Webinars

CCS -- Technology, Economics, Processes, and Challenges Associated With Permitting Storage Sites in the U.S.

Mike Godec, Advanced Resources International

June 14, 2022

Webinars

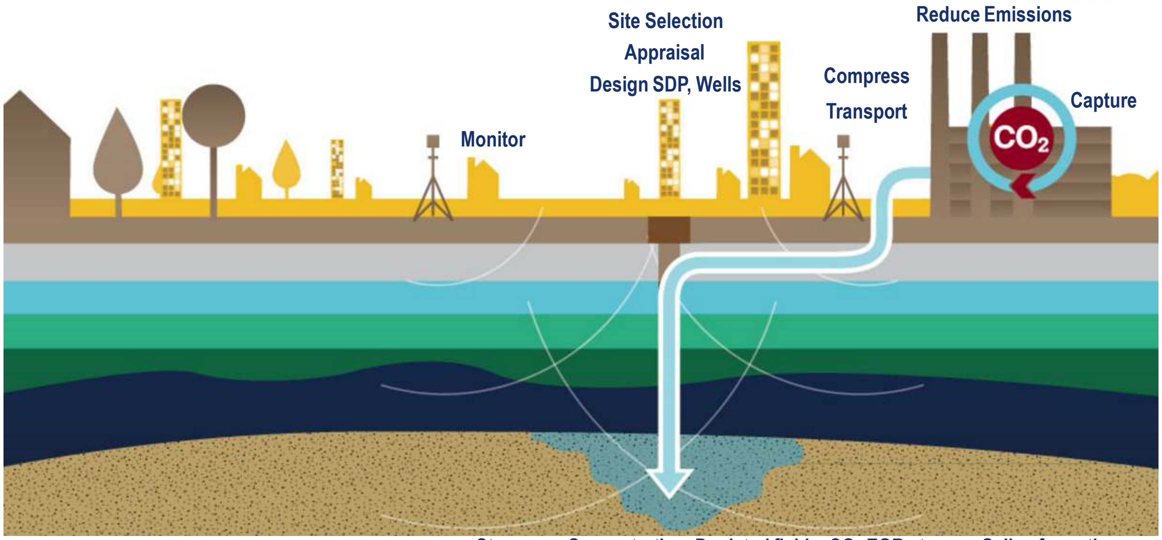
Sponsored by:

SPE Foundation

Introduction

- Today, we will provide an overview of carbon dioxide capture and storage (CCS)
  - To include a discussion of the technology, economics, processes, and challenges associated with permitting storage sites in the U.S.
- I will start by a quick review of CCS technologies and processes, the mechanics of geological storage, and what will be necessary to ensure secure geologic storage.
- Andrew Duguid will describe the processes and challenges associated with permitting storage sites in the U.S.
- And finally, Laura Sorey from the Louisiana Department of Natural Resources will provide some regulatory perspectives

What is CCS?



From: Zero Emissions Platform : http://www.zeroemissionsplatform.eu/carbon-capture-and-storage.html

Storage or Sequestration: Depleted fields, CO_2 EOR storage, Saline formations

CCS Deployment is Proceeding at a Fast Pace

Webinars

- Because of long-term consistent and predictable support with government-funding of non-commercial R&D, Carbon Capture [Utilization] and Storage (CCS/CCUS) has blossomed into commercially viable activity.
- Support has not waned when high-profile projects have been derailed.
- In the United States, carbon tax credits, AKA the **Section 45Q Tax Credit & California Low Carbon Fuel Standard**, have buoyed commercial efforts.
- Abroad, government pressures/penalties have had a similar impact on CCS development (i.e., Sleipner, Quest, Gorgon).
- Today, the mix of projects center around site characterization in support of and/or permitting efforts.

SPE International

6

Environmental, Regulatory and Policy Issues

Successful CCS deployment will require addressing critical environmental regulatory issues and keeping abreast of emerging policy issues, including:

- Taking advantage of 45Q tax credits
- Demonstrating "secure geologic storage"
  - EPA reporting requirements for storage with CO_2 EOR.
  - International (ISO) standards for establishing secure storage sites
- Social license to operate (pipelines and storage)
- Obtaining storage site construction and operating permits
- Complying with Class VI injection and post-injection monitoring requirements

IRS Section 45Q -- Highlights

Bipartisan Budget Act of 2018
• New facilities need to **"break ground" by EOY 2025.**
• Credit goes to the **owner of the capture equipment** **but** allows **transfer** of qualified credits.
• **$50/mt for geologic storage and $35/mt for EOR (reaches maximum value in 2026**).
• Capture > **500,000** metric tons CO_2/year for electric generating units; > **100,000** metric tons CO_2 /year for other.
• Available for **12 years** from date carbon capture equipment is placed in service.

Possible Enhancements to Section 45Q Tax Credits -- Highlights

Carbon Capture, Utilization, and Storage Tax Credit Amendments Acts

- Extends the commence construction window to the end of 2030.
- Provides a direct pay option, rather than just a tax credit.
- Increases the 45Q credit value (different bills have different value targets)
  - To as much as $120 per metric ton for saline formations (some propose smaller increases).
  - To as much as $75 per ton for storage in oil and gas fields (some propose smaller increases).
- Amends other conflicting and disincentivizing provisions of the tax code.

SCALE Act

- Establishes the CO_2 Infrastructure Finance and Innovation Act (CIFIA) program to finance shared CO_2 transport infrastructure.

American Jobs Plan

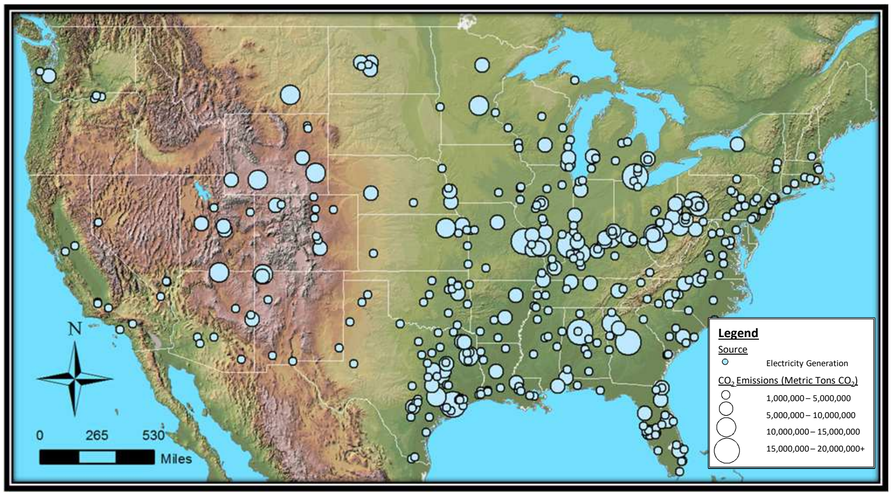
- Establish ten "pioneer" facilities that demonstrate carbon capture retrofits; $15 billion in demonstration projects, including, but not limited to, CCS projects.
- Extends the commence construction window to the end of 2030.

Several bills also lower the threshold capture amount for various categories of facilities.

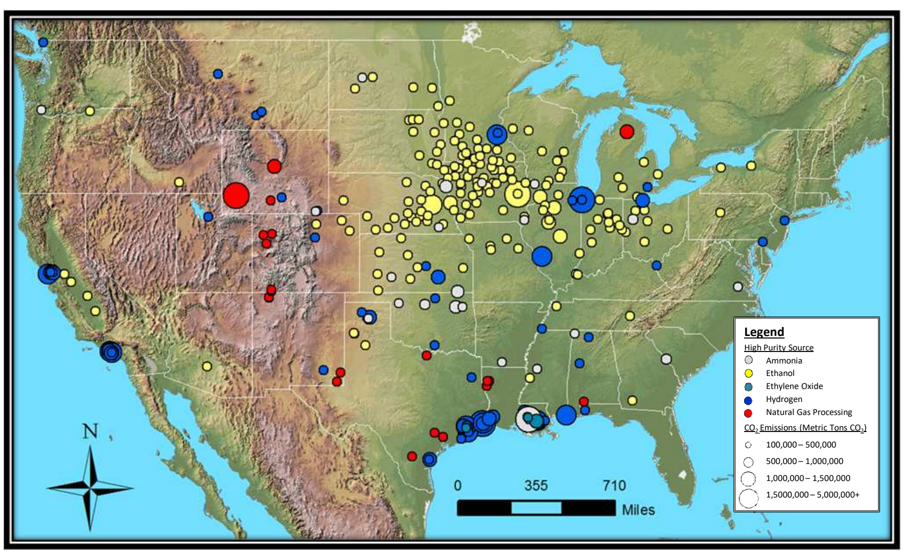
California Low Carbon Fuel Standard

- Enables CCS projects that reduce emissions associated with the production of transport fuels sold in California, and projects that directly capture CO_2 from the air, to generate LCFS credits.
- To receive certification, operators are required to meet **several minimum site selection criteria and plans** (e.g., well construction, monitoring, PISC period)
- The number of credits a project can claim is specified in the accounting requirements of the CCS Protocol. **CCS projects must contribute between 8% and 16.4% of the credits they generate** to a Buffer Account which provides a reserve that can be drawn on to maintain the environmental integrity of the LCFS in the event of CO_2 leaking.

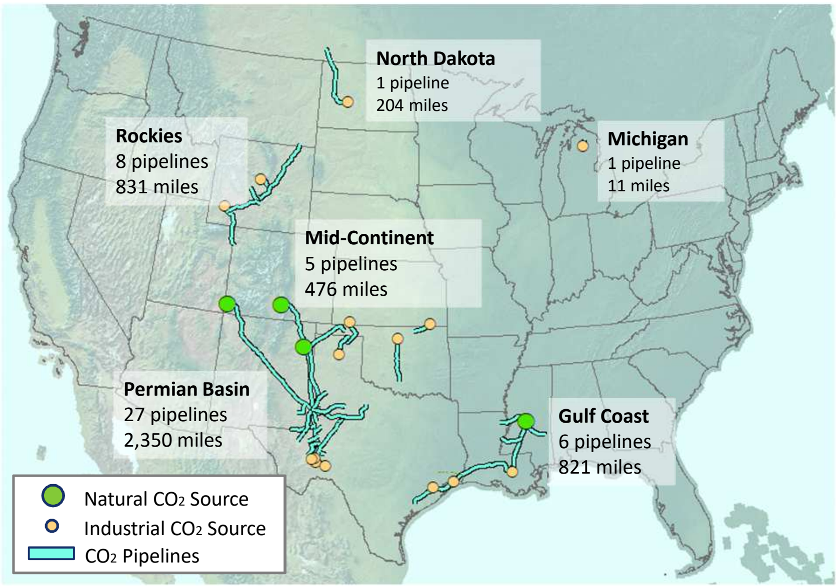
Potential Electric Generation CO_2 Sources Above 1 Million Tonnes/Year



The Low-Hanging Fruit: High Purity Stream Potential CO_2 Sources

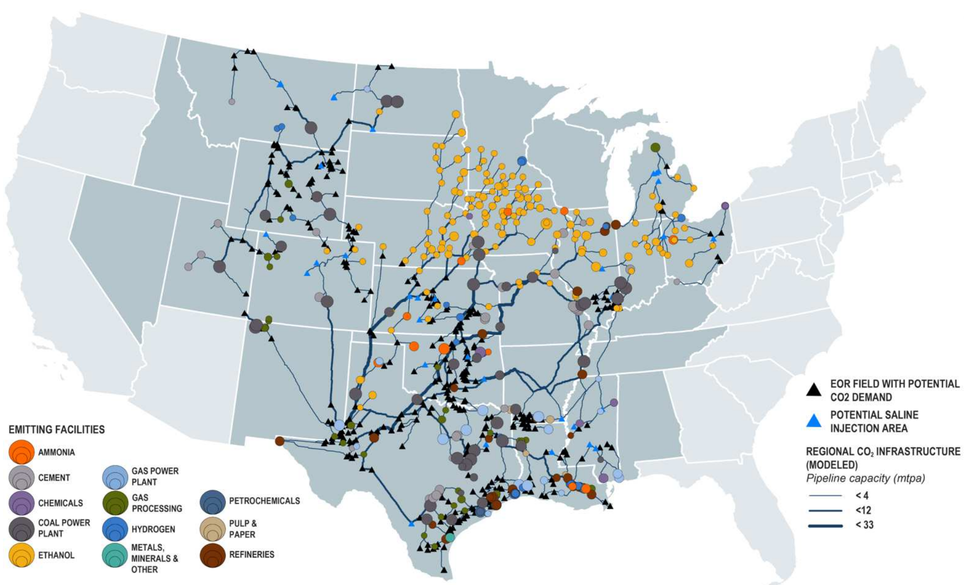


Existing CO_2 Pipelines



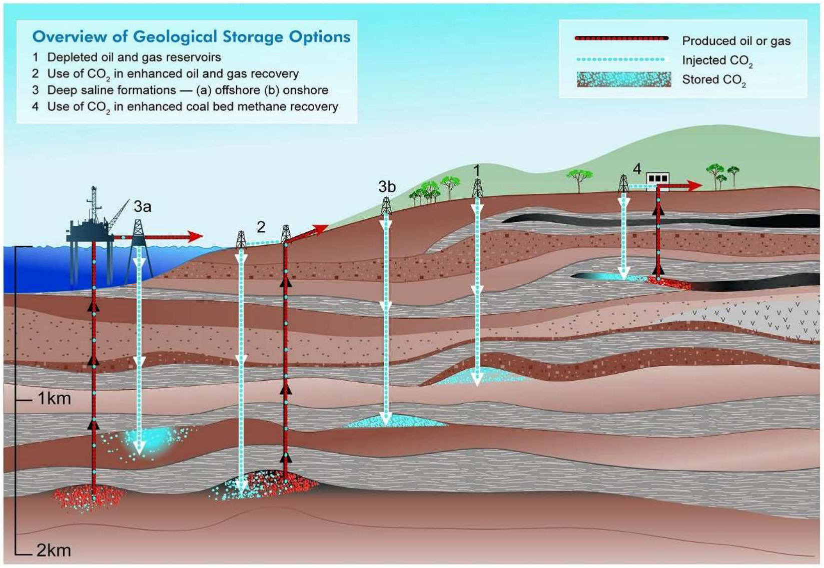
- The U.S. has a total of 48 CO_2 transportation pipelines over about 4,700 miles in length.
- These pipelines range from large capacity (1+ Bcf/d) delivery pipelines to small capacity laterals.
- Half of the CO_2 transportation pipeline length in the U.S. (2,350 miles) serves the Permian Basin.
- There must be new infrastructure developed to meet project needs.

What a Future CO_2 Network Could Look Like



Source: Great Plains Institute

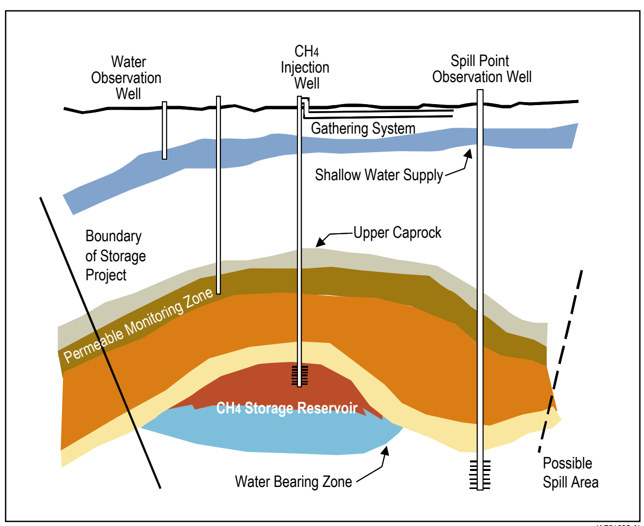
Storing CO_2 in Deep Underground Geological Formations



Source: IPCC, 2005

Comparison to Petroleum Engineering

- The skill set required for storing CO_2 is comparable that learned and applied in petroleum engineering.
- Similar exploration and characterization methods are used.
- Similar infrastructure (wells, injection/monitoring equipment, transportation).
- Differences are related to regulation, buoyancy, corrosivity, and scale, hydrate management with impure CO_2, and thermal effects in pressure depleted reservoirs.



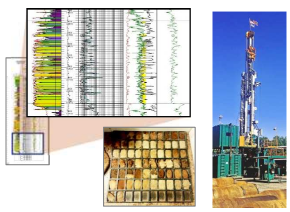
Modified after Katz, D.L, and K.H. Coats, *Underground Storage of Fluids*, Ulrich's Books, 1968.

Phases of a Carbon Capture, Storage and Utilization Projects

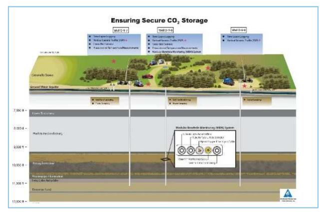
Webinars

Generalized Timeline to Implement Geologic CO_2 Storage

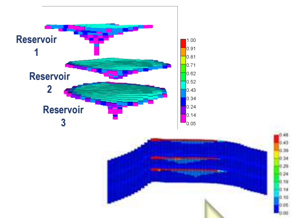
Geologic Characterization



Field Storage Implementation



CO_2 Plume Modeling and Monitoring



Screening → Feasibility → Project Design & Permit Application → Regulatory Review of Permit → Investment & Construction → Operations

- Geologic Evaluation and Screening
- Well Logs, Core Analysis, Sampling/ Testing

- Geologic Modeling
- Mapping
- Designing Well Plans
- Geophysical Analysis
- Geo-mechanical Analysis

- Drilling Characterization Well
- Core Analysis
- Seismic Monitoring and Analysis

- Drill and Construct Injection and Monitoring Wells
- Install Infrastructure
- Update Permits

- Geologic Monitoring of the Plume Space

SPE International

Seven Technical Criteria for a High Potential CO_2 Storage Site

Webinars

1	Optimum Depth	For efficient storage of dense phase CO_2, the storage horizon would be between 3,000 ft (900 m) and 10,000 ft (3,000 m) of depth.
2	Adequate Storage Capacity	High potential volume of storage, as defined by areal extent, thickness, and porosity.
3	Reliable Reservoir Seal	A confining zone that includes thick, low permeability sealing layer(s) above the storage zone(s).
4	Protection of Potable Sources of Water	The storage horizon needs to be located below potential sources of potable water separated by secure reservoir seals.
5	High CO_2 injectivity	Sufficient permeability and thickness to inject relatively large amounts of CO_2 per well.
6	Limited CO_2 Plume	Geological characteristics that help manage the areal extent of the CO_2 plume.
7	Verifiable Storage Integrity	Understanding and monitoring the storage formation (CO_2 leakage pathways such as from legacy wells, faults, fractures, etc.).

Managing and Minimizing the Risks of a CCS Project

U.S. and international CO_2 storage standards have set forth guidelines for reducing (essentially eliminating) the risks of leakage from a CO_2 storage site.

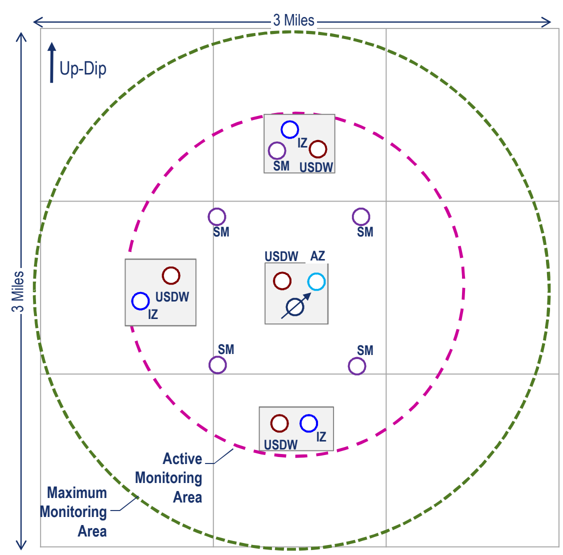
Select a geologically appropriate CO_2 storage site with high integrity.

Construct the CO_2 storage using "best practices" for well construction and operation.

Install a rigorous Monitoring, Verification and Accounting (MVA) system and reporting protocols.

- If the above three steps are followed, project risks can be managed and minimized.
- It also helps establish the social criteria by which project legitimacy can be established.

CO_2 Storage and MVA Field Design, Including Well Locations



The proposed storage field design includes the location of: (1) the CO_2 injection well, (2) the three in-zone monitoring wells, (3) the one above-zone monitoring well, (4) the four deep USDW wells, and (5) the five shallow water monitoring wells.

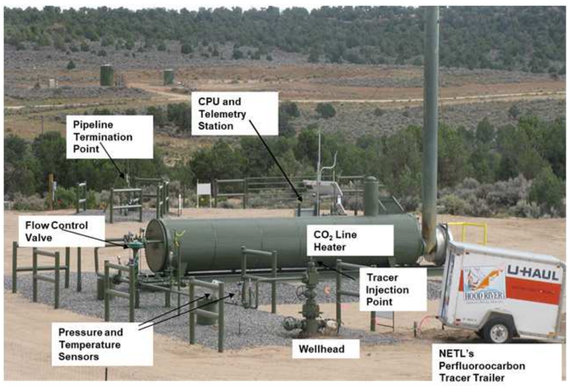
Legend

- CO_2 Injection Well
- IZ (Far Field In-Zone Pressure Monitoring Well)
- USDW (USDW Monitoring Well)
- AZ (Above Zone Monitoring Well)
- SM (Shallow Groundwater Monitoring Well)

CCS Projects Require Careful Monitoring During and After CO_2 Injection

Webinars

CCS requires wells, pipelines, monitoring technologies, and HSE protocols, though old wells may serve as monitoring wells.



MVA Method	Frequency				
	Continuous	Monthly	Quarterly	Annual	Milestone *(Baseline, Injection, Post)*
Shallow					
Soil flux		■			
Groundwater sampling (USDW)			■		
PFT survey				■	
Deep					
CO2 volume, pressure & composition	■				
Reservoir fluid sampling				■	
Injection, temperature & spinner logs				■	
Pulse neutron logs				■	
Crosswell seismic					■
Vertical seismic profile (VSP)					■
Experimental					
Distributed Temperature Sensing (DTS)		■			
Comparative fluid sampling methods				■	
MBM VSP				■	
Distributed Acoustic Sensing (DAS)				■	
MBM VSP & OVSP Seismic				■	

SPE International

Economics of CCS

Webinars

The economics of CCS are highly scale, technology and site dependent. Provided below are some examples of revenues and costs of actual/planned CCS projects.

Revenues. In the U.S., revenues for CCS/CCUS projects stem from three sources:

- Sales of CO_2 to EOR, typically \$30 to \$35 per metric ton, depending on oil prices.
- Incentives such as the 45Q tax credit of \$35/mt for storage with EOR and \$50/mt for geological storage.
- Direct government support.

Capital Costs. Front-end capital costs for:

1. CO_2 Capture Plant (shown on following slide)
2. CO_2 Pipelines
3. CO_2 Storage Site

SPE International

Economics of CCS (Cont'd)

Capital Investment Costs for Reference CO_2 Capture Plants

The National Petroleum Council estimated that capital costs would decline by up to 30% as technology improves and commercial-scale projects are launched.

Facility Type	Reference Plant Size	CO_2 Volume Captured (tonnes/year)	Capital Cost Low-High ($ millions)	Unit Capital Cost 20-Year Life Low-High ($/tonne)
Natural Gas Processing	140 MMCF/D	234,000	17-28	7-12
Cement Plants	1 million tonnes/yr	842,000	148-247	17-29
Steel/Iron Plants	2.54 million tonnes/yr	3,324,000	805-1342	26-44
Coal Power Plants	550 MW net	3,089,000	891-1485	33-55

Modified from National Petroleum Council, 2019.

Operating Costs. We need more information on labor, energy and electricity costs to estimate operating costs for CO_2 capture. A rule of thumb would be to double capital investment.

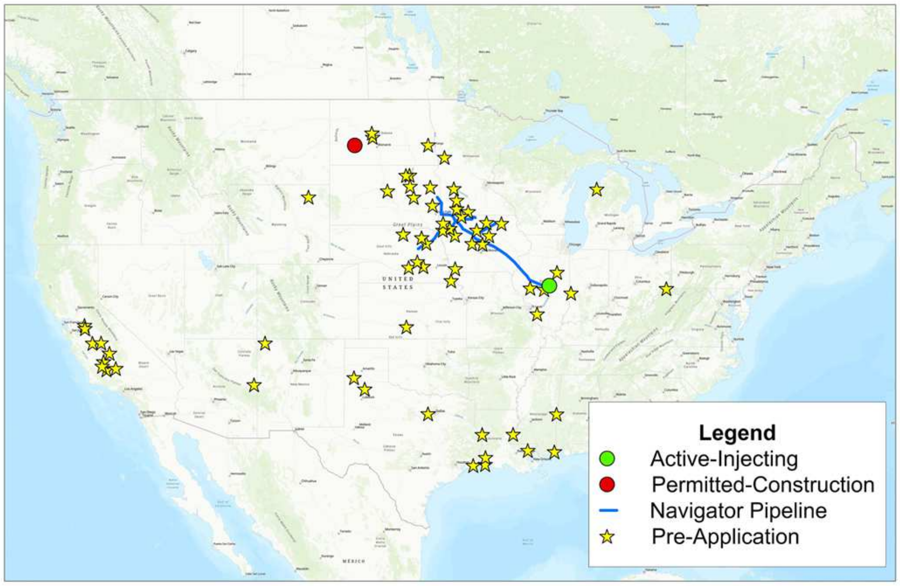
Economics of CCS (Cont'd)

CO_2 Pipelines. A 200-mile (300 km), 16-to-20-inch diameter, high pressure CO_2 pipeline could cost \$300 to \$400 million to install, equal to $\pm$\$5/mt. Operating costs for 20 years would add about \$2 to \$3/mt.

CO_2 Storage. CO_2 storage costs are highly site, process, and scale specific:

- For EOR, the oil field operator purchases the CO_2 from the pipeline and assumes the costs of storage.
- For natural gas processing, can use Class II wells instead of Class VI, and also bears the cost of storage.
- Constructing a storage facility in a high geologic quality site will cost \$100 to \$150 million (depending on number of injection and monitoring wells required), equal to about \$2 to \$3 per metric ton. Twenty years of storage site operating costs would be about equal to capital costs.

These Projects are Preparing to Enter the Permit Phase



North Dakota Department of Mineral Resources Employment Opportunities (nd.gov), Class VI Wells Permitted by EPA | US EPA, Global Status Report - Global CCS Institute

Closing Remarks

- There is a need to reduce the amount of carbon emissions and the oil and gas industry is taking notice.
- The US has the people, skills, and technologies to deploy CCS at scale, but most of the key risks remain non-technical.
- Regulatory frameworks/standards are being established to ensure the proper care in project development.
- Buoyed by tax incentives and readily available, high purity sources of CO_2, CCS is proving to be a viable commercial activity.
- Work still needs to be done on bringing down the cost of capture.

CCS -- Challenges Associated With Permitting Storage Sites in the U.S.

Webinars

Andrew Duguid, Advanced Resources International

June 14, 2022

SPE International

Interstate Oil & Gas Compact Commission

EDF Environmental Defense Fund — Finding the ways that work

U.S. Regulation of Storage

Webinars

- From 20 years' worth of R&D, a significant foundation of experience regarding CO_2 storage has been established.
- In 2010, U.S. EPA promulgated Underground Injection Control (UIC) well (Class VI) requirements for geologic storage of CO_2.
- Two states have been awarded primacy for the Class VI program – North Dakota and Wyoming.
  - Louisiana should obtain primacy this year; others are in the process of preparing primacy applications to submit to EPA.
- EPA guidance confirms that CO_2-EOR can result in stored CO_2; conversion to Class VI is not required for assuring storage.

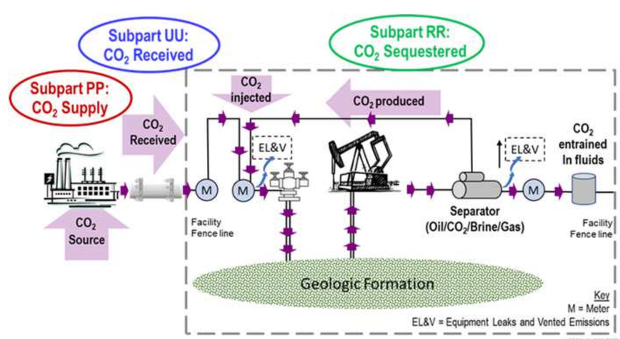
SPE International

U.S. Regulation of Storage

- Additional regulatory regimes exist for stackable credits
- California Air Resources Board's Carbon Capture and Sequestration Protocol under the Low Carbon Fuel Standard
  - Very similar to UIC Class VI
  - Longer post injection period, lower maximum bottomhole pressure, explicit risk assessment requirement
- International Standard's Organization
  - Saline Storage Standard
  - CO_2-EOR Standard

Establishing "Secure Geologic Storage"

- EPA Greenhouse Gas Reporting Program (GHGRP) Subpart RR and federal/state Underground Injection Control (UIC) program rules are the status quo.
- For storage with EOR, accepted alternative to Subpart RR is the use of standards for EOR published by the International Standards Organization (ISO). EPA proposal exists to allow such reports to be published for purposes of transparency.
- Subpart RR:
  - Accounting framework only – no authority for containment assurance.
  - For CO_2-EOR, not required to report under Subpart RR unless operator chooses to opt-in
  - To get 45Q credits for EOR, operator must opt in.
  - Facilities reporting under Subpart RR must have an EPA-approved, site-specific monitoring, reporting and verification (MRV) plan.



BOEM-BSEE in Process of Establishing a CCS Regulatory Framework for the Federal Offshore

Webinars

- BIL amends OCSLA, authorizing DOI to administer leases, easement, and rights-of-way on submerged federal lands for geologic storage of CO_2.
- Also requires DOI to promulgate regulations by [November 14, 2022], one year of the law's enactment.
- A joint BOEM–BSEE rulemaking is underway. Rulemaking team was established relying on existing expertise throughout the bureaus, with extensive outreach underway
- BOEM–BSEE currently reviewing numerous industry standards and existing regulatory frameworks.
- BOEM-BSEE is also actively engaging other Federal and State Agencies with associated expertise.
- Offshore currently not permittable under CARB rules.

SPE International

Process Initiated to Establish New Standards for CO_2 Pipelines in the U.S.

Webinars

- In late May, the Department of Transportation's (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA) announced plans to update CO_2 pipeline standards, including emergency response and preparedness requirements.
- The objective is to develop "common sense safety measures" that bolster a regulatory regime needed to scale up use of CCS technology crucial to achieving deep cuts in CO_2 emissions.
- DOT coupled its announcement of a new rulemaking with the release of its report on a recent Satartia, MS CO_2 pipeline failure incident.

SPE International

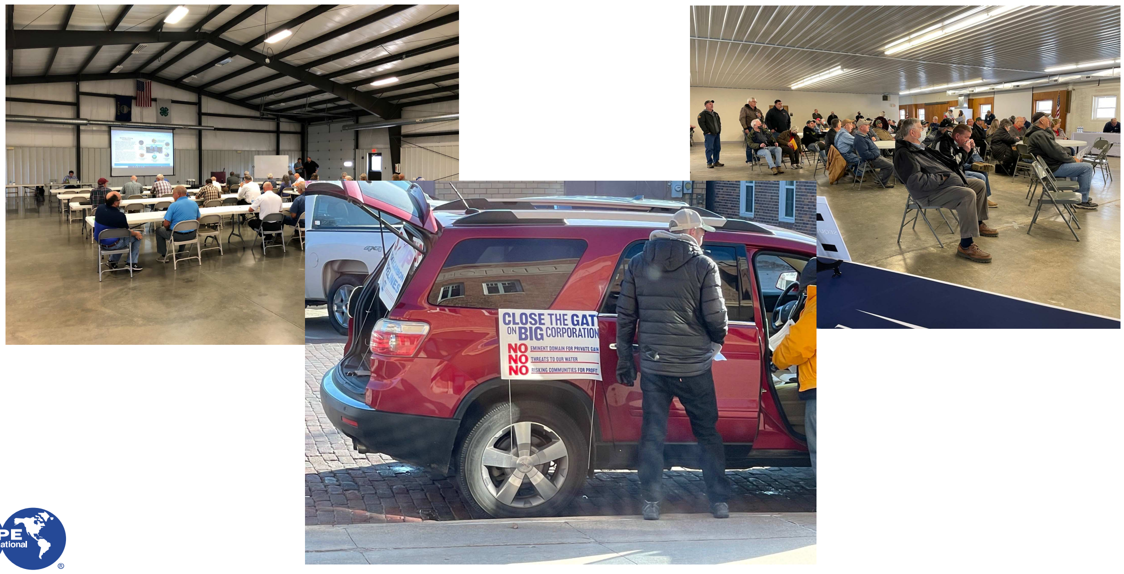
Possible Additional State Support/Incentives

- Clear and supportive state regulatory policies
- Clear rules for long term storage
- CO_2 pipelines – common carrier/eminent domain
- Financial incentives for carbon capture
  - Financial assistance, off-take priority, cost recovery, eligibility under "clean energy" standards, assumption of long-term liability
- Tax incentives/optimization
  - Additional tax credits for CO_2-EOR + storage, tax exemptions for "pollution control equipment" associated with CO_2 capture.

Multiple Regulations, One Project

- 45Q tax credits are a good start but many projects need additional value to fully support the project
- Stacking of credits is possible but this stacks regulatory regimes
  - To include Section 45Q credits, CARB LCFS credits, and other carbon markets
- Requires submittal of multiple permit applications, with different sets of requirements, but with a consistent narrative and justification.
- Regulatory authorities can change mid-project from federal to state jurisdiction, as states gain primacy for regulating Class VI wells.

People



Pore space

- Pore space ownership needs are somewhat uncertain; the challenges associated with pore space vary from location to location
  - But still generally requires permission of the owners of surface rights, pore space rights (if different, and mineral rights)
  - Differ permission necessary of different aspects of a process – seismic acquisition, pipeline rights of way, drilling access, etc.
- California rules requires pore space access demonstration prior to permit approval; though this is not required for federal Class VI permits

Summary

Webinars

- **Policy uncertainty is perhaps the biggest obstacle impacting large scale CCS deployment**
    - Incentives may need to be expanded; Congressional uncertainty is certainly leading to delays
- **Another big issue is the high capital costs for entry; and a misunderstanding of the risks and rewards, particularly for private capital providers not familiar with CCS.**
    - High returns necessary to overcome uncertainty
    - But ESG investors are still willing to pursue CCS
- **Greater certainty on all fronts critical to establishing potential commercial viability for large scale deployment.**
- **Social license to operate will require significant outreach.**
- **Need to anticipate/plan for/train for the next "great crew change" from traditional oil and gas to CCS and the energy transition.**

SPE International