Regional CO$_2$ Transport Infrastructure for US Midcentury Decarbonization

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Great Plains Institute
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Facilitated by GPI:

STATE CARBON CAPTURE WORK GROUP

REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

CARBON CAPTURE COALITION

State Participation in the Regional Deployment Initiative

- Western Region
- Midwest Region
- Both Regions
State & Regional Efforts on Carbon Capture

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

2015
- Work Group, comprised of more than a dozen states, develops comprehensive policy recommendations on carbon capture.

2016
- Work Group publishes additional papers on CO2 transport infrastructure, electricity market issues and opportunities for carbon capture and ethanol.

2017
- Regional stakeholders across 25 states meet to evaluate initial analysis and begin to identify near-to medium-term opportunities for deployment.

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

Fall 2018
- RDI work broadens to focus on state policies and other regional efforts that can help close the “cost cap” for carbon capture deployment.

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

Winter 2019
- Analytical research initiated.

2020
- Analytical white paper is published.
- RDI is working with states to prepare for 2021 legislative session.
- States are also cooperating on regional CO2 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
- Accelyergy
- 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
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

Primary Partners:
Section 45Q
Tax Credit for CO₂ Storage

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
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

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

Source: Jeff Brown, 2019
Near- and Medium-Term Scenario:
Optimized transport network for CO₂ capture and storage under 45Q

Capture and storage:
~ 300 million metric tons per year

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.

<table>
<thead>
<tr>
<th>Cost Range</th>
<th>Length (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low</td>
<td>18,006</td>
</tr>
<tr>
<td>Low to Moderate</td>
<td>4,744</td>
</tr>
<tr>
<td>Moderate to High</td>
<td>6,960</td>
</tr>
</tbody>
</table>
Shared CO₂ Transport Infrastructure: Beneficial Economies of Scale

Higher capacity achieves lower costs per ton

**Infrastructure investment by capacity**

$ per inch-mile

- Transport costs decrease as diameter increases
- Cost per inch-mile trend line

**Transport tariff by capacity**

$ per ton

- Larger segments have reduced tariffs.

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Investment by owner/operator

Cost to user/customer

Calculated with:

CO₂ Transport Cost Model
Midcentury: Long-term Economy-Wide Deployment
Expanded storage in saline formations and petroleum basins

Capture and storage: ~ 670 million metric tons per year
### 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

<table>
<thead>
<tr>
<th>Scenario</th>
<th>CO₂ Stored</th>
<th>Land Use</th>
<th>Capital Investment</th>
<th>Project Labor Investment</th>
<th>Annual O&amp;M Spending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near- and Medium-Term</td>
<td>281 million metric tons</td>
<td>29,710 miles</td>
<td>$16.6 billion</td>
<td>$14.3 billion</td>
<td>$252 million</td>
</tr>
<tr>
<td>Midcentury</td>
<td>669 million metric tons</td>
<td>29,922 miles</td>
<td>$19.3 billion</td>
<td>$15.3 billion</td>
<td>$254 million</td>
</tr>
<tr>
<td><strong>Midcentury</strong> scenario increase over Near- and Medium-Term scenario</td>
<td>x 2.38 more CO₂ stored</td>
<td>+0.7%</td>
<td>16.3%</td>
<td>7.0%</td>
<td>0.8%</td>
</tr>
</tbody>
</table>
Analytical Report

Published June 30, 2020

Transport Infrastructure for Carbon Capture and Storage

WHITEPAPER ON REGIONAL INFRASTRUCTURE FOR MIDCENTURY DECARBONIZATION

Authored by:
Elizabeth Altemose and Dane McFarlane
Great Plains Institute

Jeff Brown
University of Wyoming

JUNE 2020

Download the paper at:
carboncaptureready.org/analysis
End of presentation.

Appendix: Additional slides below.
Achieving lower costs through shared high capacity infrastructure

Type of infrastructure built in each scenario

![Graph showing the share of total pipeline flow for different pipeline diameters across two scenarios: Near- and Medium-Term Scenario and Midcentury Scenario. The graph indicates a decrease in mid-size lines and an increase in high-capacity lines in both scenarios.](image-url)
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.
SCO$_2$T Model: Nation-wide geologic storage potential
Transport segments that essentially “pay for themselves”. Capital investment easily paid for by revenue.

High-purity industrial sources choose local saline storage.
US EPA
US DOE
ABB / Energy Velocity

Stanford
NETL
IEA

NETL & USGS
Los Alamos National Lab
Indiana University
Ohio State

Advanced Resources
International

NETL
Los Alamos
Princeton
Industry Consulting

CO2 Supply
Industrial & Power

Capture Costs

Saline
Storage Potential
SCO2T

EOR
Potential Demand

Infrastructure
Costs

SimCCS
Los Alamos
Montana State

Identify feasible projects

Plan regional scale infrastructure to maximize CO2 capture and storage