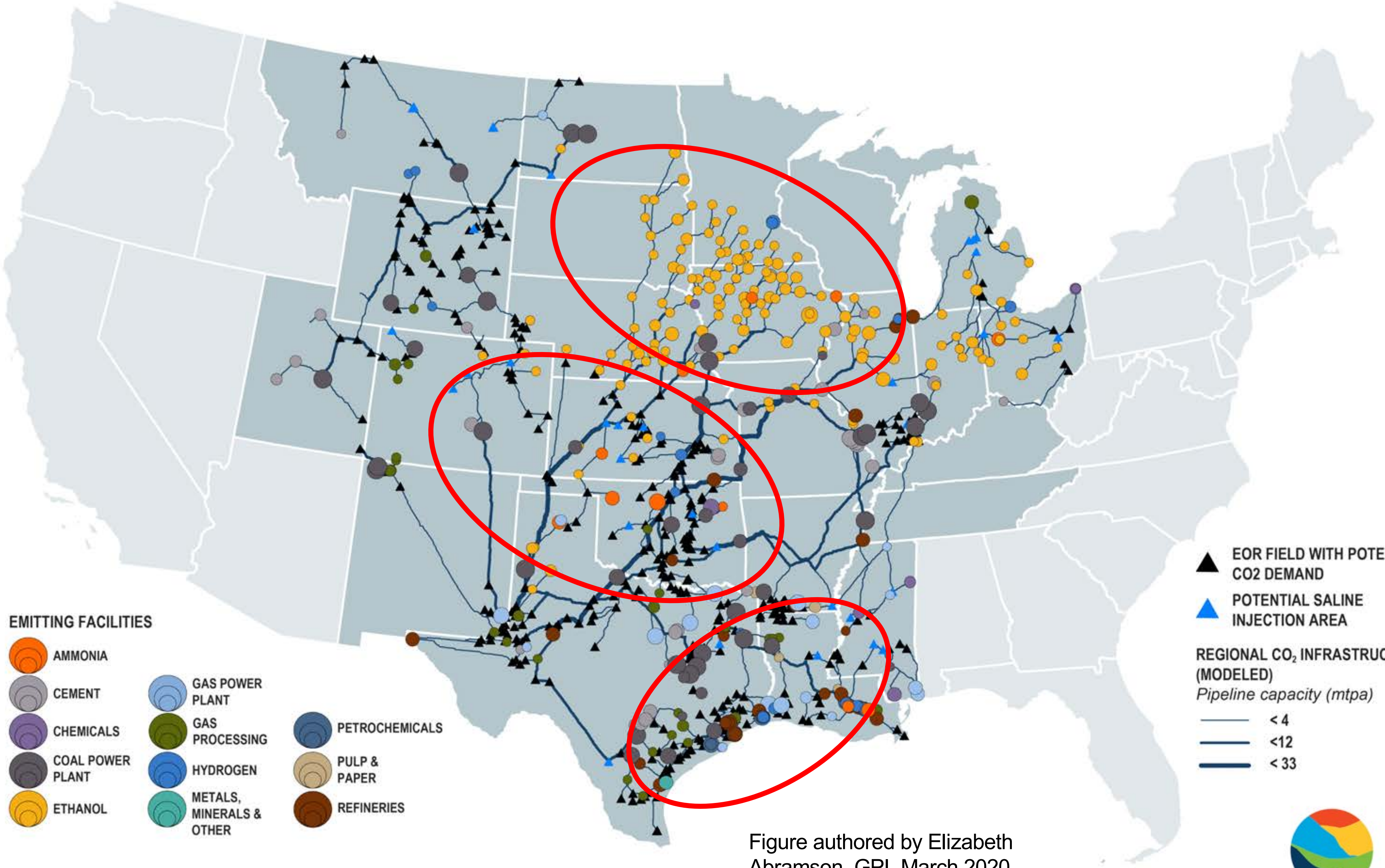
Near- and Medium-Term Scenario:

Optimized transport network for CO_2 capture and storage under 45Q



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Capture and storage:
~ 300 million metric tons per year

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SimCCS CO_2 transport model

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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

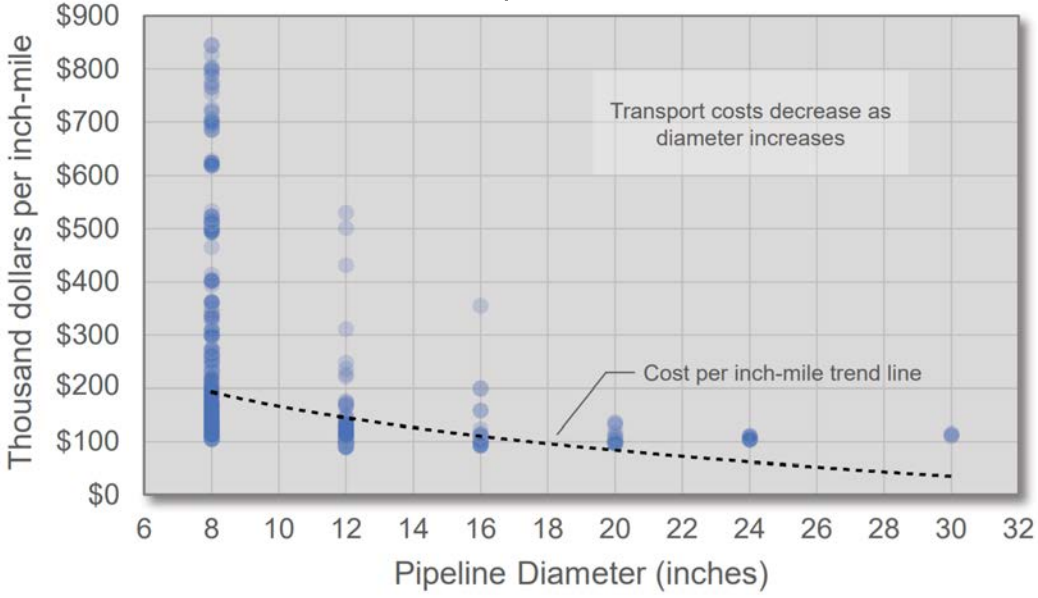

Figure authored by GPI based on calculations performed using the NETL CO_2 Transport Cost Model.

Transport tariff by capacity
$ per ton

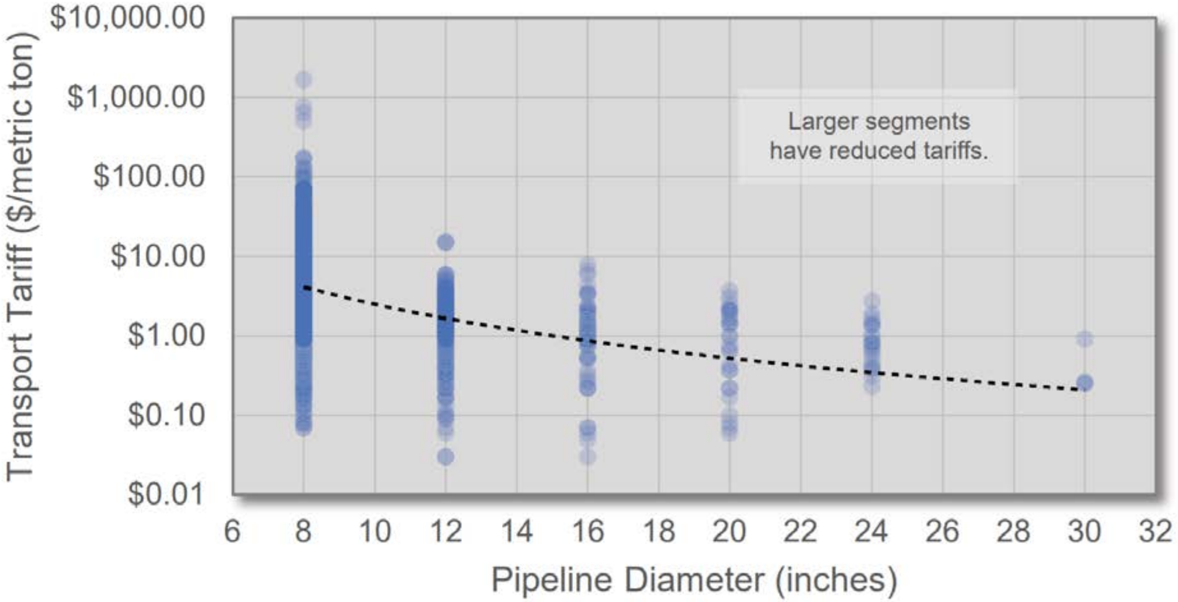

Figure authored by GPI based on calculations performed using the NETL CO_2 Transport Cost Model, as modified by McFarlane, Dubois, and Edwards, 2018.

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

Calculated with:

NATIONAL ENERGY TECHNOLOGY LABORATORY CO_2 Transport Cost Model

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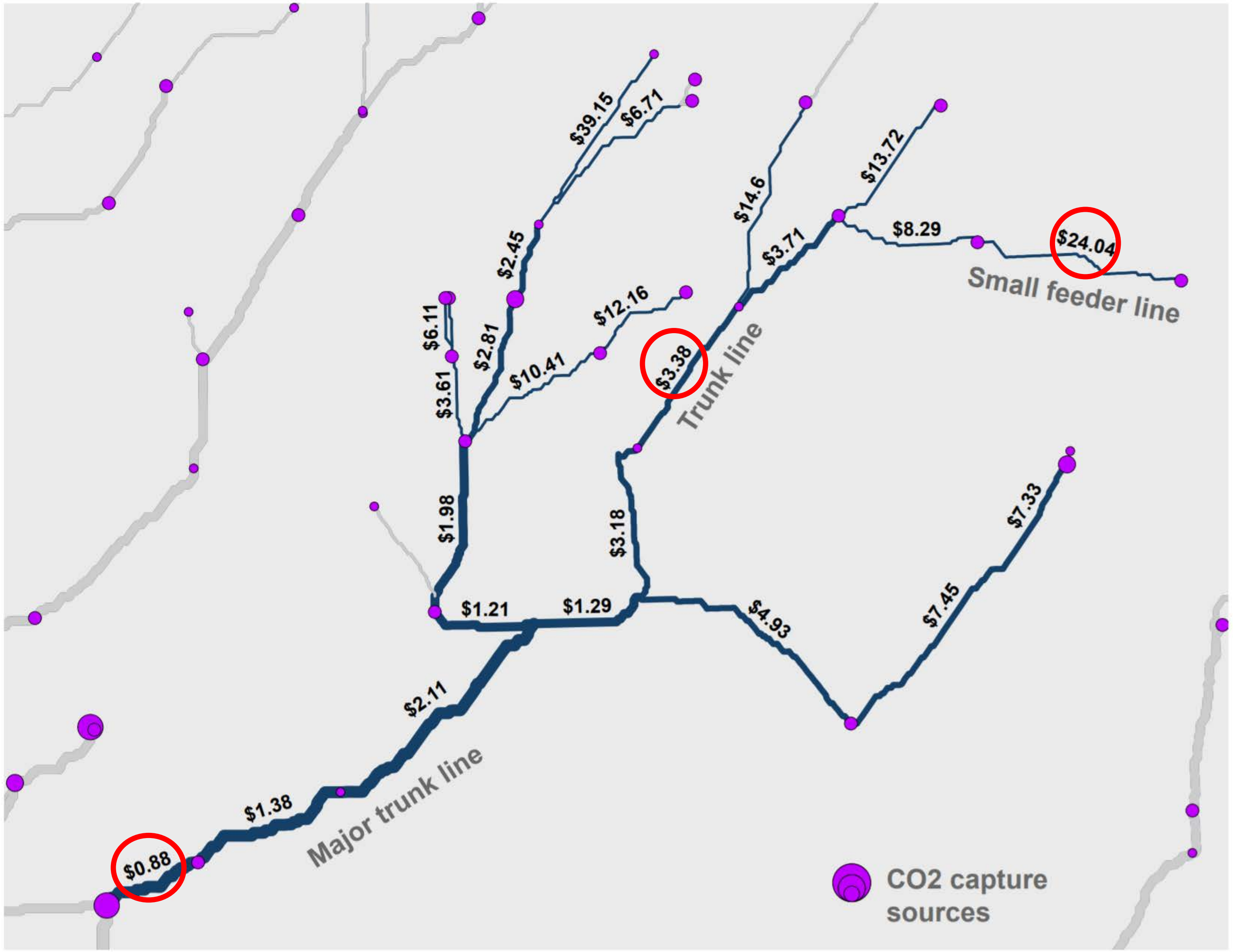
Shared CO_2 Transport Infrastructure: Beneficial Economies of Scale



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

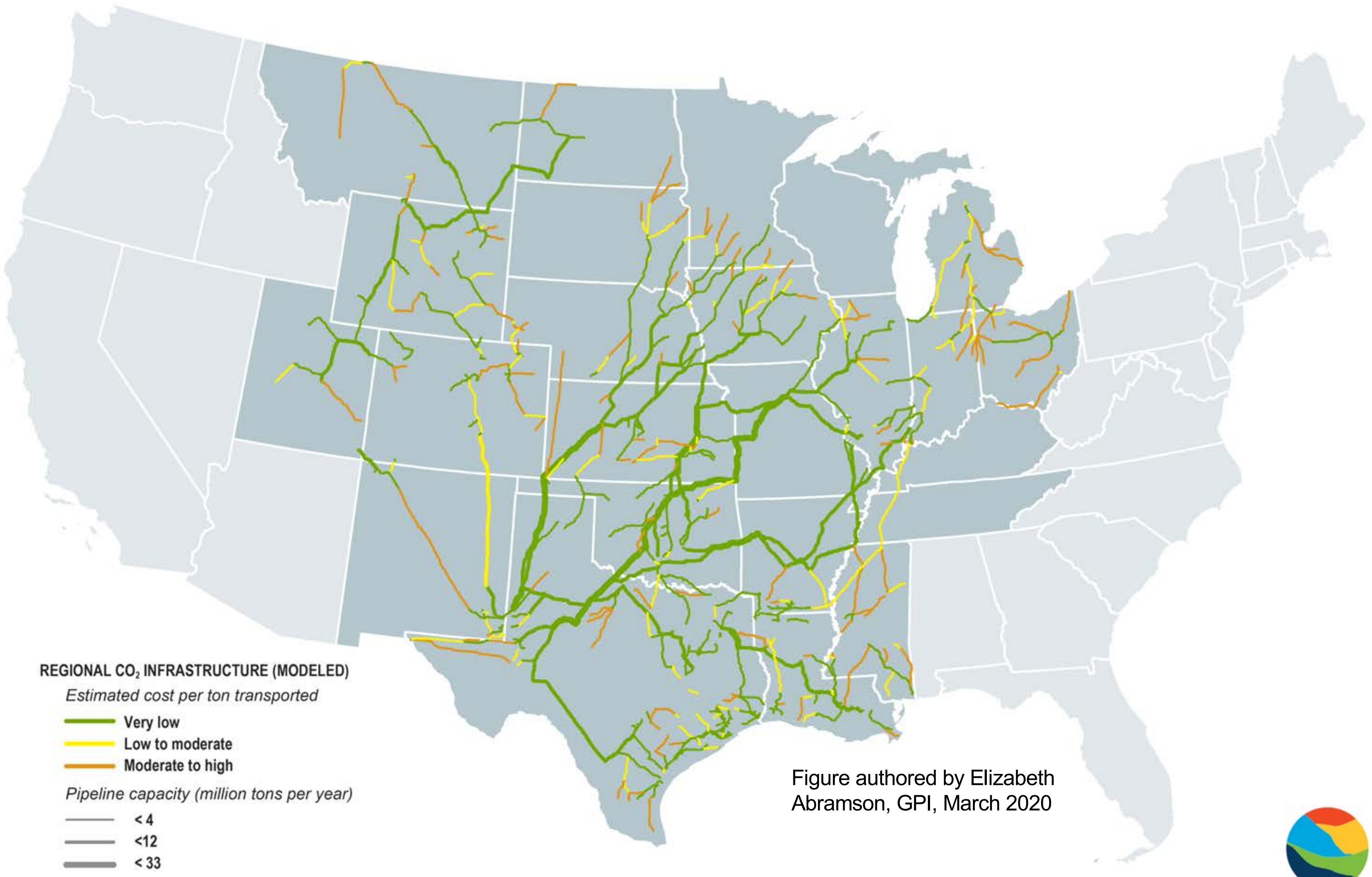

Figure authored by Elizabeth Abramson, GPI, March 2020

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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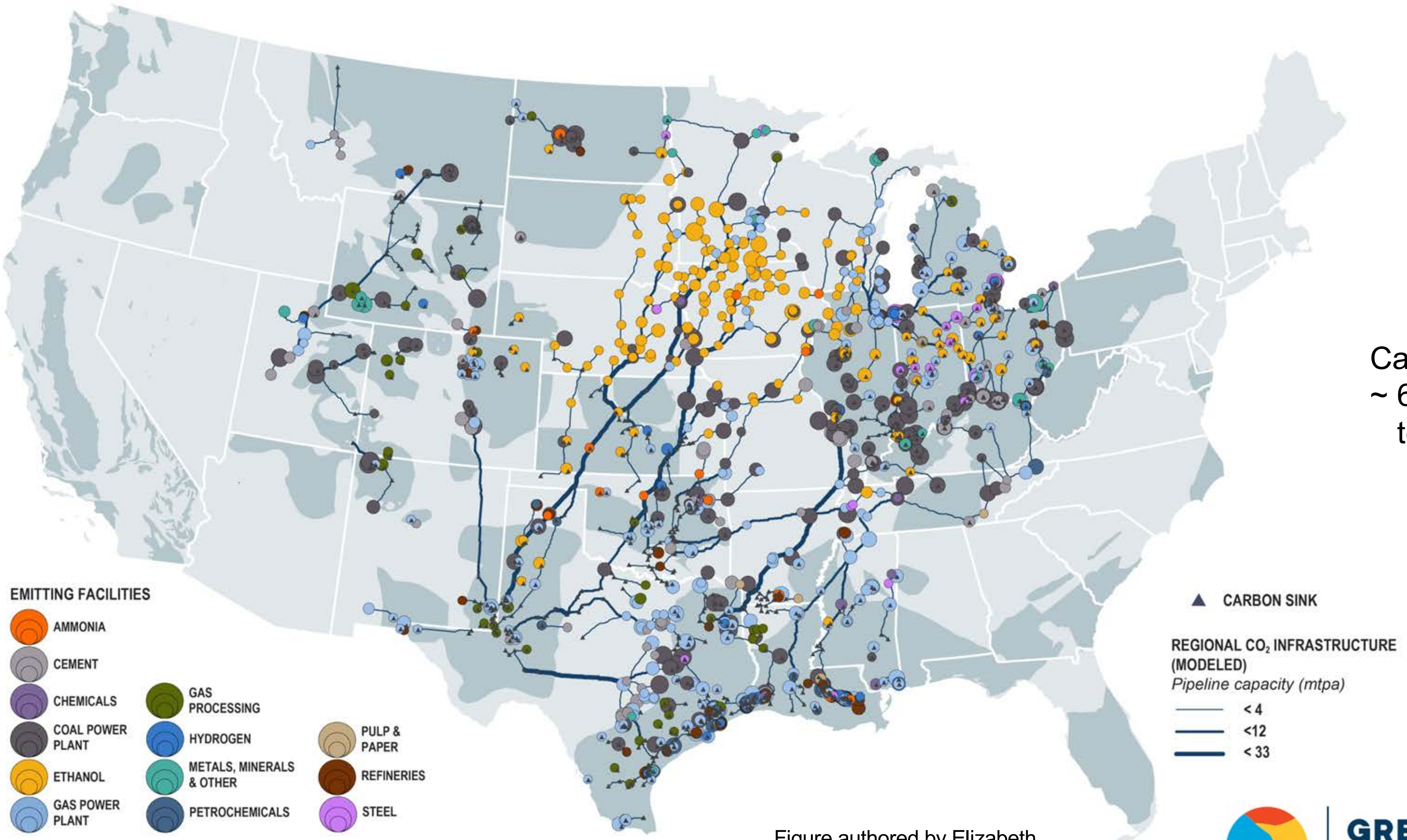
Midcentury: Long-term Economy-Wide Deployment

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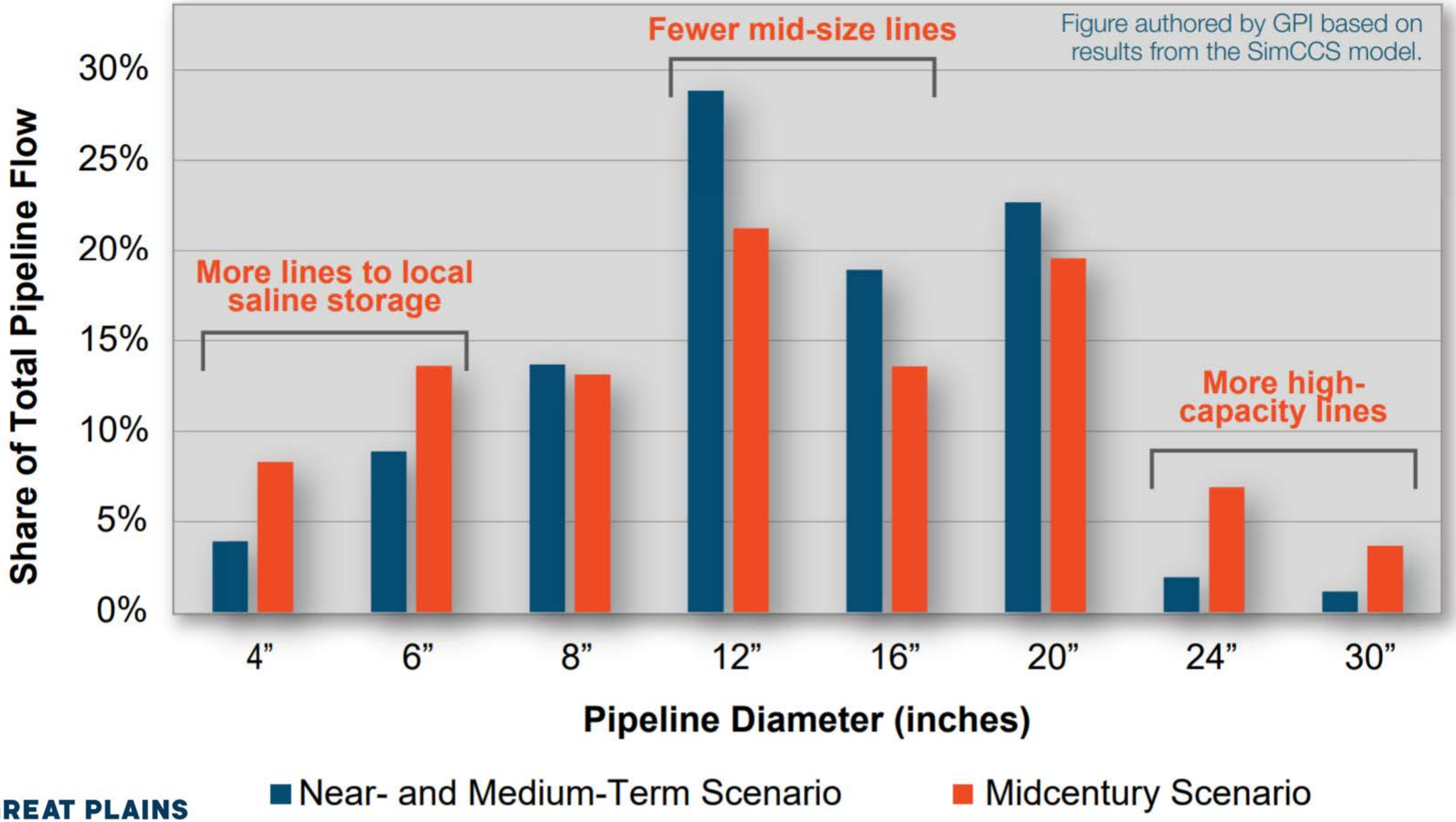
Transport Network Size for Near- and Medium-Term versus Midcentury Scenario



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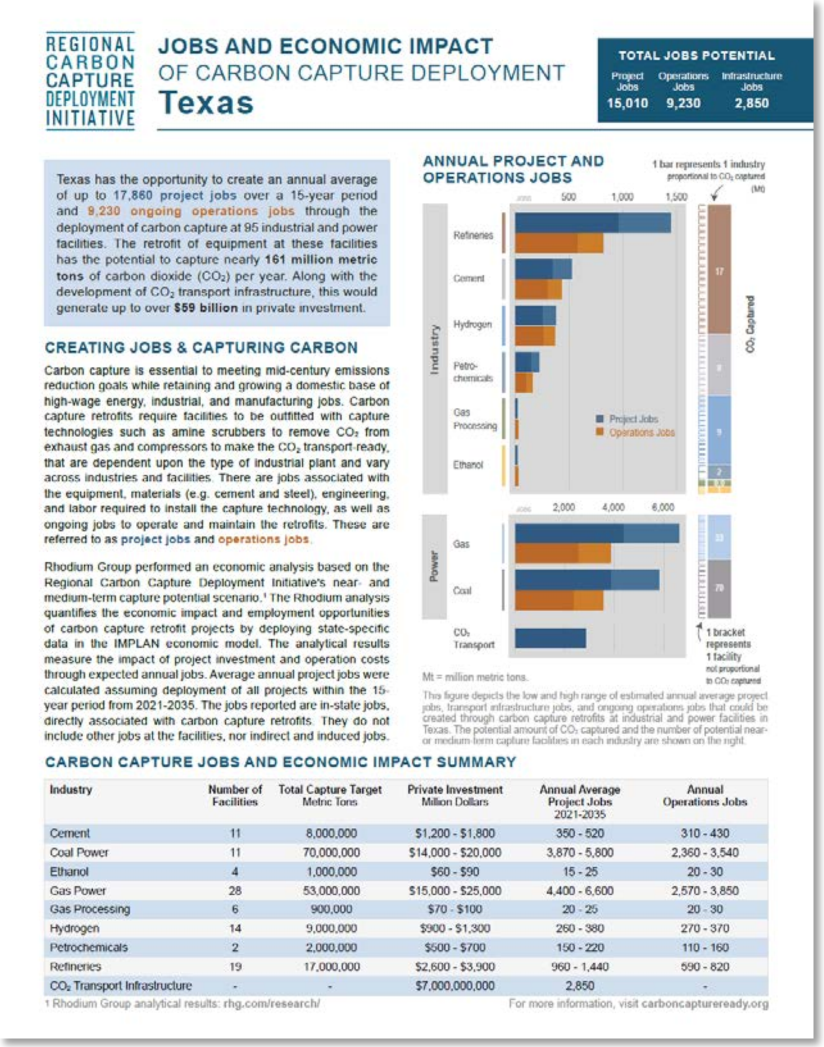
Carbon Capture Ready Website

RDI Homepage

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



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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 (CO_2) per year. Along with the development of CO_2 transport infrastructure, this would generate up to over **$59 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 CO_2 from exhaust gas and compressors to make the CO_2 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.

ANNUAL PROJECT AND OPERATIONS JOBS

1 bar represents 1 industry proportional to CO_2 captured (Mt)

Industry: Refineries, Cement, Hydrogen, Petro-chemicals, Gas Processing, Ethanol

Power: Gas, Coal, CO_2 Transport

Project Jobs
Operations Jobs

CO_2 Captured

1 bracket represents 1 facility not proportional to CO_2 captured

Mt = million metric tons

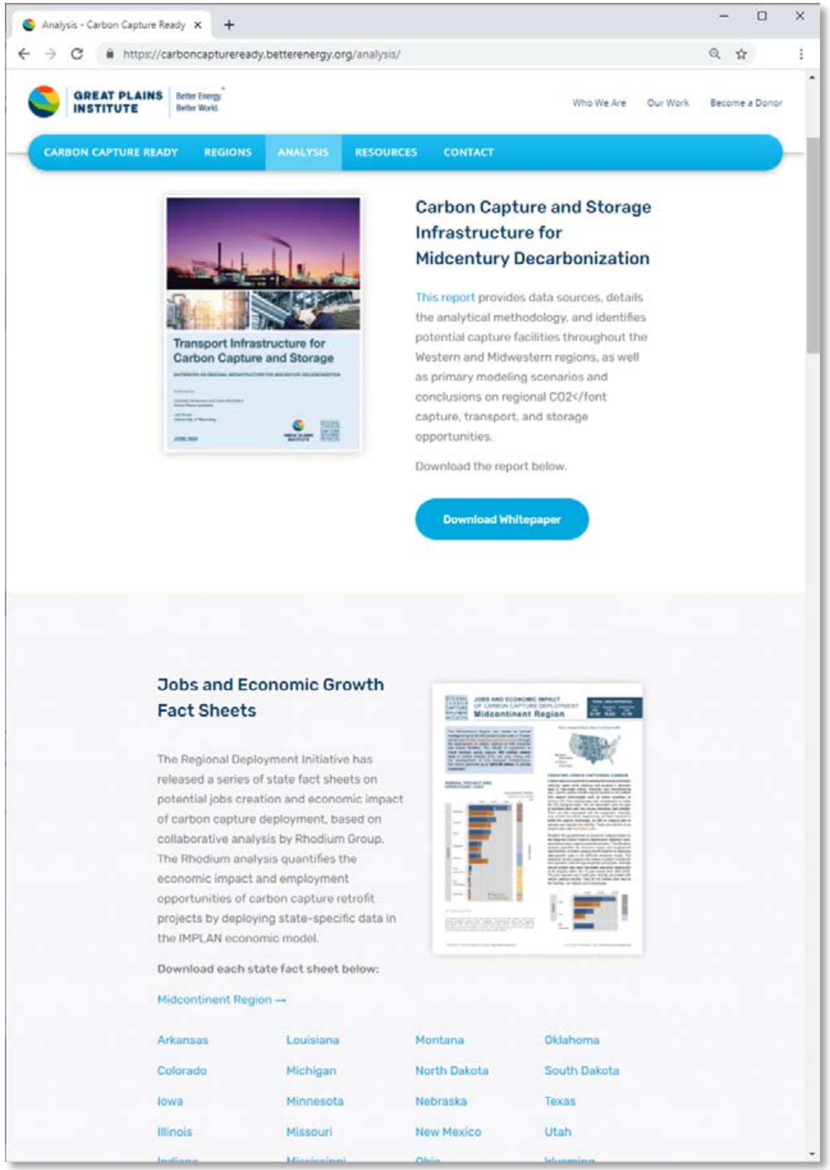
This figure depicts the low and high range of estimated annual average project jobs, transport infrastructure jobs, and ongoing operations jobs that could be created through carbon capture retrofits at industrial and power facilities in Texas. The potential amount of CO_2 captured and the number of potential near- or medium-term capture facilities in each industry are shown on the right.

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	590 - 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



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Thank You

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