CARBON CAPTURE, UTILIZATION, AND STORAGE (CCUS): INSIGHTS, OPPORTUNITIES, AND CHALLENGES

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Presented at the Ground Water Protection Council 2021 Annual Meeting, Salt Lake City, September 26-29, 2021

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WHAT IS CARBON CAPTURE, UTILIZATION, AND STORAGE?

CARBON SEQUESTRATION OF CARBON DIOXIDE (CO_2) IS THE LONG-TERM PLAN FOR THE REMOVAL, CAPTURE, AND GEOLOGIC SEQUESTRATION OF CO_2 FROM THE ATMOSPHERE.

THE PLAN IS FOR LONG-TERM STORAGE OF CARBON IN PLANTS, SOILS, SUBSURFACE GEOLOGIC FORMATIONS, AND IN THE OCEAN.

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HISTORY OF CARBON CAPTURE, UTILIZATION AND STORAGE

- THE CARBON SEQUESTRATION INITIATIVE WAS LAUNCHED IN JULY OF 2000.
- ORIGINALLY CALLED CARBON CAPTURE AND SEQUESTRATION (CCS) BACK IN THE EARLY TO MID-2000S, NOW IT'S CALLED CARBON CAPTURE, UTILIZATION, AND STORAGE (CCUS).
- THE U.S. DEPARTMENT OF ENERGY (DOE) STARTED TO INCREASE FUNDING FOR CCUS IN 2003 WITH THE FUTUREGEN PROJECT AND THE FORMATION OF 7 REGIONAL CARBON SEQUESTRATION PARTNERSHIPS (RCSP) INVOLVING STATE AGENCIES, PRIVATE COMPANIES, AND UNIVERSITIES ACROSS THE U.S.

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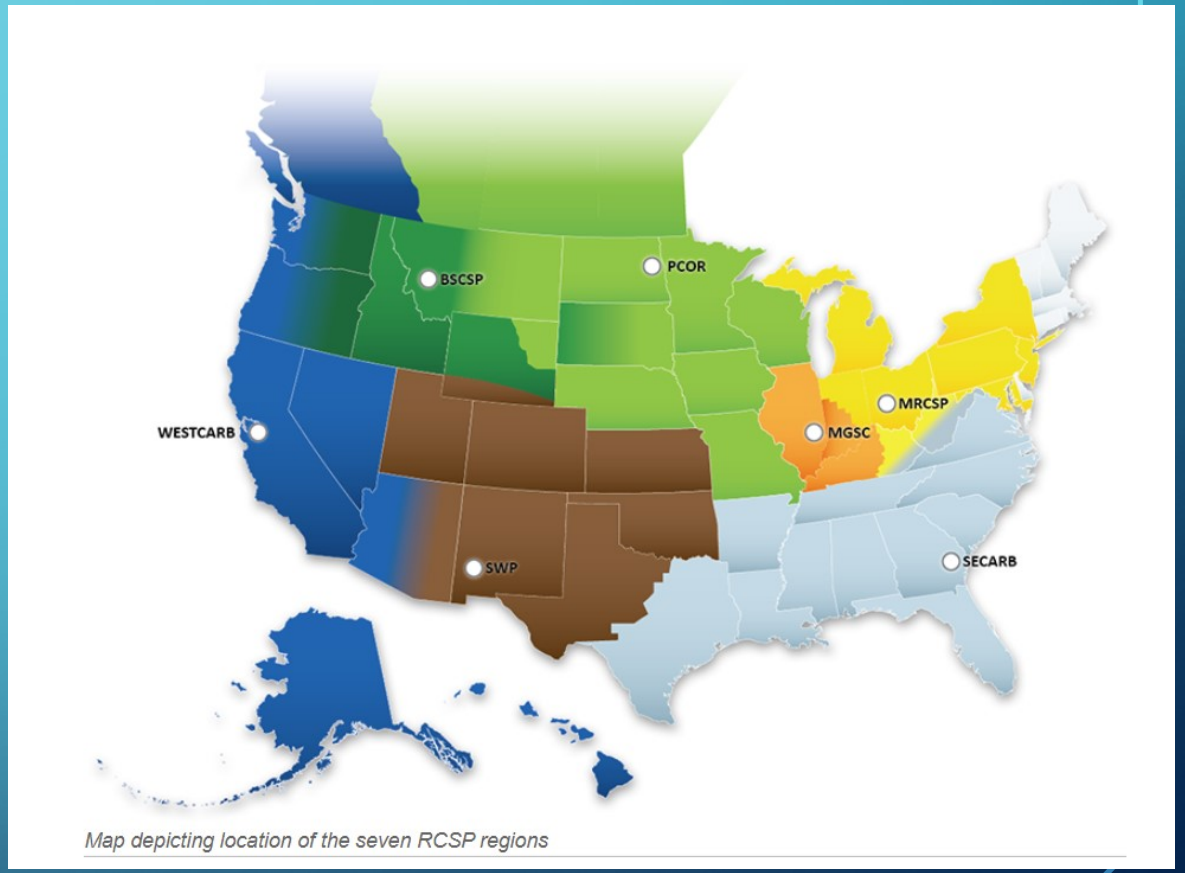
RCSP INITIATIVE

- This initiative began in 2003 through the National Energy Technology Laboratory (NETL) with the characterization of each region's potential to sequester CO2 in subsurface geologic formations.



Map depicting location of the seven RCSP regions

Source: NETL, 2021

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NETL INITIATIVE – VALIDATION PHASE

- By 2005, NETL selected the most promising sites with the commencement of a series of small-scale regional field projects called the validation phase.
- This validation phase led to the successful completion of 19 small-scale field projects in a variety of subsurface geologic environments (8 in oil and gas fields, 5 in unmineable coal seams, 5 in saline geologic reservoirs, and 1 in basalt).
- These field studies provided valuable information on reservoirs and sealing properties of regionally significant geologic formations, testing methodology, initial validation of computer modeling, and CO2 monitoring capabilities.

RCSP	Abbreviation	Lead Organization
Big Sky Carbon Sequestration Partnership	BSCSP	Montana State University – Bozeman
Midwest Geological Sequestration Consortium	MGSC	Illinois State Geological Survey
Midwest Regional Carbon Sequestration Partnership	MRCSP	Battelle Memorial University
Plains CO_2 Reduction Partnership	PCOR	University of North Dakota Energy and Environmental Research Center
Southeast Regional Carbon Sequestration Partnership	SECARB	Southern States Energy Board
Southwest Regional Partnership on Carbon Sequestration	SWP	New Mexico Institute of Mining and Technology
West Coast Regional Carbon Sequestration Partnership	WESTCARB	California Energy Commission

Regional Carbon Sequestration Partnerships (RCSPs)

Source: NETL, 2021

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NETL INITIATIVE – DEVELOPMENT PHASE

- In 2008, RCSP focused on large-scale field projects in saline reservoirs and in oil and gas fields with a target of injecting at least 1 million metric tons of CO2 for each project.
- Many of the technologies developed during the research phase were integrated into the development phase and were essential in CCUS development technology.

Regional Carbon Sequestration Partnerships (RCSP) Infographic

Source: NETL, 2021

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CCUS TECHNOLOGY – CLEAN ENERGY TRANSITION TO NET-ZERO EMISSIONS

- According to the International Energy Agency's (IEA) 2020 Report, reaching net-zero emissions will be virtually impossible without CCUS.
- According to the IEA, CCUS contributes to clean energy transitions in several ways:
  - By tackling emissions from existing energy infrastructure,
  - By creating a solution for the addressing more challenging emissions,
  - Providing a cost-effective pathway for low-carbon hydrogen production from fossil fuels, and
  - Has the capability of removing CO2 from the atmosphere
- CCUS is the only technology that contributes both to reducing emissions directly in key sectors and removing CO2 to balance emissions.

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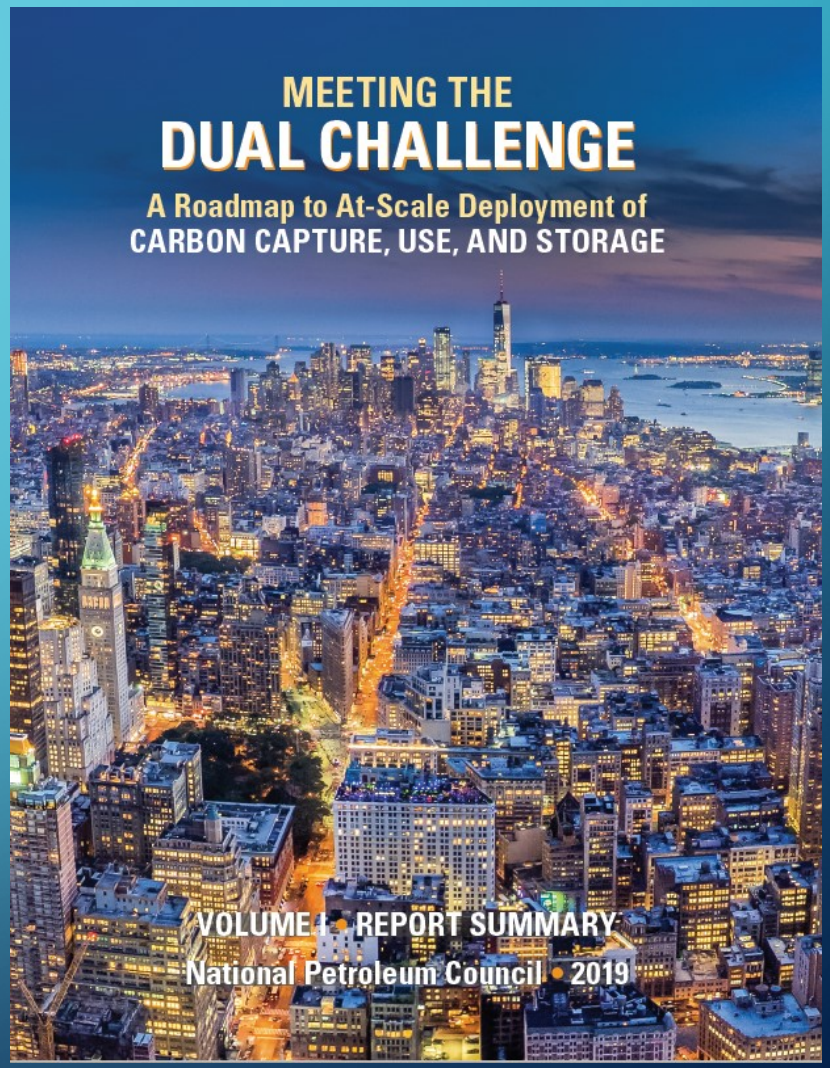
NATIONAL PETROLEUM COUNCIL

- This report demonstrated that:
  - The United States is positioned as the world leader in CCUS.
  - There is a need for increased government and private research, development, and demonstration to improve CCUS performance, reduce costs, and advance alternatives beyond currently deployed technology.
  - Congress should expand and amend the tax credits to all CCUS projects to further economic investment.



Source: National Petroleum Council, 2021

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CCUS

- CCUS is extensively used in the oil and natural gas industry, power generation, fertilizer, and other various industrial sectors.
- Globally, there are around 20 commercial CCUS facilities in operation with plans announced for more than 30 additional commercial CCUS facilities within the last few years.

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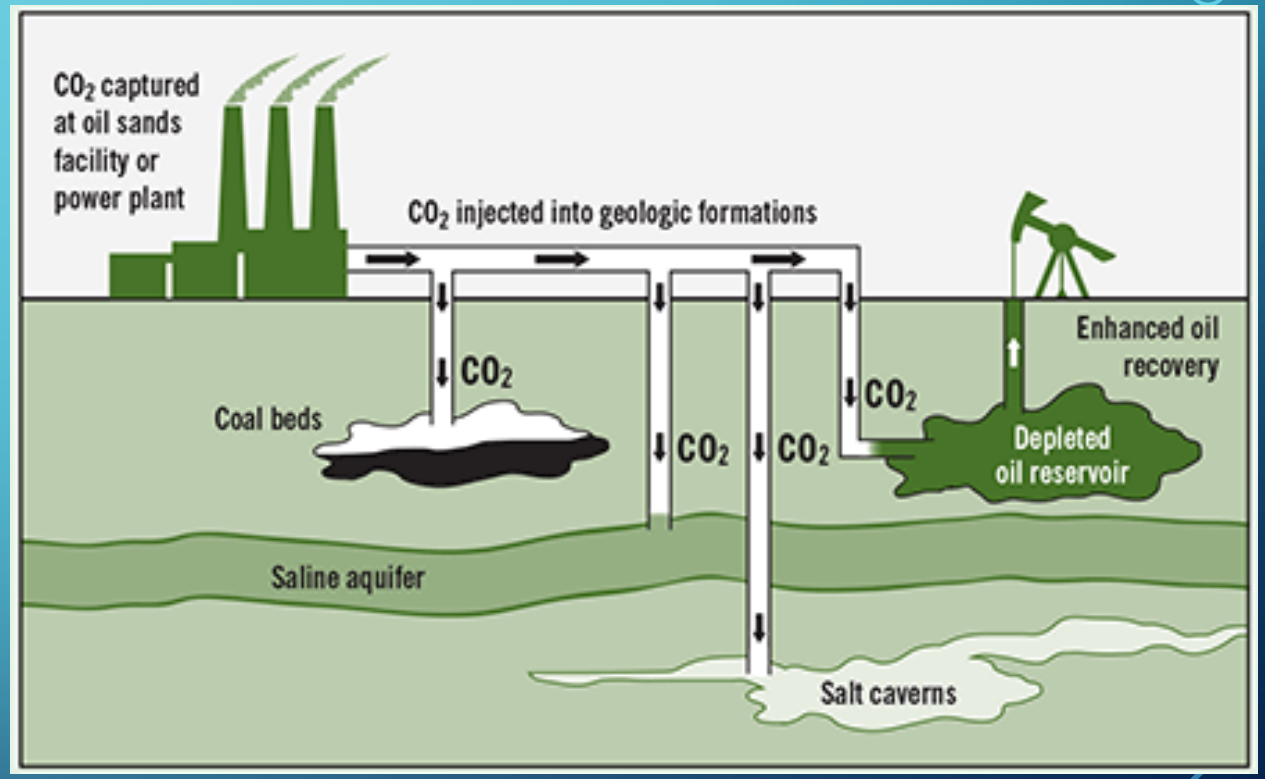
HOW DOES CCUS WORK?

- CO2 is captured and injected thousands of feet below the surface (minimum depth is approximately 2,600 feet so CO2 remains as a supercritical fluid) for storage into saline formations or is injected into depleted oil reservoirs for enhanced oil recovery operations.



Source: energywatch-inc.com

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WHO REGULATES CCUS?

- In 2008, U.S. EPA created a new class of injection well called Class VI, which is to be used exclusively for the geologic sequestration of CO2.
- Federal regulations were codified in December of 2010 under U.S. EPA's Underground Injection Control (UIC) Program, which outlines the federal requirements for the permitting, siting, construction, operation, monitoring, and site closure of Class VI sequestration injection wells.
- CO2 for enhanced oil recovery is regulated by U.S. EPA or states' UIC primacy under the existing Class II injection well program.

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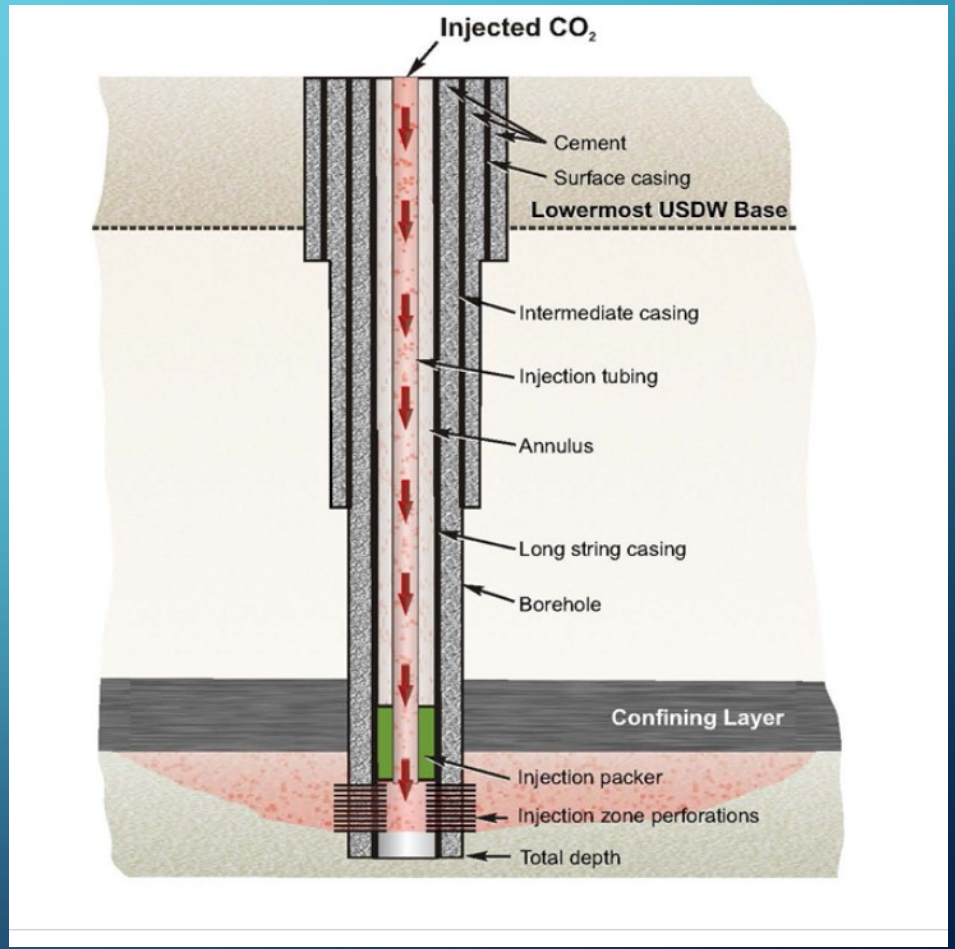
CLASS VI INJECTION WELL REGULATION

- Currently, only North Dakota and Wyoming have primacy of their Class VI injection well program.
- There are several other states pursuing Class VI primacy such as Louisiana.
- All other CCUS projects are regulated by one of the U.S. EPA regional offices.



Source: Cadmus Group, 2021

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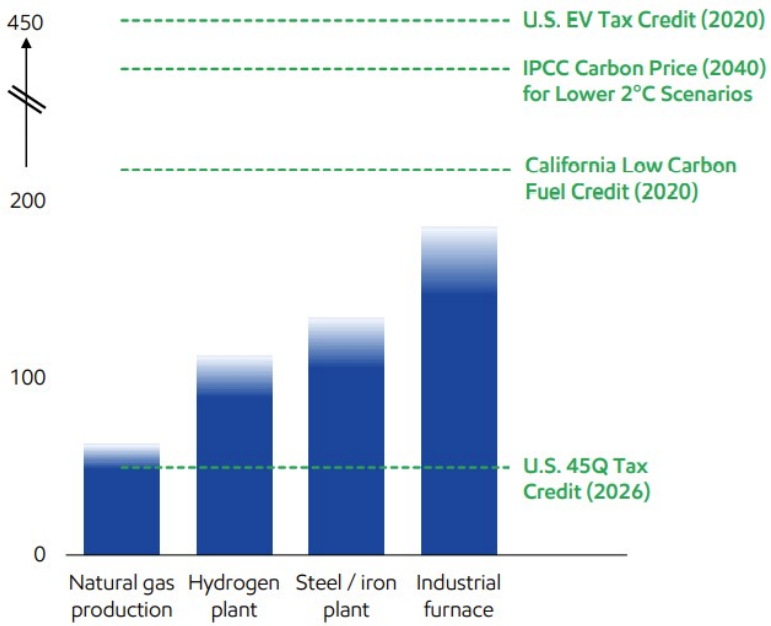
CCUS IS COST EFFECTIVE

CCS MORE COST EFFECTIVE THAN OTHER TECHNOLOGIES

Cost of CCS is well below many carbon reduction policies

CCS COSTS FOR MITIGATING INDUSTRIAL EMISSIONS[1,2]
$/tonne CO_2 for conventional technology



- Two-thirds of emissions from point sources conducive to CCS[3]
- Mitigates emissions at costs below policy support in other sectors
- Costs well below average carbon price projected in IPCC Lower 2°C
  - Projected to reduce cost of 2°C by >50%[4]
- Potential to generate tradeable carbon offsets

Source: National Petroleum Council report: A Roadmap to At-Scale Deployment of Carbon Capture, Use, and Storage (2019).
See Supplemental Information for footnotes and definitions.

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Source: ExxonMobil, 2021

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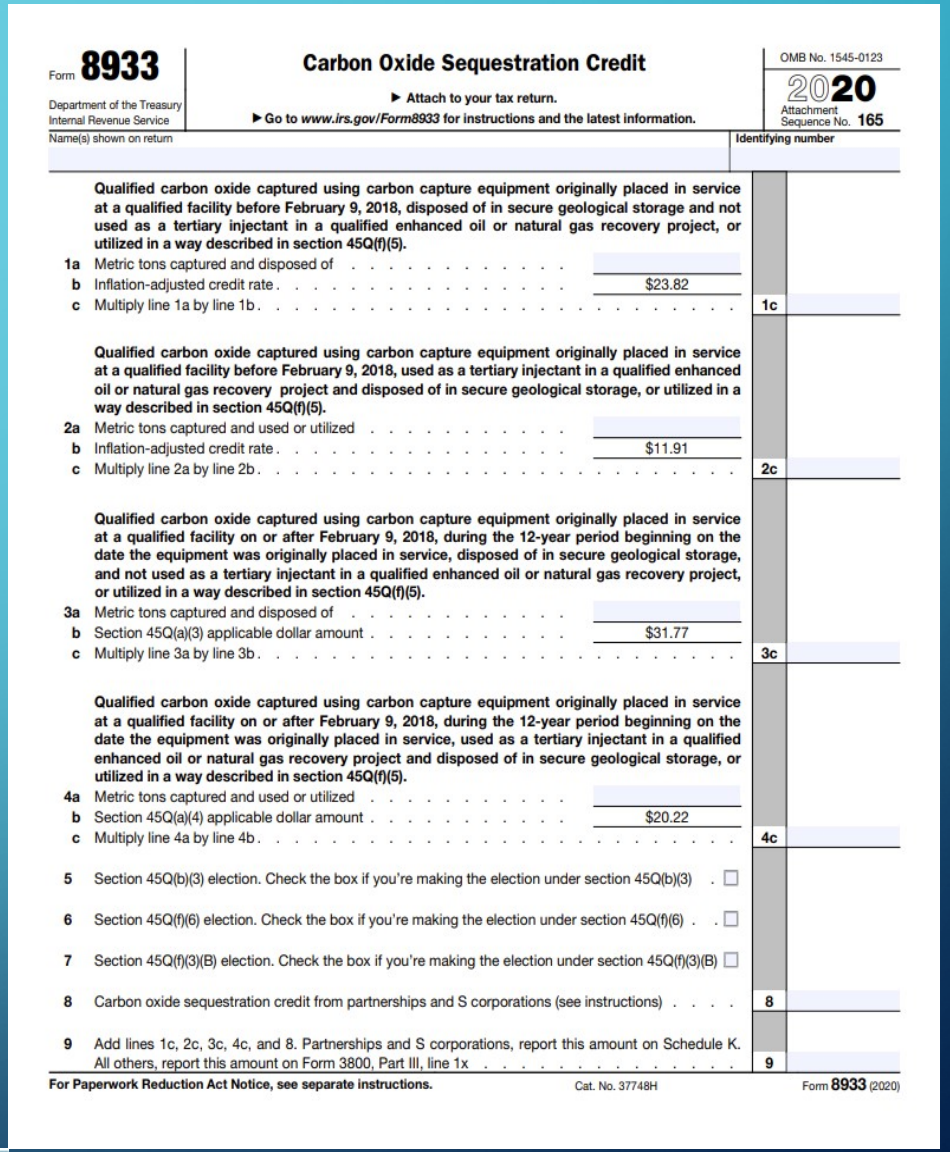
INCENTIVES FOR CCUS

- The Department of the Treasury, Internal Revenue Service (IRS) enacted Section 45Q within the tax code on October 3, 2008, by Section 115 of Division B of the Energy Improvement and Extension Act of 2008 to provide a tax credit for CO2 geosequestration.
- On June 2, 2020, the IRS issued a notice of proposed rulemaking in the Federal Register for setting regulations for the sequestration of CO2.
- Currently, 45Q allows for a CO2 tax credit for enhanced oil recovery storage tax of $35/ton and a CO2 tax credit of $50/ton for saline reservoir storage, which is extended to January 1, 2026.



Form **8933** — Carbon Oxide Sequestration Credit

Department of the Treasury, Internal Revenue Service

▶ Attach to your tax return.

▶ Go to *www.irs.gov/Form8933* for instructions and the latest information.

OMB No. 1545-0123

2020

Attachment Sequence No. 165

Name(s) shown on return | Identifying number

Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility before February 9, 2018, disposed of in secure geological storage and not used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, or utilized in a way described in section 45Q(f)(5).

1a Metric tons captured and disposed of

b Inflation-adjusted credit rate $23.82

c Multiply line 1a by line 1b 1c

Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility before February 9, 2018, used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project and disposed of in secure geological storage, or utilized in a way described in section 45Q(f)(5).

2a Metric tons captured and used or utilized

b Inflation-adjusted credit rate $11.91

c Multiply line 2a by line 2b 2c

Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility on or after February 9, 2018, during the 12-year period beginning on the date the equipment was originally placed in service, disposed of in secure geological storage, and not used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, or utilized in a way described in section 45Q(f)(5).

3a Metric tons captured and disposed of

b Section 45Q(a)(3) applicable dollar amount $31.77

c Multiply line 3a by line 3b 3c

Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility on or after February 9, 2018, during the 12-year period beginning on the date the equipment was originally placed in service, used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project and disposed of in secure geological storage, or utilized in a way described in section 45Q(f)(5).

4a Metric tons captured and used or utilized

b Section 45Q(a)(4) applicable dollar amount $20.22

c Multiply line 4a by line 4b 4c

5 Section 45Q(b)(3) election. Check the box if you're making the election under section 45Q(b)(3) ☐

6 Section 45Q(f)(6) election. Check the box if you're making the election under section 45Q(f)(6) ☐

7 Section 45Q(f)(3)(B) election. Check the box if you're making the election under section 45Q(f)(3)(B) ☐

8 Carbon oxide sequestration credit from partnerships and S corporations (see instructions) 8

9 Add lines 1c, 2c, 3c, 4c, and 8. Partnerships and S corporations, report this amount on Schedule K. All others, report this amount on Form 3800, Part III, line 1x 9

For Paperwork Reduction Act Notice, see separate instructions. Cat. No. 37748H Form **8933** (2020)

Source: IRS, 2021

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TECHNICAL ASPECTS OF CLASS VI INJECTION

- Extensive site characterization, geologic evaluation, and protection of underground sources of drinking water (USDWs).
- Well construction that is compatible with and can withstand contact with CO2 over the life of the project.
- Comprehensive monitoring requirements that address well integrity, CO2 injection and storage, plume boundary modeling, and protection of groundwater quality.
- Financial responsibility and assurance for the life of the project.
- Reporting and recordkeeping that continuously evaluates operations and protection of USDWs.

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TECHNICAL NEEDS OF CLASS VI INJECTION

- Site selection based on geologic and hydrogeologic characterization
- Regional and local structural analysis including detailed fault/fracture identification
- Injection and confining zone geologic assessment and reservoir integrity
- Geochemical analysis and compatibility of fluids
- Seismic history and seismic risk assessment
- Seismic monitoring and mitigation
- Surface and/or soil gas monitoring
- Conceptual and computational modeling
- Groundwater quality monitoring, CO2 plume and pressure front tracking

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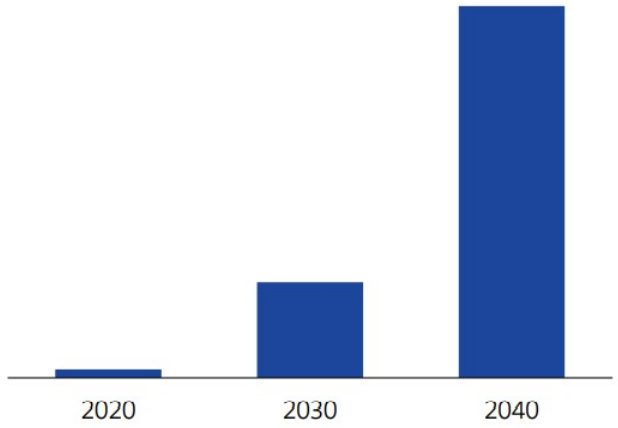
TWO TRILLION-DOLLAR CCUS MARKET BY 2040

POSITIONED TO SUCCEED IN CARBON CAPTURE

Leveraging position as the global CCS leader in a ~$2 trillion addressable market by 2040

TOTAL CO_2 CAPTURE[1]
Million tonnes



~$2 trillion addressable market
~35% projected growth per year

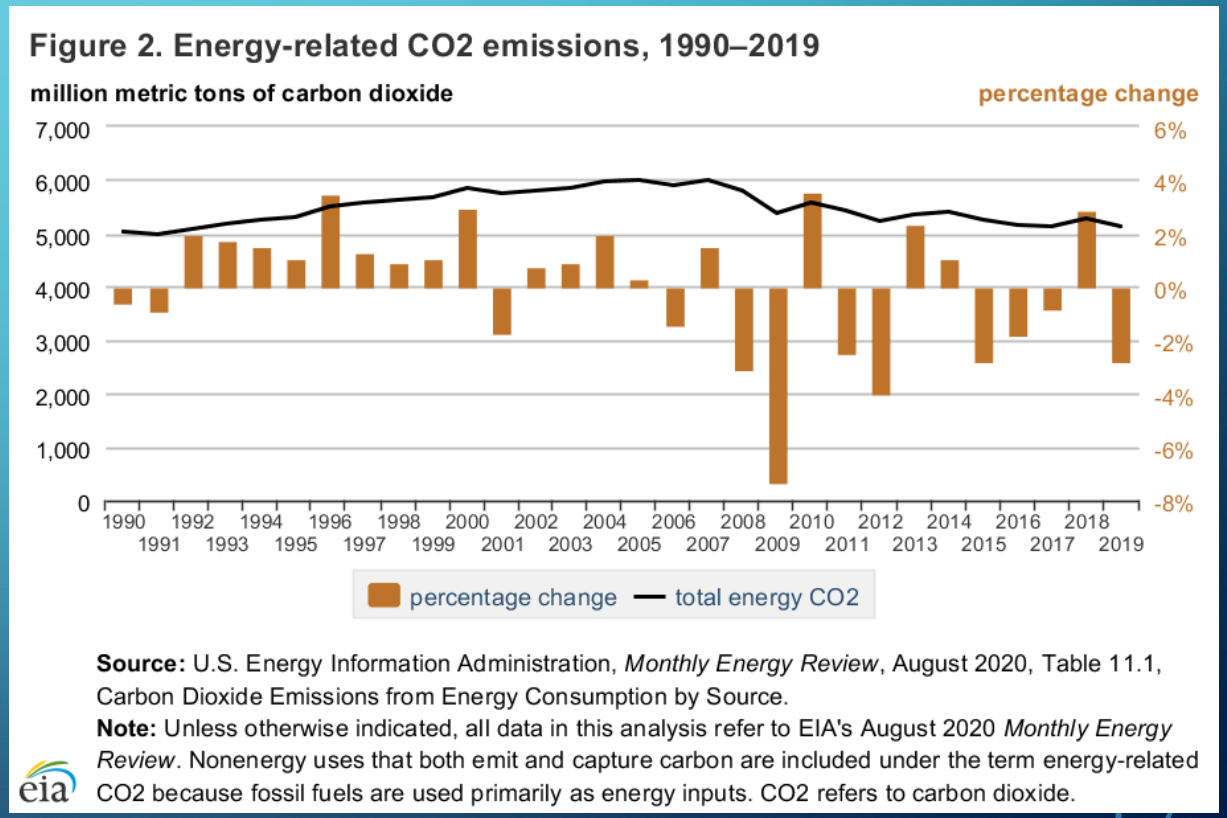
- Leverages history and experience at scale
  - #1 in the world for CO_2 capture; 9 Mta capacity[2]
  - #2 in the world for CO_2 pipelines[3]
  - #2 in the world for CO_2 geologic storage[4]
- Consistent with core capabilities and advantages
  - Subsurface and reservoir expertise
  - Project development and execution
  - Responsible and efficient operations
- Advancing plans for >20 new CCS opportunities

Source: IAMC 1.5°C Scenario Explorer and Data, average of IPCC Lower 2°C scenarios.
See Supplemental Information for footnotes.

Source: ExxonMobil, 2021

CO2 EMISSIONS AND CCUS DISPOSAL VOLUMES

- CO2 emissions in the U.S. saw a decline of 2.8% in 2019 to 5,130 MM tons.
- This volume of CO2 equates to 5,130 X 7,330,000 bbls/MM tons = 37.6029 billion barrels of fluid.
- This would equal an injection rate of 103,021,643.8 barrels per day across the U.S.
- This is approximately 216% more fluid than the U.S. EPA estimates to be injected into Class II wells in the U.S. each day.



Source: EIA, 2020

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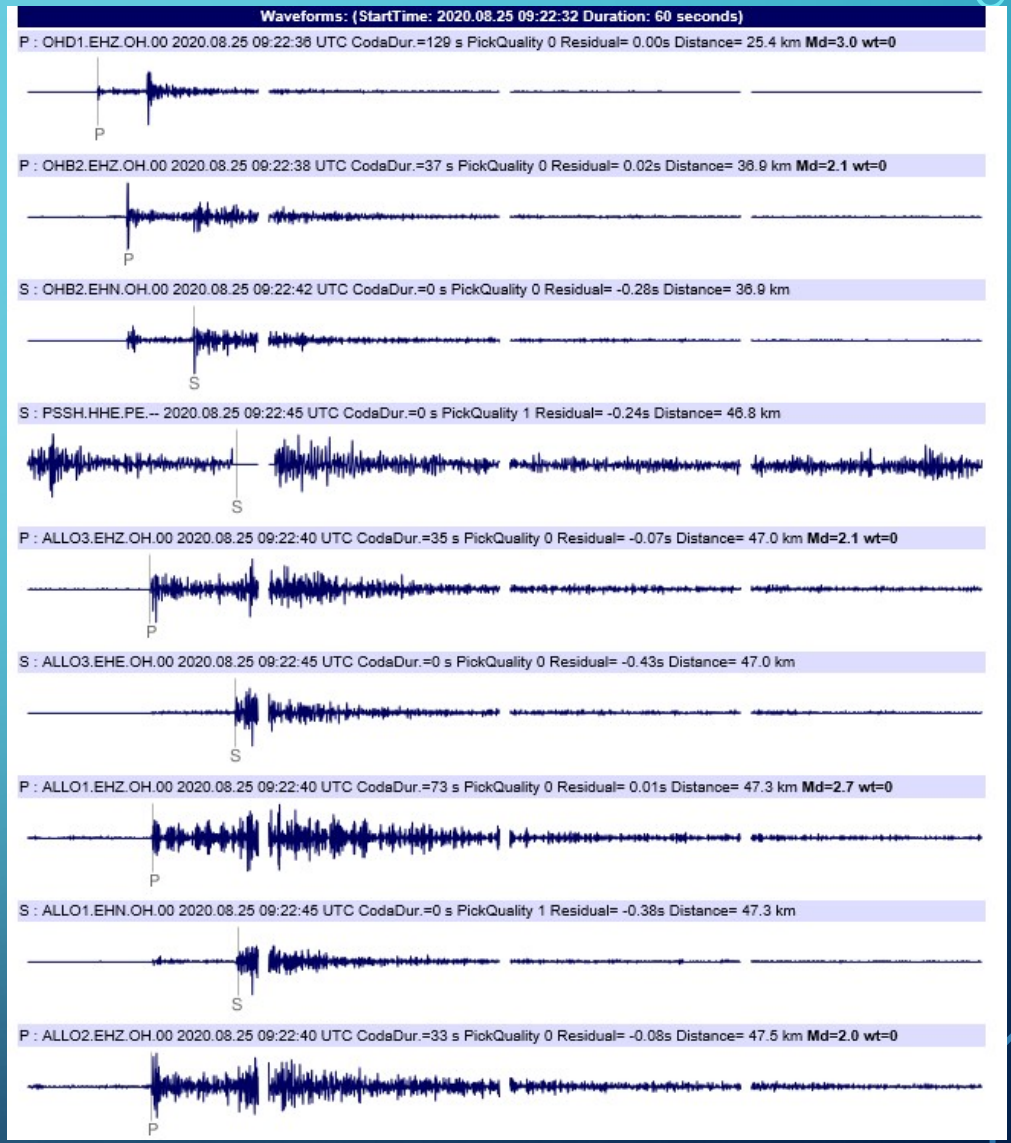
CHALLENGES FACING CCUS

- CO2 needs to be injected at depths greater than approximately 2,600 feet so it can be maintained as a super critical fluid.
- Identifying adequate geologic formations for storage as one million metric tons of CO2 equals 7,330,000 barrels of fluid.
- Assessing the risk for injection-induced seismicity.
- Current high cost of direct air carbon capture.
- Competition for the pore space with other types of injection wells.
- Leasing of the pore space in the area of review.



Source: ALL Consulting, 2020

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SUMMARY OF CCUS

- Energy transition means emissions reduction through decarbonization of existing hydrocarbon industries to generated electricity.
- Without CCUS you cannot get to the very challenging goal of net-zero emissions.
- Efforts must be focused on the clusters of CO2 sources where commercial CCUS can grow from. **That will mean a lot of pipelines.**
- Realize that CCUS will have its limitations due to the large volumes of fluids to be injected for storage and the potential for injection-induced seismicity.
- Additionally, will need to see faster issuance of Class VI permits, increases in 45Q tax credits (around $90/ton) and more federal funding must be addressed to make CCUS a reality.

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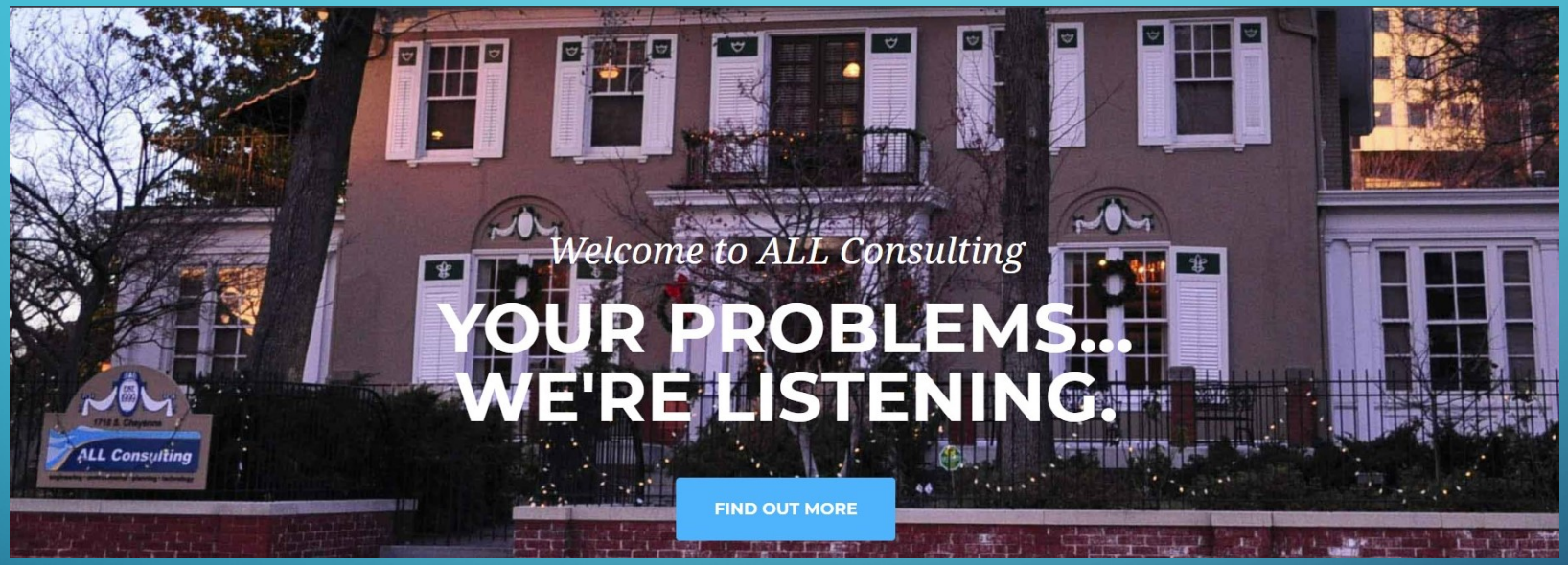

Citation Information: Tom Tomastik and Dan Arthur, "Carbon Capture, Utilization, and Storage (CCUS): Insights, Opportunities, and Challenges." Presented at: Ground Water Protection Council 2021 Annual Meeting, Salt Lake City, Utah, September 26-29, 2021