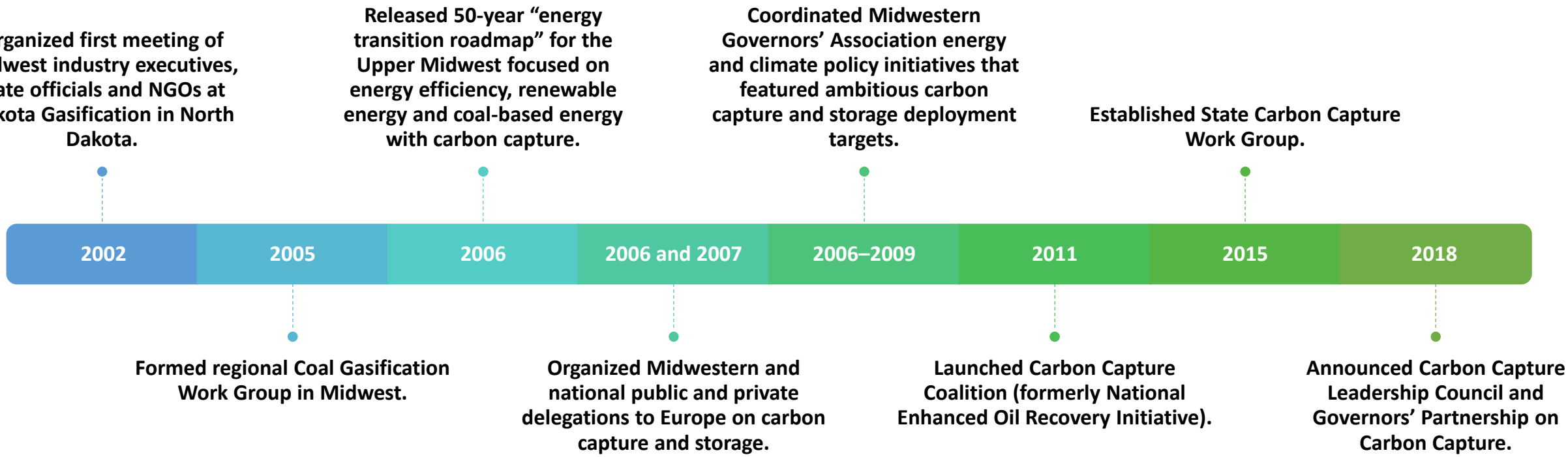
GREAT PLAINS INSTITUTE | Better Energy. Better World.

Developing a Federal and State Policy Framework for Carbon Capture

The Future of Carbon Capture in Maryland
November 20, 2019

Brad Crabtree
Vice President, Carbon Management
Great Plains Institute

Great Plains Institute: Nearly Two Decades Working on Carbon Capture, Utilization & Storage



1972: Val Verde Gas Processing Plants in Texas

1982: Koch Nitrogen Company Enid Fertilizer Plant in Oklahoma

1986: Exxon Shute Creek Gas Processing Facility in Wyoming

2000: Dakota Gasification's Great Plains Synfuels Coal Gasification Plant in North Dakota

2003: Core Energy/South Chester Gas Processing Plant in Michigan

2009: Chaparral/Conestoga Energy Partners' Arkalon Bioethanol Plant in Kansas

2010: Occidental Petroleum's Century gas processing plant in Texas

2012: Air Products Port Arthur Refinery Hydrogen Production in Texas

2012: Conestoga Energy Partners/PetroSantander Bonanza Bioethanol Plant in Kansas

2013: ConocoPhillips Lost Cabin Gas Processing Plant in Wyoming

2013: Chaparral/CVR Energy Coffeyville Fertilizer Gasification Plant in Kansas

2014: SaskPower Boundary Dam Coal Power Plant Post-Combustion Capture Retrofit in Saskatchewan

2015: Shell Quest hydrogen production at bitumen upgrader in Alberta

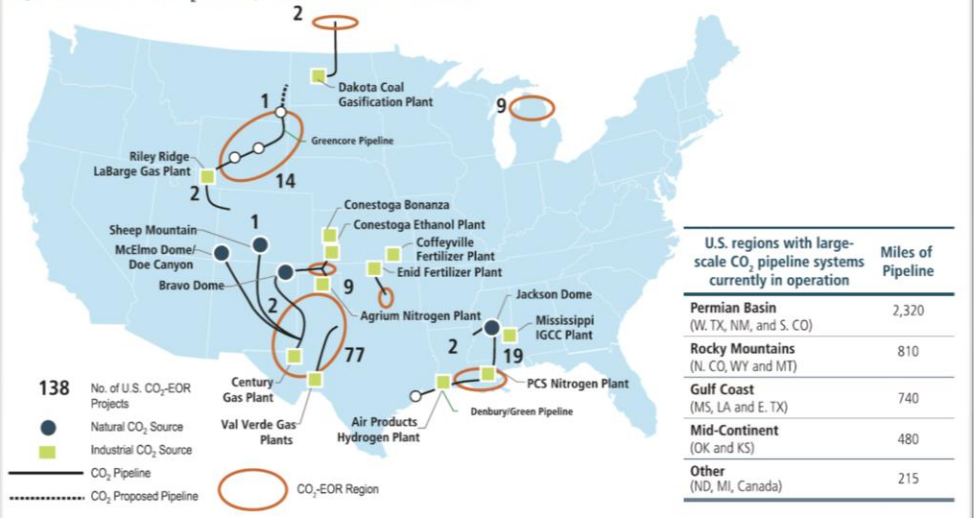
2016: Emirates Steel's Mussafah direct reduction iron plant in the United Arab Emirates

2017: NRG Petra Nova Coal Plant Post-Combustion Retrofit in Texas

2017: Archer Daniels Midland large-scale ethanol capture in Illinois

Carbon Capture Works:
Nearly 50 Years of Commercial Experience

Figure 7-8. Current CO_2-EOR Operations and Infrastructure[112]



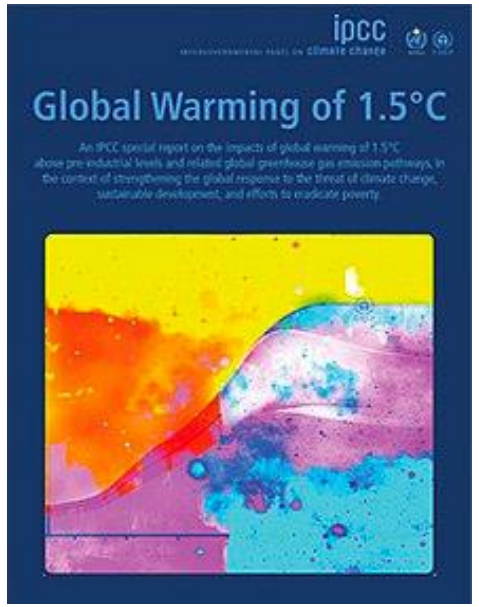
U.S. regions with large-scale CO_2 pipeline systems currently in operation	Miles of Pipeline
Permian Basin (W. TX, NM, and S. CO)	2,320
Rocky Mountains (N. CO, WY and MT)	810
Gulf Coast (MS, LA and E. TX)	740
Mid-Continent (OK and KS)	480
Other (ND, MI, Canada)	215

The current CO_2 pipeline system has been built to deliver CO_2 for CO_2-EOR to oil fields in the Permian Basin of west Texas and eastern New Mexico. This system spans across more than a dozen U.S. states and into Saskatchewan, Canada.

13 commercial-scale U.S. facilities capturing ~25 million metric tons of CO_2 per year. Over 5,000 miles of U.S. CO_2 pipeline infrastructure.

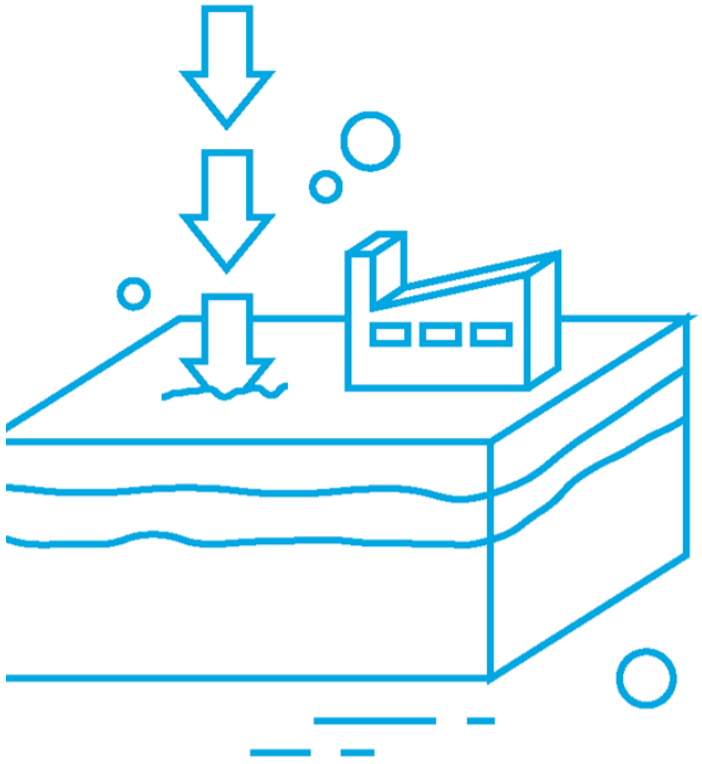
Carbon Capture, Use, Removal and Storage is Essential to Meeting Mid-Century Climate Goals—and Doing So Affordably

- **IEA modeling of 2° C goal**: Carbon capture achieves 1/5th of reductions by midcentury; nearly half from industrial facilities.
- **IPCC 5th Assessment**: Meeting 2° C goal costs 138% more without carbon capture.



IPCC 1.5 C modeling: Atmospheric CO_2 removal through direct air capture and bioenergy with carbon capture needed—in addition to economywide power plant and industrial capture.

Carbon Capture is Not a Niche: It's Scalable to Meet Midcentury Climate Goals



- **U.S. oil industry has purchased, transported and injected nearly 1.5 billion tons of CO_2 over the past half century** with no fatalities, serious injuries, or major environmental incidents (~65 million tons annually; nearly 4 percent of U.S. oil production).
- **~37% net lifecycle emissions reductions achieved through geologically storing industrial and power plant CO_2 through enhanced oil recovery (EOR),** *including the additional oil produced* (IEA analysis).
- **Saline geologic storage of CO_2 has been demonstrated successfully at scale** (e.g. ADM in Illinois and Equinor the North Sea) and achieves even greater lifecycle emissions reductions, including potentially atmospheric carbon removal for negative emissions.
- **Well over a century's worth of U.S. stationary source emissions can be stored in oil and gas fields**; thousands of years' worth in saline formations.

Source: IEA

Carbon Capture is Cost-Effective: Preliminary Revised Estimates of Capture Costs Compare Favorably to Other Low and Zero-Carbon Options

Capture Category (CO2% is molar concentration)	Main Equipment Needed	Industrial Application	US$ per MT Captured/Compressed
Pure CO2 emissions	Compression & Dehydration only	Ethanol, Natural Gas Processing, Ammonia	$15-20/metric ton
CO2 emissions @ **16-50%** concentration	Amine CO2 separation equipment plus Compression	Hydrogen Plants, Cement, Fluidized Catalytic Cracking Unit (Refineries), Blast Furnace Gas Combustion (Steel)	$40-60
CO2 emissions @ **~13-15%** concentration		Pulverized Coal Power Plants	$55-65
CO2 emissions @ **~4%**		Natural Gas Combined Cycle Power Plants	$65-75

Source: Jeff Brown, Stanford University. These figures above are broad category summaries, and individual projects costs vary widely.
Key price assumptions: $50/MWh for electricity, $3.50/MMBtu natural gas, 10% Capital Recovery Factor.
Capture plant size: For amine solvent carbon capture systems cited above (all at 85% capacity factor) capture plant size for hydrogen is 350k MTPA (metric tons per annum), cement 1 million MTPA, FCCU 500k MTPA, Blast Furnace 3 million MTPA, Pulverized Coal Power 3 million MTPA, NGCC, 1.5 million MTPA. Pure emissions have compression/dehydration only.
Power and steam supply: Coal power plants and NGCCs can supply parasitic electric and steam loads from the power plants themselves, or can buy grid electricity and build separate steam boilers. The exact impact of this supply decision depends on power plant value, fuel costs, and the local grid.

CARBON CAPTURE COALITION

STATE CARBON CAPTURE WORK GROUP

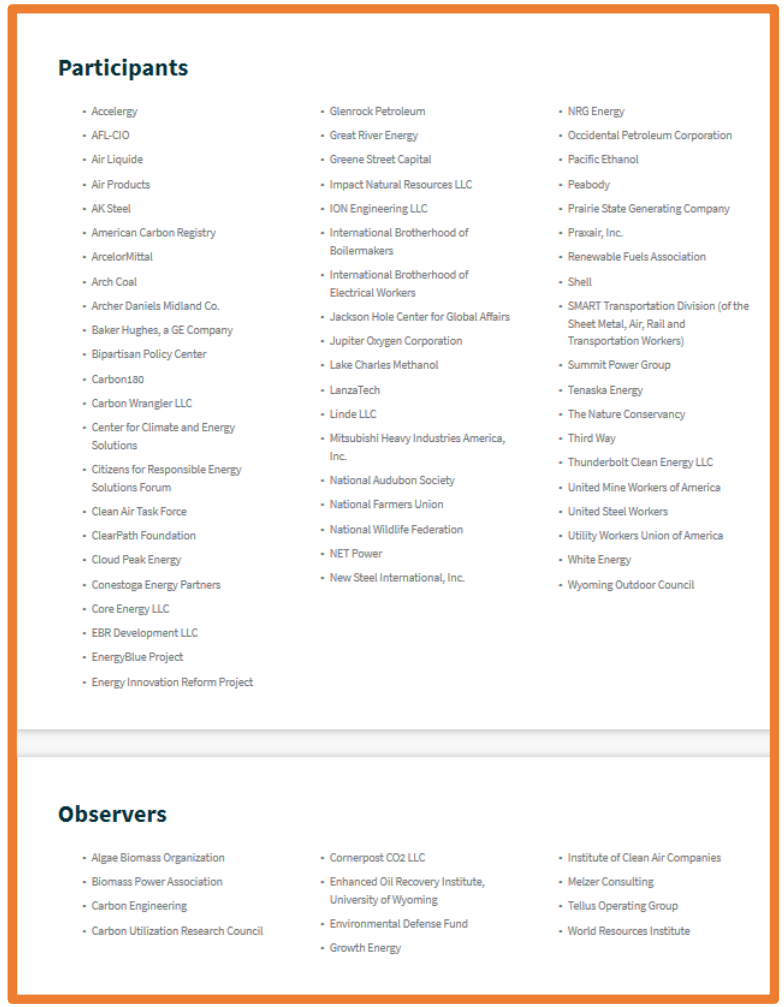
REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

"All hands on deck" to achieve economywide deployment of carbon capture in the U.S.

CARBON CAPTURE COALITION

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

- 70+ members, including industry, NGO and labor interests.
- Climate, jobs and energy/industrial benefits unite very diverse interests in a common purpose.
- Supports innovation and deployment across all energy resources and industry sectors.
- **Goal**: achieve economywide deployment of carbon capture to reduce emissions, foster domestic energy and industrial production, and support jobs.



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
- 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
- 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.
- Renewable Fuels Association
- Shell
- SMART Transportation Division (of the Sheet Metal, Air, Rail and Transportation Workers)
- Summit Power Group
- 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
- Cornerpost CO2 LLC
- Enhanced Oil Recovery Institute, University of Wyoming
- Environmental Defense Fund
- Growth Energy
- Institute of Clean Air Companies
- Melzer Consulting
- Tellus Operating Group
- World Resources Institute

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

Carbon Capture Coalition and Partners Led Multi-Year Effort to Secure Congressional Passage of U.S. Federal 45Q Tax Credit Reform Last Year

Key Changes of Reformed 45Q Tax Credit

Increases credit values to US$ 35 and 50 per metric ton.

Expands eligibility to include other beneficial uses of captured carbon (in addition to EOR), projects that capture CO and direct air capture projects.

Creates **greater financial certainty** by lifting the credit cap and providing clear timing for eligibility

Expands eligibility to more industries by lowering the annual carbon capture threshold and expanding definitions for qualified facilities and qualified carbon.

Enables the owner of the capture equipment to transfer the credit to another party that stores the CO_2 or puts CO_2 or CO to beneficial use.

45Q Tax Credit Amount: Depends on Project Type

There is a 10-year ramp up to the following dollar per ton amounts, with the value depending on project type as shown below.

$35/ton

for CO_2 stored geologically through EOR.

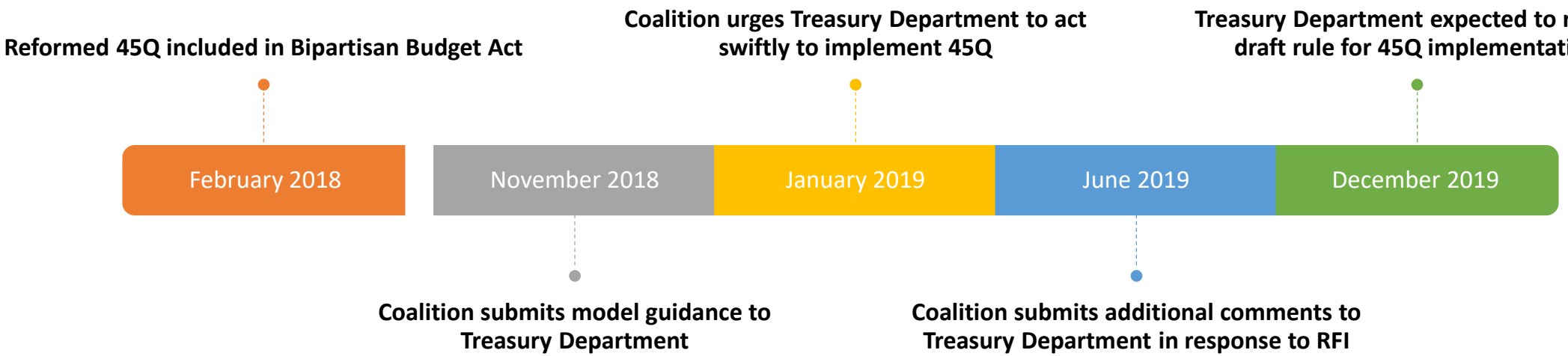
$35/ton

for other beneficial uses of CO_2 or CO such as converting carbon emissions into fuels, chemicals, or useful products like concrete.

$50/ton

for CO_2 stored in other geologic formations and not used in EOR.

Shaping U.S. Treasury's 45Q Tax Credit Guidance



Key Recommendations

Ensure flexible contractual assurance and transferability of the tax credit.

Limit investor risk of credit recapture by establishing a safe harbor.

Define commence construction and continuous construction for projects to qualify.

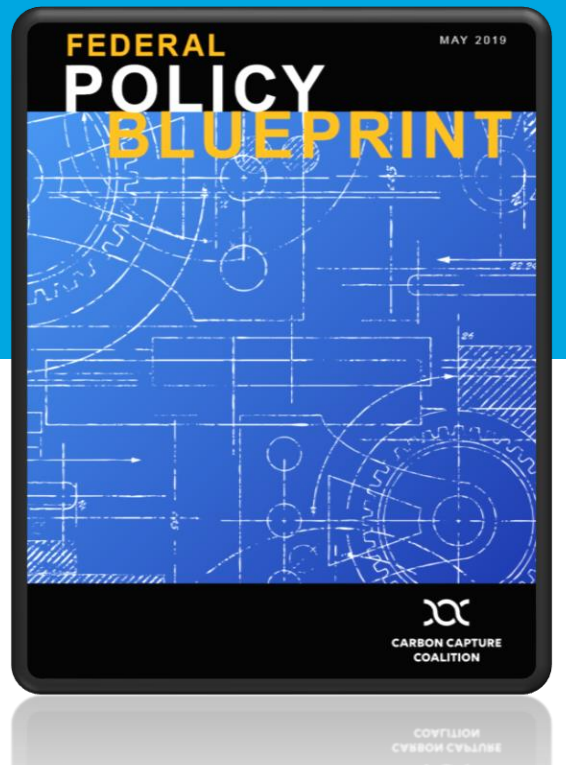
Provide an equivalent ISO-based monitoring and reporting program (in addition to the Subpart RR Greenhous Gas Reporting Program) for demonstrating secure geologic storage through CO_2-enhanced oil recovery.

U.S. Federal Policy Agenda Going Forward

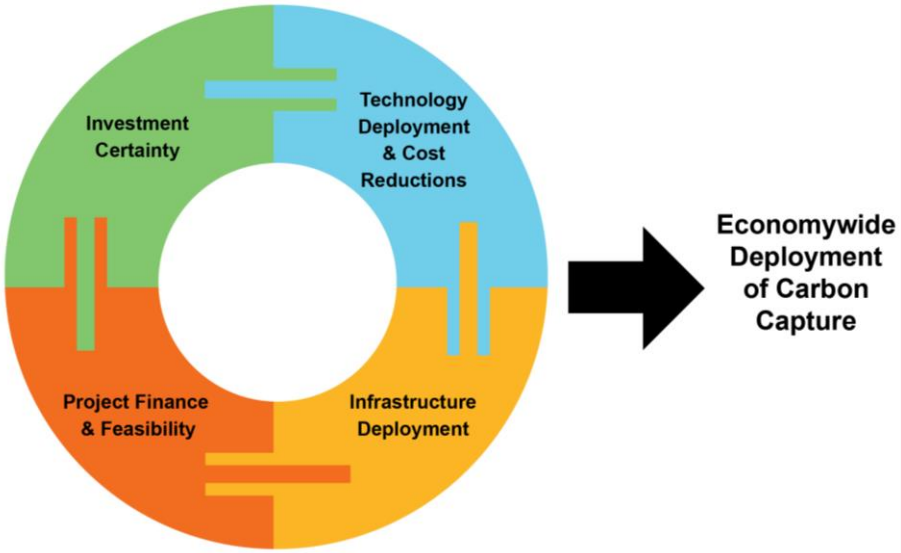
- **Ensure effective implementation of 45Q by the U.S. Treasury** to provide investment certainty and business model flexibility;
- **Enact a broader portfolio of federal carbon capture policies** to complement 45Q;
- **Incorporate CO_2 pipeline infrastructure into national infrastructure policy**; and
- **Expand and diversify federal R&D, demonstration and deployment funding** for carbon capture, utilization, removal and geologic storage.
- **Ensure inclusion of industrial sectors in federal policy** and eligibility of both CO_2 and CO emissions, where applicable.

CARBON CAPTURE COALITION

Carbon Capture Coalition's Federal Policy Blueprint



- ✓ Agenda for economywide deployment.
- ✓ Recommends full policy portfolio, similar to current support for wind, solar and other low and zero-carbon technologies.
- ✓ Consensus of Coalition's 70+ companies, unions, and NGOs.



CARBON CAPTURE COALITION

Current Legislation to Enhance and Expand on 45Q Tax Credit Enjoys Broad Political Support in Congress

Technical improvements to 45Q and other incentives:

- **Enhanced monetization of 45Q (legislation forthcoming)**
  - Expands the pool of eligible investors in projects.
- **Carbon Capture Modernization Act (introduced)**
  - Corrects design flaws in Section 48A tax credit to enable carbon capture retrofits of coal power plants.

Additional incentives to complement 45Q:

- **Carbon Capture Improvement Act (introduced)**
  - Authorizes use of tax-exempt private activity bonds in financing carbon capture and utilization projects.
- **Financing Our Energy Future Act (introduced)**
  - Makes carbon capture and utilization projects eligible for master limited partnerships (tax advantage of partnerships, with ability to raise equity in public markets).

CARBON CAPTURE COALITION

Current Legislation cont.

Expanding and retooling federal R&D:

- **USE IT Act (passed U.S. Senate)**
  - Supports demonstration of direct air capture and R&D for CO_2 and CO utilization; and
  - Facilitates planning, siting and permitting of CO_2 transport infrastructure.
- **Senate EFFECT & LEADING Acts/House Fossil Energy R&D Act (reported out of House/Senate committees)**
  - Expands and retools U.S. DOE research, development, demonstration and deployment (RDD&D) objectives and programs for carbon capture, utilization, removal and storage.

Clean Industrial Technology Act (reported out of House/Senate committees)

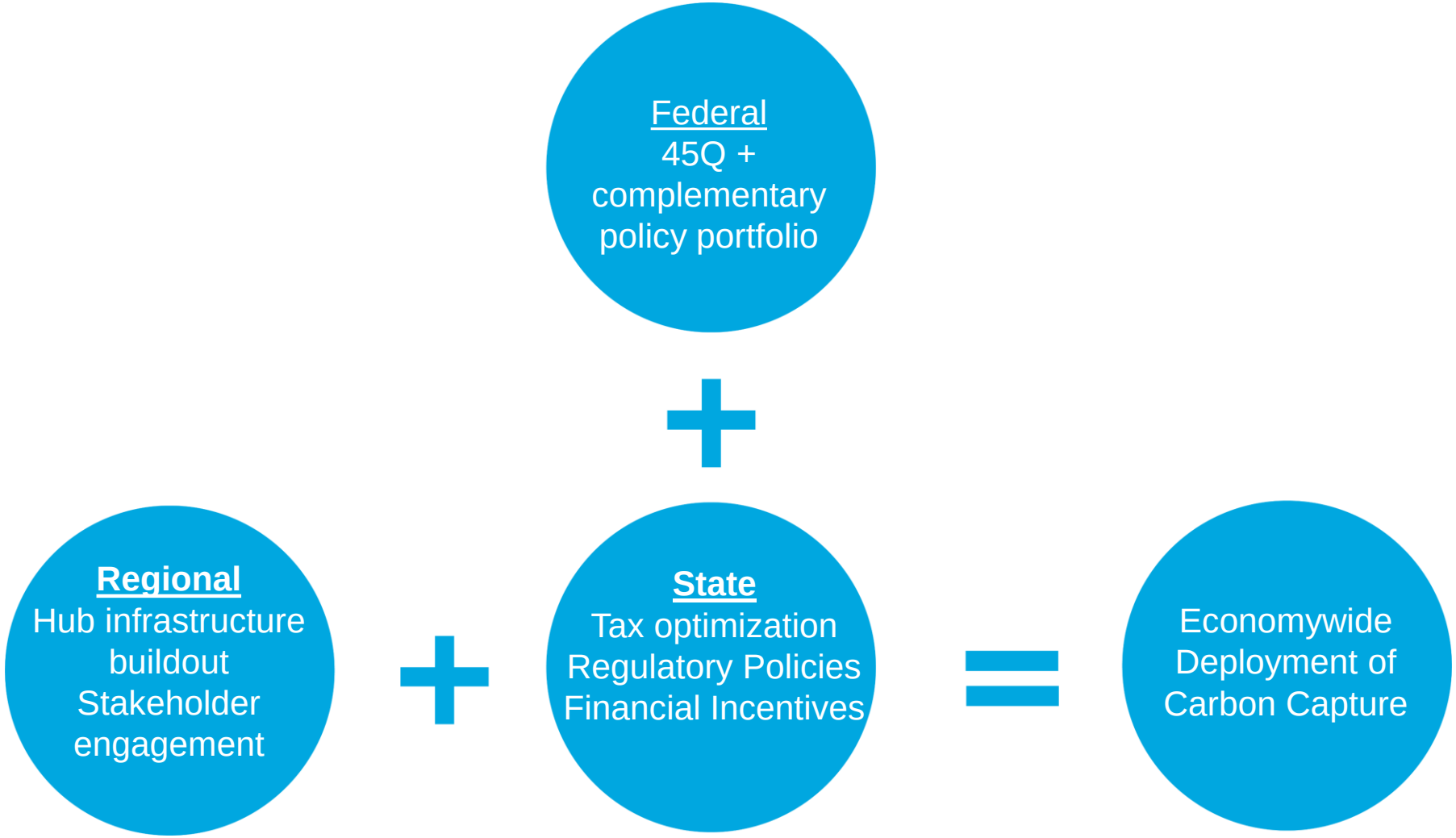
- Establishes Industrial Emissions Reduction Technology Development Program for innovative technologies, including carbon capture.

INVEST CO_2 Act: First-Ever Federal CO_2 Transport Infrastructure Financing Legislation Introduced Last Week

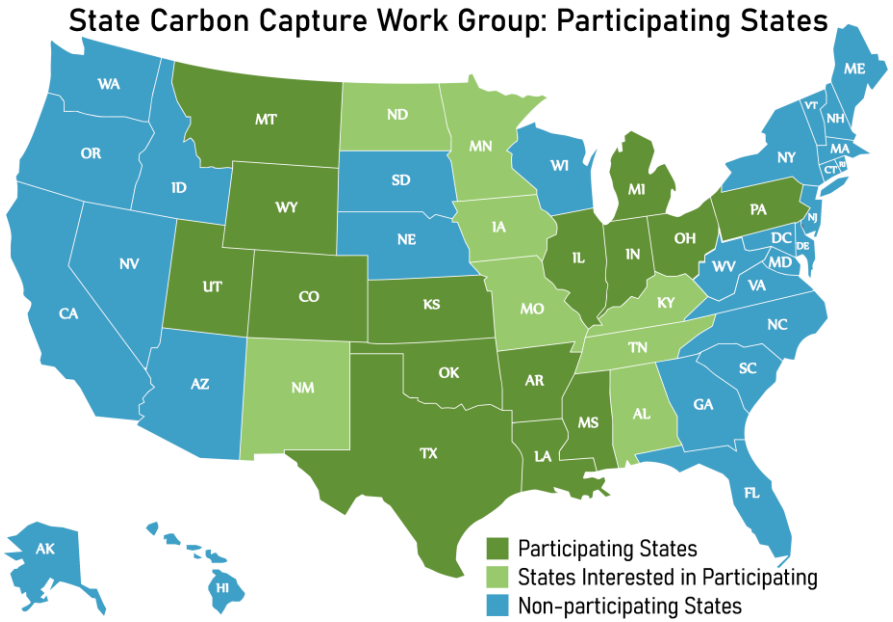
Rep. Cheri Bustos (D-IL) introduced the **Investing in Energy Systems for the Transport of CO_2 Act of 2019 (INVEST CO_2 Act).**

- Advances key recommendations of the Carbon Capture Coalition's Federal Policy Blueprint:
  - Low-interest federal loans to finance extra pipeline capacity and realize economies of scale;
  - Federally-supported large-volume, long-distance CO_2 trunk lines to support development of key regional hubs; and
  - Encouragement to state and local governments to designate anthropogenic CO_2 pipelines as "pollution control devices" to enable tax abatement.
- Legislation aims to help enable state/regional efforts to advance specific infrastructure projects.

Integrated Federal-State Policy & Regional Hub Development are Key to Success



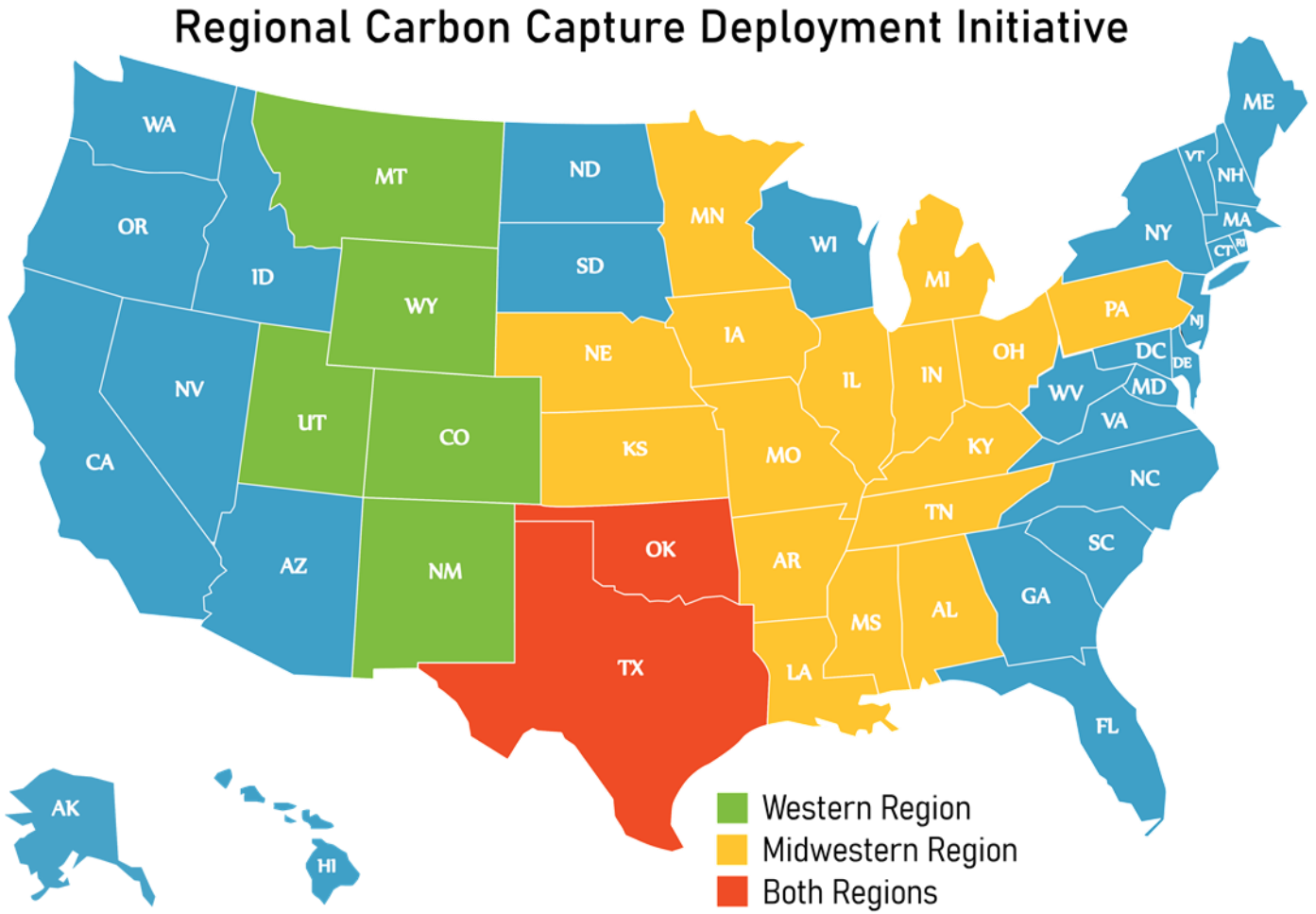
STATE CARBON CAPTURE WORK GROUP



Interest in State Carbon Capture Work Group Continues to Grow

- Formed in 2015 by then Gov. Mead (R-WY) and Gov. Bullock (D-MT). Actively recruiting additional states (light green).
- Made comprehensive state and federal policy recommendations from 2015-2018.
- Now overseeing Midwestern and Western Regional Carbon Capture Deployment Initiatives.
- Modeling candidate capture and storage projects and pipeline infrastructure (two-year effort).
- Forming state policy teams to develop tailored policy recommendations to complement the federal 45Q tax credit.

Regional Deployment Initiatives: Western & Midwest Regions



REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

Regional Deployment Initiatives: Where We are in the Process

Phase I

Preliminary Analysis (Jan-Sep 2018)

Mapping industrial facilities, power plants and CO_2 storage opportunities, initial cost analysis, and preliminary pipeline modeling.

Phase II

Convening State Officials and Stakeholders (October 2018)

Launched Initiatives in Columbus, OH and Salt Lake City, UT.

Phase III

Supporting State Policy Development and Projects (Underway)

Identify candidate projects and state policies to complement 45Q credit.

Prepare for 2020 state legislative sessions.

Cooperate regionally on CO_2 transport infrastructure and hub development.

REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

EPA GHGRP & eGRID
US DOE EIA
ABB / Energy Velocity

CO2 Supply
Industrial & Power

Stanford
NETL, IEA
National Petroleum Council

Capture Costs

Advanced Resources
International

EOR
Potential Demand

NETL & USGS
Los Alamos National Lab
Indiana University
Ohio State

Saline
Storage Potential
SCO2T

NETL
Los Alamos
Princeton
Industry Consulting

Pipeline Costs

REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

SimCCS
Los Alamos

GPI Coordinated Team

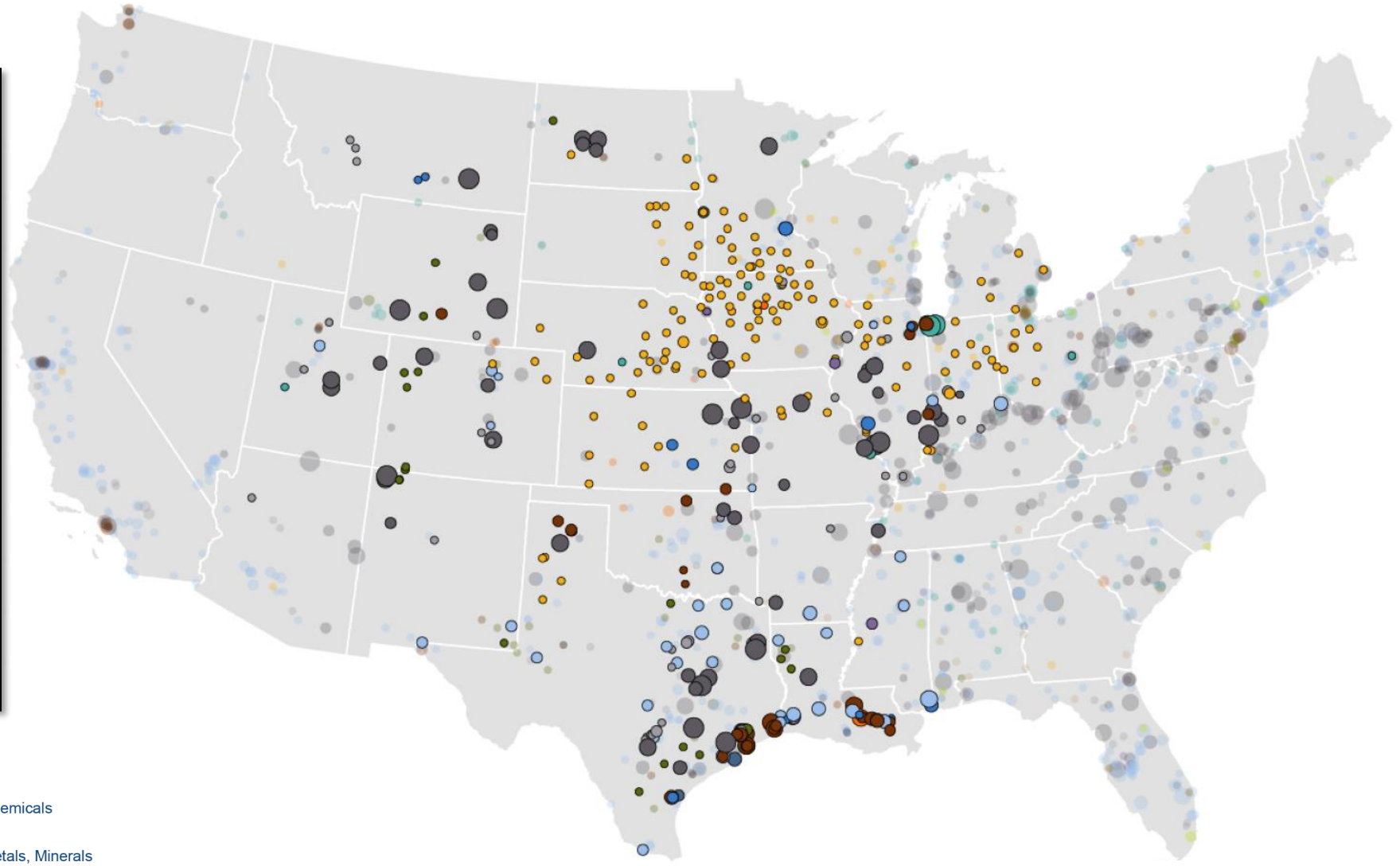
Identify potential early mover capture projects by state.

Model regional CO_2 transport infrastructure to maximize feasible capture, use and storage.

Economically Feasible Capture Retrofit with 45Q

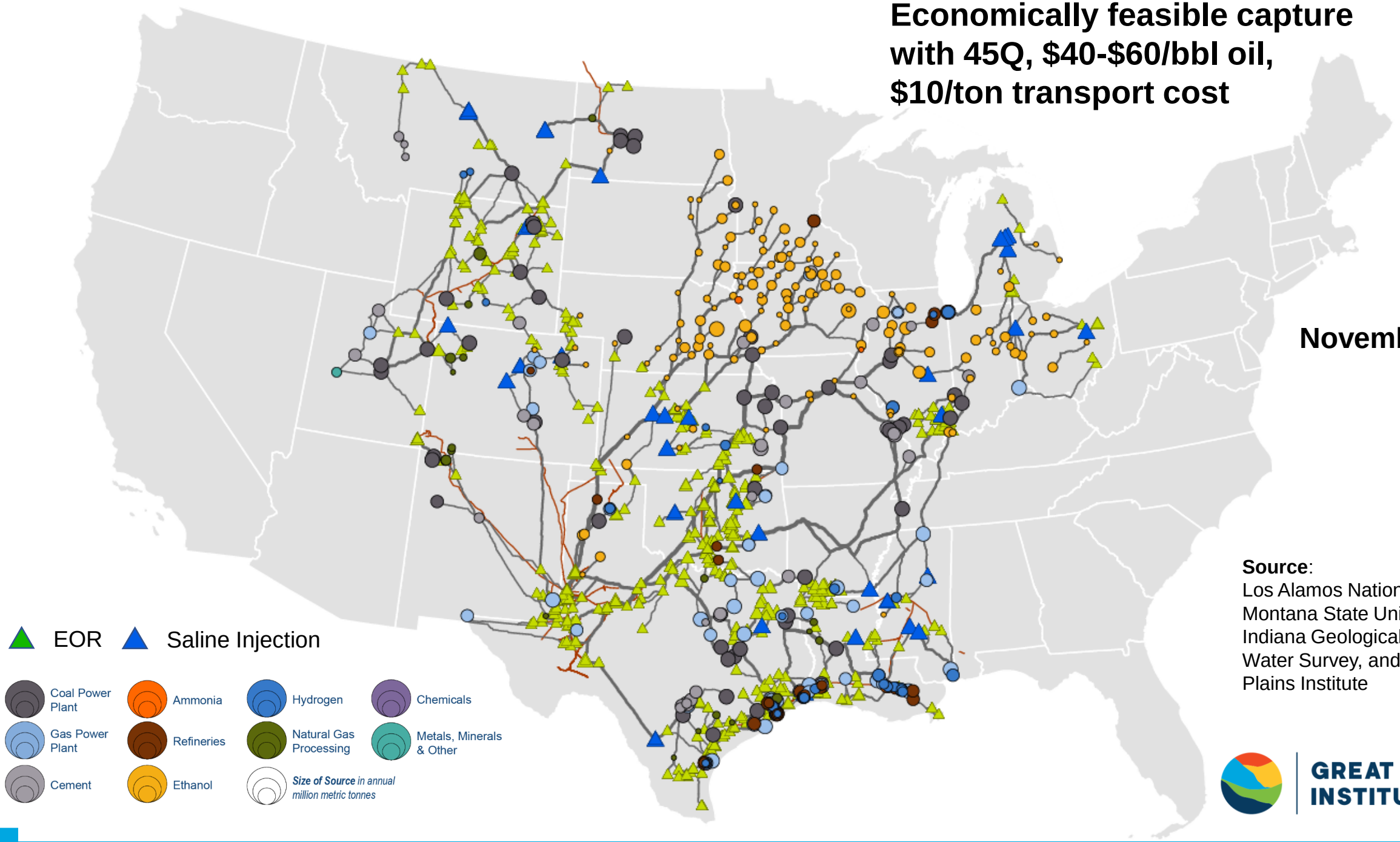
Facilities identified by Regional Deployment screening

Industry	Capture Target (million MT/yr)
Steel (Blast Furnace)	12.5
Cement	29.5
NG Processing	4.5
Ethanol	36.2
Refineries (FCC)	25.4
Hydrogen	14.7
Lime	0.9
NG Power Plants	65.9
Ammonia	0.7
Coal Power Plants	132.6
Total	**322.9**



GREAT PLAINS INSTITUTE

Economically feasible capture with 45Q, $40-$60/bbl oil, $10/ton transport cost



November 2019

Source:
Los Alamos National Lab, Montana State University, Indiana Geological and Water Survey, and Great Plains Institute

GREAT PLAINS INSTITUTE

Regional Carbon Capture Deployment Initiative: Deliverables for States and Stakeholders

- Dynamic **database of industrial and power facilities**
  - Emissions, energy use, industrial processes
  - Theoretical capture cost and capture rates
  - Economic feasibility
- **Pipeline modeling**
  - Regional scenarios for maximum efficiency, minimum cost
  - Local modeling by request
- **State fact sheets and resources**
- **White paper** (Spring 2020)
- **Economic Impact & Jobs Analysis** (2020)

GREAT PLAINS INSTITUTE

Carbon Capture Deployment Fact Sheets: Tailored to Each State

REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

Wyoming

IMPLEMENTING CARBON CAPTURE AND STORAGE TECHNOLOGY

Wyoming is home to the nation's second largest emerging hub of CO_2 pipeline infrastructure and projects, serving not just Wyoming, but linking in Colorado and Montana. As such, Wyoming is strategically positioned to become both a major source of CO_2 captured from industrial facilities and power plants, as well as a hub for the beneficial use and geologic storage of captured carbon. Ranked 1st among states in the production of coal and 8th in crude oil production, while also containing 30 facilities eligible for the newly reformed and expanded federal 45Q tax credit, Wyoming has immense opportunity for the deployment of carbon capture technology and enhanced oil recovery (EOR) to lower carbon emissions and transform captured carbon into an economic resource. As one of the first states to enact legislation on carbon capture, Wyoming now has among the most comprehensive carbon capture incentives and legislation in the nation. Uniquely among states, Wyoming also developed a pipeline corridor initiative to facilitate the development of statewide and regional infrastructure for the transport and management of CO_2. With a supportive tax structure, comprehensive legislation and geologic potential, Wyoming is projected to continue as a leader in carbon capture policy development and project deployment.

SOURCES BY INDUSTRY & VOLUME

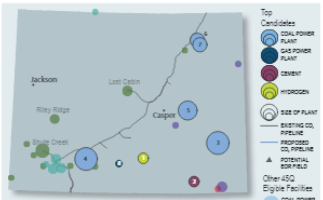


Figure 1: Wyoming has many facilities large enough to qualify for the 45Q carbon capture tax credit, including coal and gas power plants, gas processing facilities, and petroleum refineries. Facilities identified by the Regional Carbon Capture Deployment Initiative as potential early candidates for capture retrofit based on emissions, equipment, and estimated capture cost, are shown with outlines and darker colors. Details on these facilities are listed below. Two existing capture facilities are also labeled on the map. Source: GPI 2019, EPA 2018.

POTENTIAL CANDIDATE FACILITIES FOR CAPTURE WITH ANNUAL

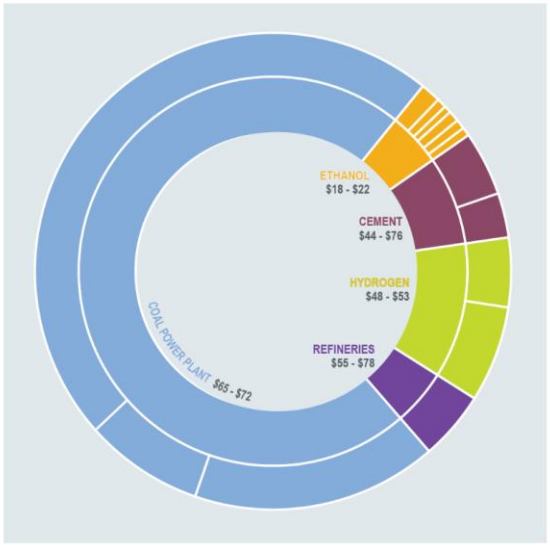
ID	Facility Name	Location	Industry	Total CO2 Emissions thousand tons	Captured Emissions thousand tons	Estimated Capture Cost $/ton
1	Sinclair Oil Corporation	Sinclair	Refineries	1,033	194	$55
2	Mountain Cement	Laramie	Cement	935	574	$63
3	Laramie River	Wheatland	Coal Power Plant	11,203	3,200	$65
4	Jim Bridger	Point Of Rocks	Coal Power Plant	11,762	1,600	$68
5	Dave Johnston	Glenrock	Coal Power Plant	5,008	1,600	$68
6	Dry Fork Station	Gillette	Coal Power Plant	3,283	1,600	$68
7	Wyodak	Gillette	Coal Power Plant	3,067	1,600	$68
8	Echo Springs Gas Plant	Wamsutter	Gas Processing	538	231	$82

Table 1: The Regional Carbon Capture Deployment Initiative estimated, theoretical facility capture costs based on published capture equipment costs, facility-specific operational patterns, existing equipment, and level of emissions. Most states have a large number of facilities eligible for 45Q. Of those facilities, the above table lists likely economically feasible candidates based on estimated capture cost. This list is not meant to be definitive. Commercial decisions by participating companies, and policy and regulatory decisions by state governments, will ultimately determine if a project is feasible for carbon capture. Captured Emissions refers to the amount of carbon dioxide that can be expected to be captured at a facility considering relevant technological and economic constraints. Source: GPI 2019; EPA 2018.

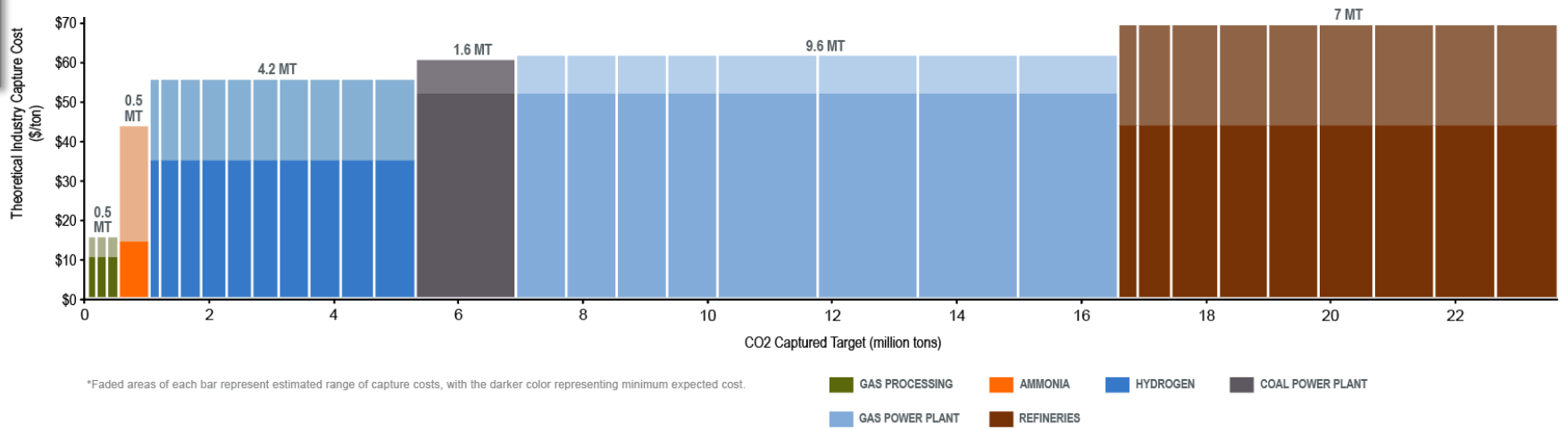
LEGISLATIVE CONTEXT

Wyoming has a comprehensive legislative tool kit for carbon capture. For geologic storage of carbon, key issues such as pore space ownership, long-term management, CO_2 ownership and liability, unitization, and primacy as well as an established regulatory scheme are defined in statute. Permitting processes and certifications for implementing carbon capture projects are also outlined in legislation. See Table 2 for Wyoming's most prominent carbon capture policies. To ensure timely additions and updates to legislation regarding carbon capture and storage, Wyoming has created the Enhanced Oil Recovery Commission to continue research and development of carbon capture technologies. The University of Wyoming's Enhanced Oil Recovery Institute (EORI) works within the commission to research enhanced oil and gas recovery potential in the state, with the goal of increasing state tax revenue. Through research, field demonstrations and commercial-scale implementation of EOR technology, EORI has predicted that within the next 20 years one billion additional barrels of oil will be produced using EOR technology, which would be a pathway to geological carbon storage in Wyoming.

POTENTIAL CANDIDATE FACILITIES FOR CAPTURE, BY CO2 EMISSIONS AND COST RANGE

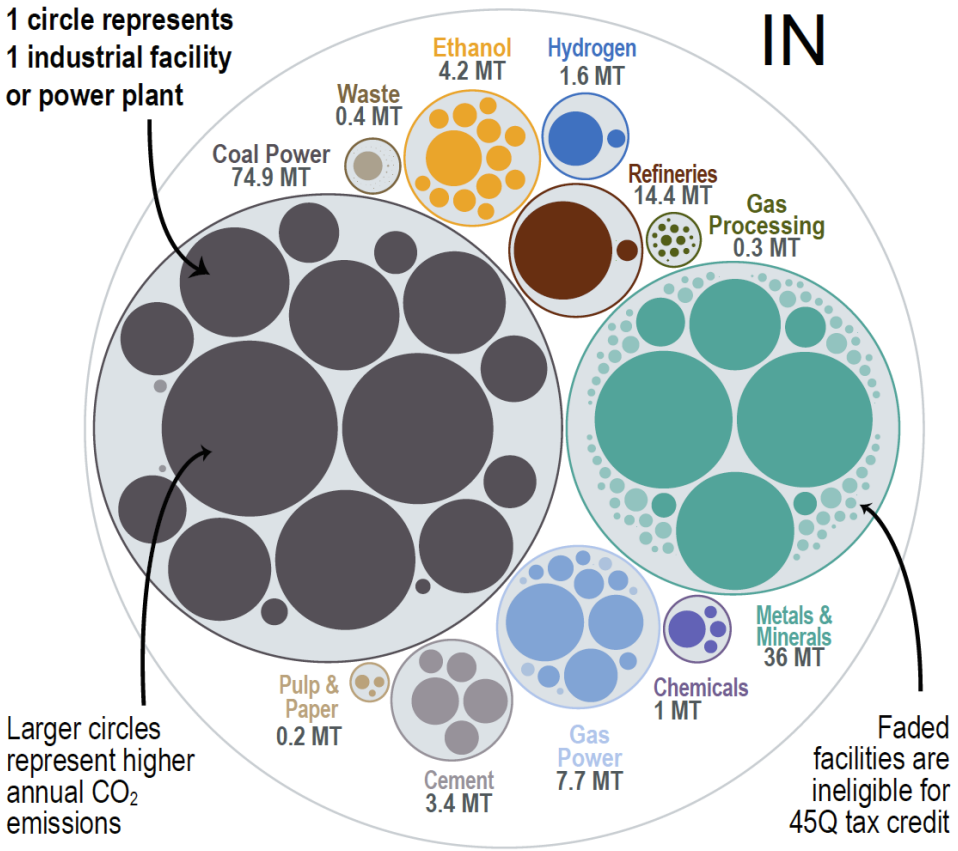


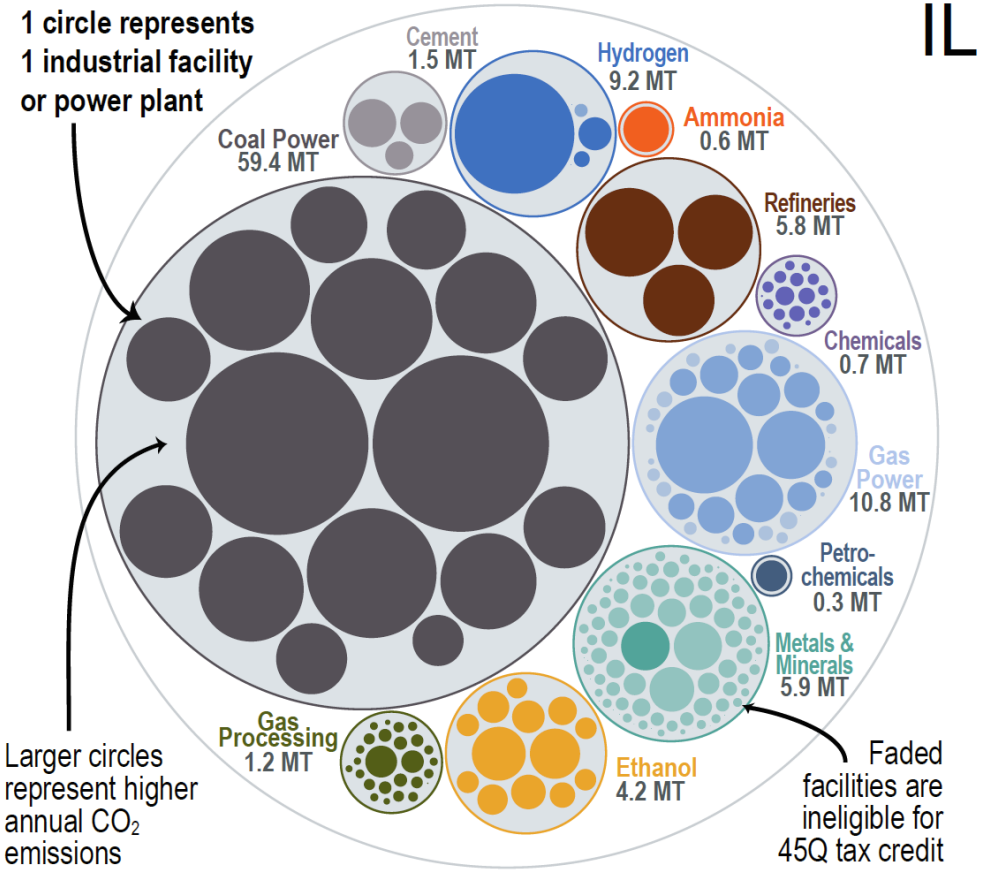
POTENTIAL CANDIDATE FACILITIES FOR CAPTURE, BY CAPTURE TARGET AND COST RANGE



GREAT PLAINS INSTITUTE

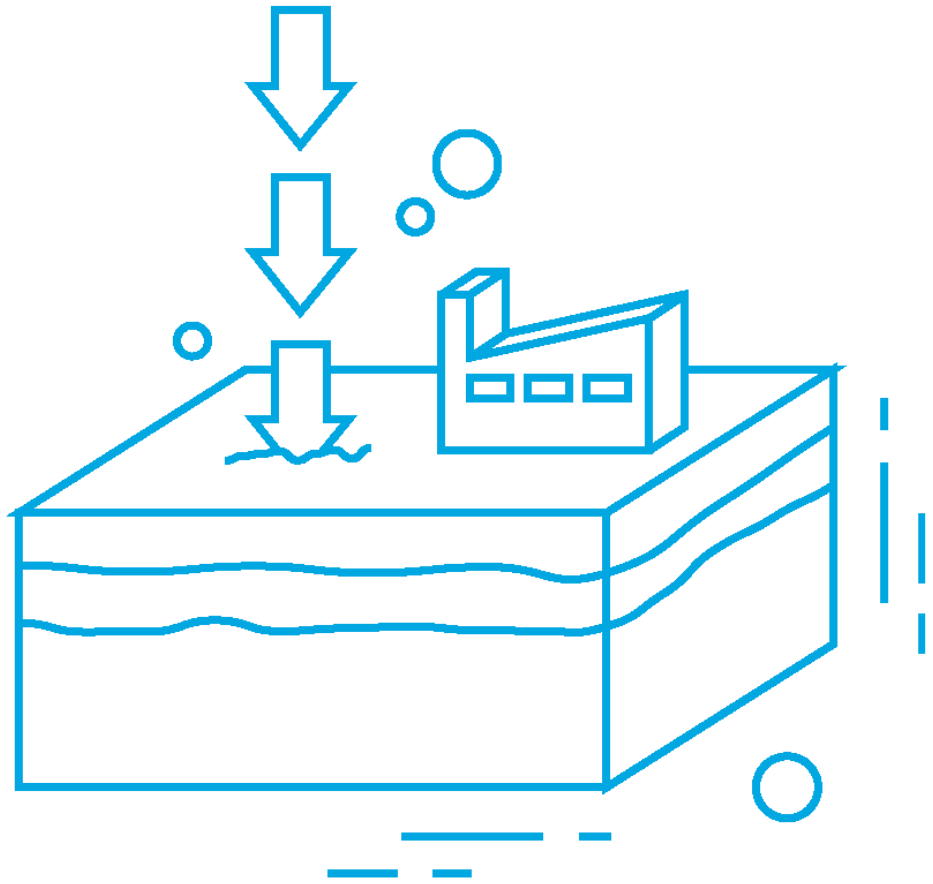
Carbon Capture Deployment Fact Sheets cont.





GREAT PLAINS INSTITUTE

Figures authored by Elizabeth Abramson, Great Plains Institute, 2019



Carbon Capture Ready

Legislative Readiness: Policy Approaches & Best Practices to Leverage Federal 45Q Credit Before End of 2023 Deadline to Begin Construction

- Developing print and online policy checklist for states, combined with complete updated state-by-state inventory of existing policies:
  - ✓ Delegation of EPA authority for permitting saline storage projects (federal UIC Class VI) to states
  - ✓ Rules for long-term CO_2 storage
  - ✓ Rules for CO_2 transport and storage space
  - ✓ Rules for clarifying the purpose of CO_2 injection
  - ✓ Financial incentives for carbon capture
  - ✓ Optimization of state taxes to incentivize capture, transport, use and storage
- Establishing state policy teams to develop legislative and other policies for their states, based on modeling and analysis.
- **Next step: 2020 state legislative sessions. Please join us!**

Modeling is Setting Stage for Longer-Term Development of Regional Carbon Capture, Transport and Storage Hubs

REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

- Modeling is driving awareness among state officials and industry, labor and NGO stakeholders of the opportunity presented by the 45Q tax credit.
- Strategy: Advance state CO_2 transport infrastructure planning and policy development in conjunction with CO_2 pipeline financing legislative effort in Congress.
- Reframing the challenge as opportunity: Building a new carbon economy for emissions reductions, domestic energy and industrial production and high-wage jobs.

Thank You

Brad Crabtree
Vice President, Carbon Management
Great Plains Institute
(701) 647-2041 work | (701) 830-0302 mobile
bcrabtree@gpisd.net

GREAT PLAINS INSTITUTE
Better Energy. Better World.