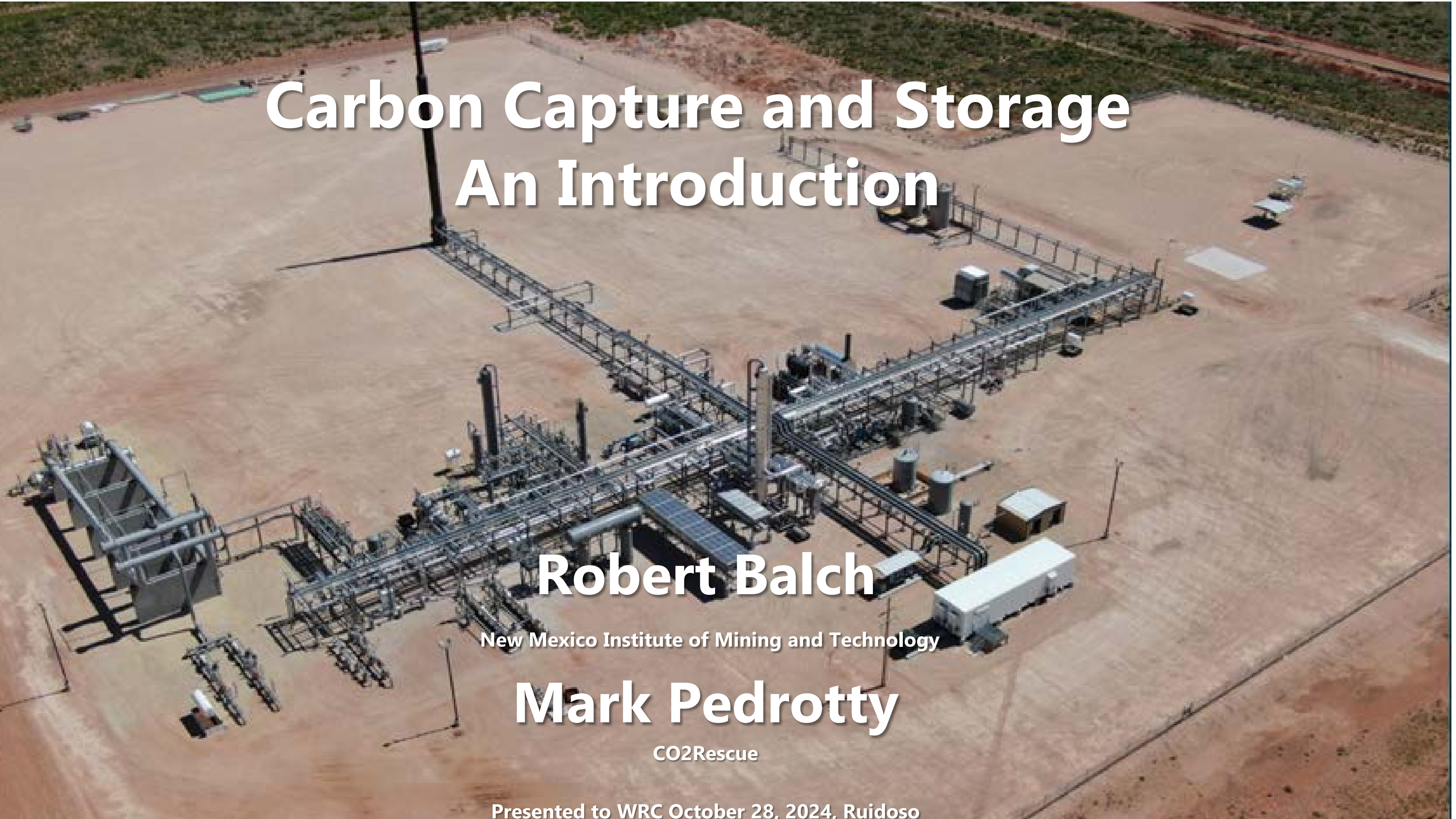

Carbon Capture and Storage
An Introduction

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CO2Rescue

Presented to WRC October 28, 2024, Ruidoso

Why CCS (and DAC)

Why CCS/DAC?: Challenges for Decarbonization

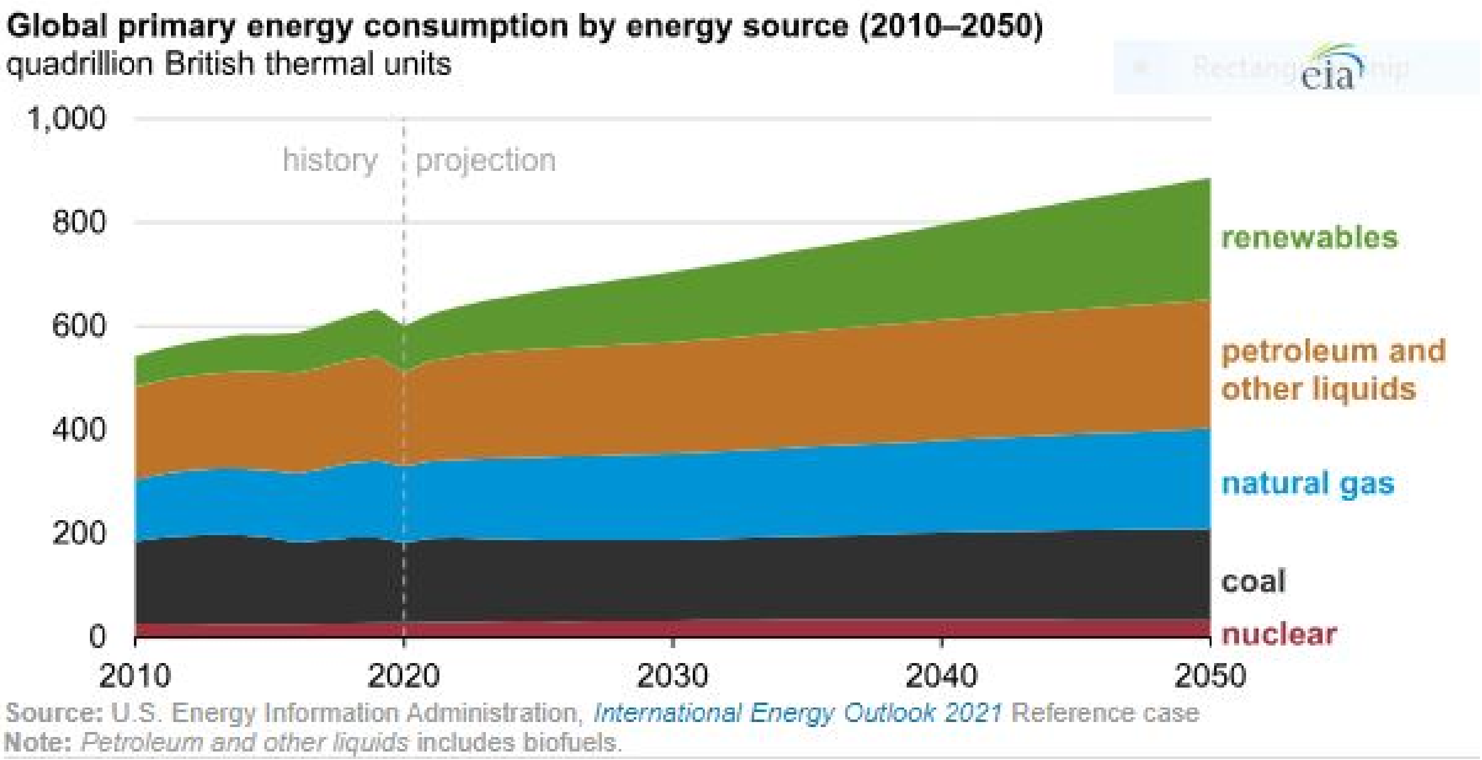
Four major categories provide significant challenges to reaching climate coals on a global scale:

1. Energy Demand vs. Supply
2. Critical Building Materials
3. Strategic Minerals
4. Geopolitics

And two other categories requiring DAC also needs to be addressed

5. Unmitigated future emissions from the developing world
6. Legacy Emissions – more than 1 trillion tonnes since 1750

1. Global Energy Mix in 2050



- Renewables are the fastest growing category (45%)
- However, world energy demand is expected to grow by 50% in the same time period.
- Renewables are displacing, in part, new hydrocarbon demands, but all energy sources are increasing by 2050

2. Critical Building Materials

- Work is being done on reducing emissions from these sources, but many of these solutions are in the realm of **Science**, not **Engineering**

- **Concrete, Steel, Glass**

- These are difficult materials to replace and are also essential for renewables
  - Wind Tower materials include (NREL):
    - 71-95% steel and Iron by mass (150 metric tonnes)
    - 11-16% fiberglass resin or plastic by mass (950 barrels of oil)
    - Concrete (400 m^3)
    - Copper for turbines (1% by mass)
    - Does not consider fuel for trucking and manufacturing

* US National Renewable Energy Lab

Likely need to mitigate rather than eliminate most of these emissions

3. Strategic Minerals

- Materials needed for generators, catalysts (hydrogen), and batteries to build and store energy from renewables
- Minerals used include (futures prices):
  - **Copper** ($1.95 per lb in 2016, $4.03 per lb in 2023 **2X**)
  - **Cobalt** ($13,486 per ton in 2016, $51,826 per ton in 2023 **4X**)
  - **Nickel** ($6,201 per ton in 2016, $20,539 per ton in 2023 **3X**)
  - **Rare Earths** (varies but typically has gone up **3-4X**)
  - **Lithium Carbonate** ($137,980 per tonne in 2017, $493,028 in 2023 **3.5X**)
  - **Silver** ($13.5 per oz in 2016, $24.279 per oz in 2023 **2X**)

– 2022 spike was over $80k/tonne

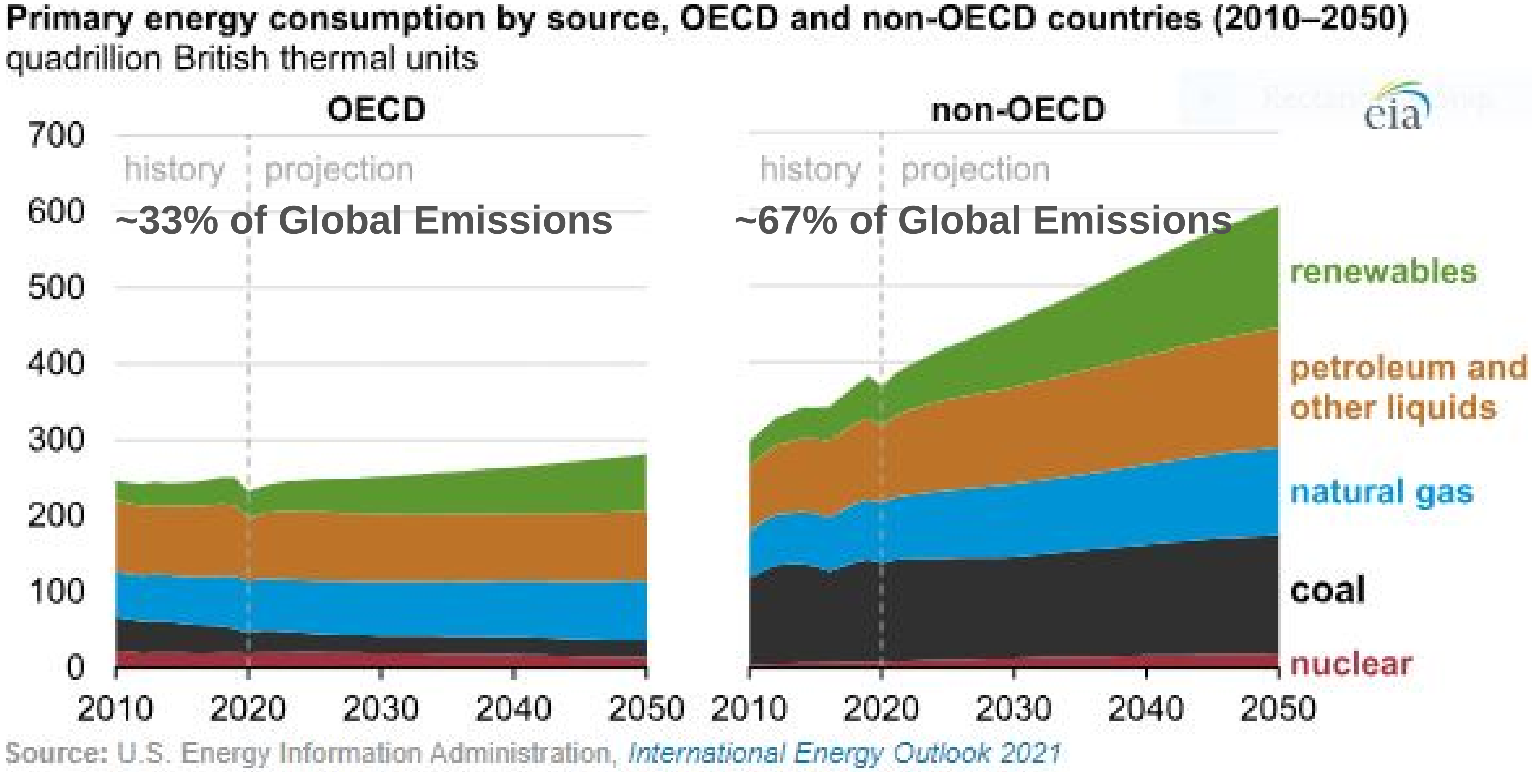
– 2022 spike was over 48k/tonne

- Batteries need vast quantities of materials
  - To electrify all 3 billion estimated vehicles in the world in 2050
    - Would require **all** of the proven reserves of lithium on the planet
    - Leaves nothing for grid scale batteries
    - Or your Smart Phone…

*Tradingeconomics.com

Primarily mined in non-OECD countries relatively scarce and underproduced compared to demand

4. Geopolitics Plays a Large Role…
5. Unmitigated Future Emissions



OECD Countries: Primarily Europe, North America, Far East Asia are expected to slightly reduce Hydrocarbon use by 2050, and have modest growth in demand covered by renewables

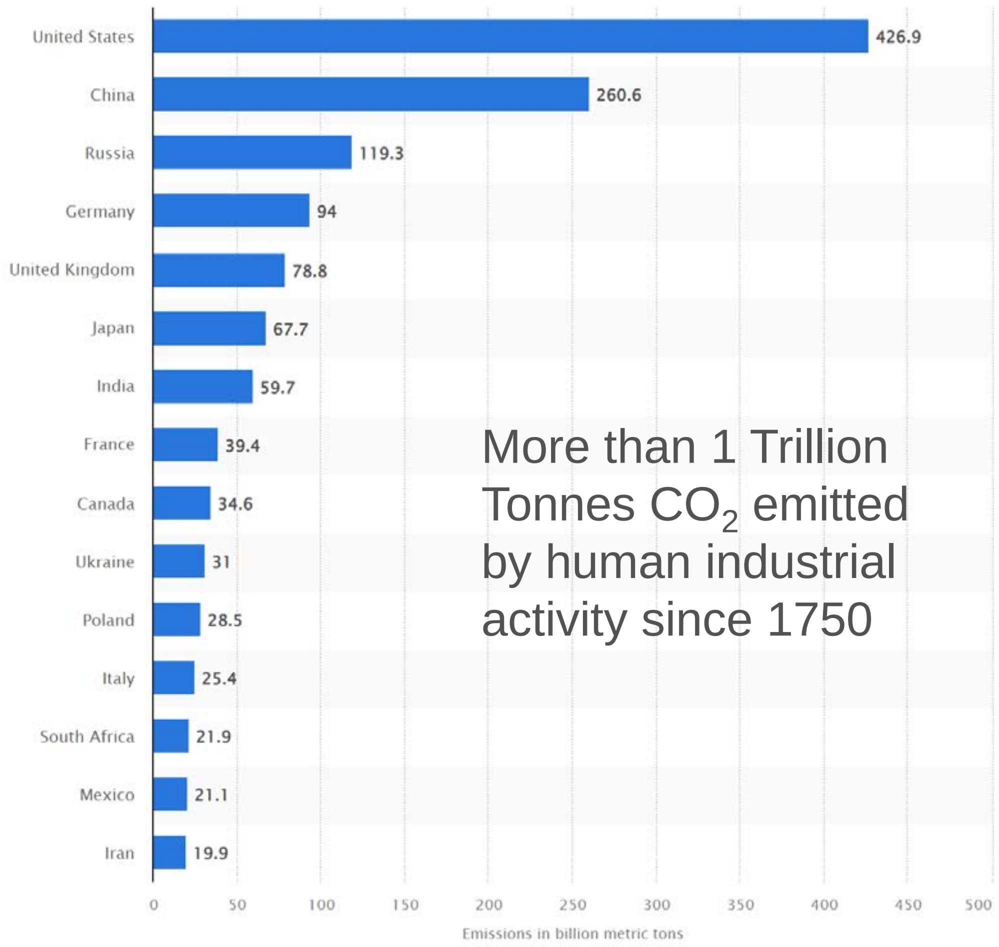
Non-OECD Countries: See rapid growth in every energy category, leading to a net increase in hydrocarbon use world-wide in 2050

6. Legacy Emissions

The problem is not just current emissions…

While China and ultimately India will surpass US total emissions, at present OECD Countries represent over 75% of all the CO_2 that has been emitted by human activities since the beginning of the industrial revolution (1750 to present)

CO_2 molecules resides in the atmosphere for an average of 990 years



More than 1 Trillion Tonnes CO_2 emitted by human industrial activity since 1750

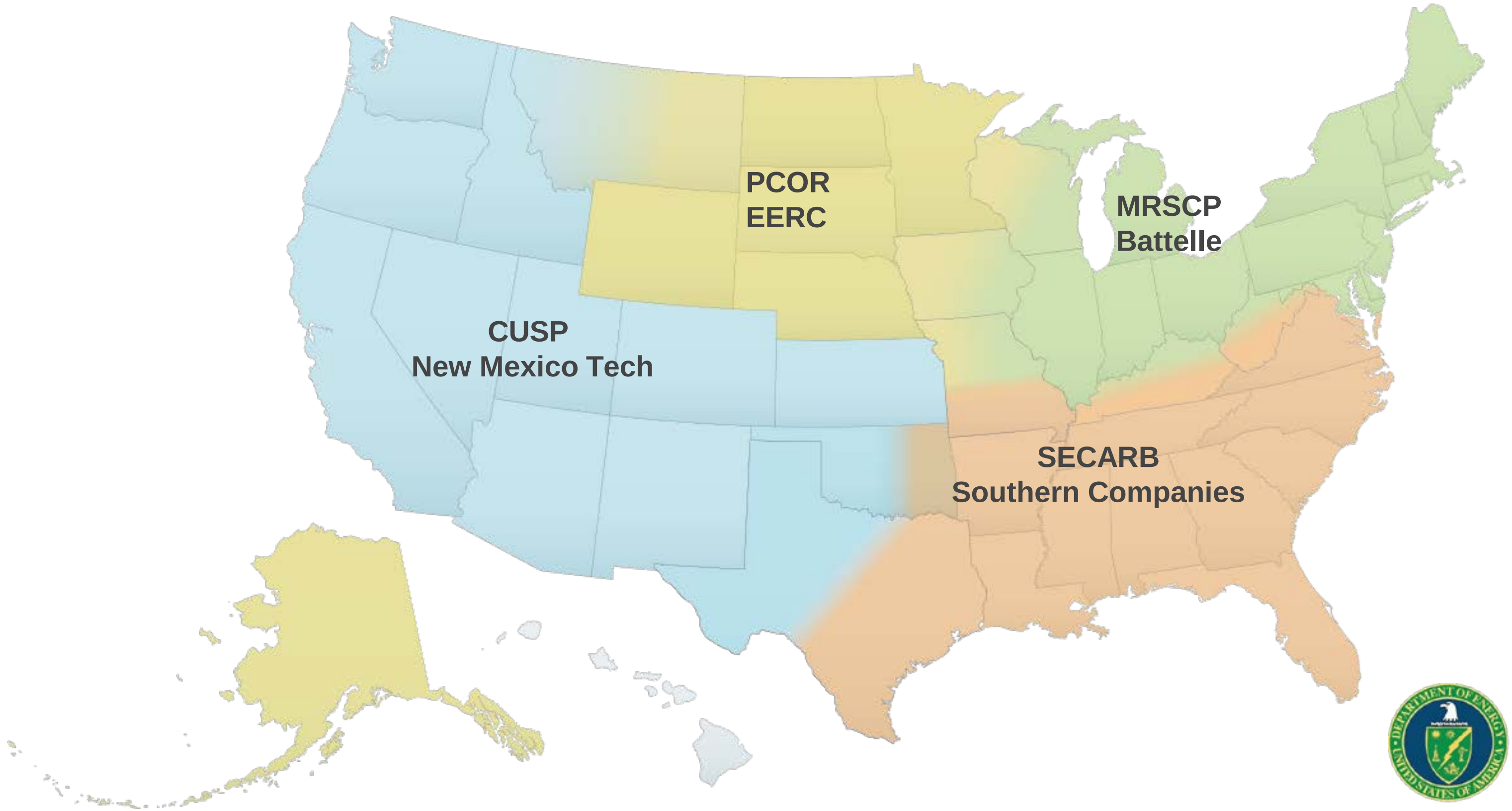
How Do We Effectively Reduce Atmospheric Carbon?

Simply stated this is an immense challenge

- **Hydrocarbon Energy:** Is pervasive and impacts every aspect of modern life
  - Coal-fired power (~30% of world CO_2 emissions)
  - Natural gas (~22%)
  - Vehicle Fuel (~9%)
- **Critical Building Materials:** Drive economic development
  - Cement (~8% world emissions)
  - Steel (~9%)
  - Glass (~2.5%)
- **Strategic Minerals are Scarce:** Relative to new demands we lack sufficient supplies to meet demand for renewables, *renewable power storage*, and 0 emissions vehicles

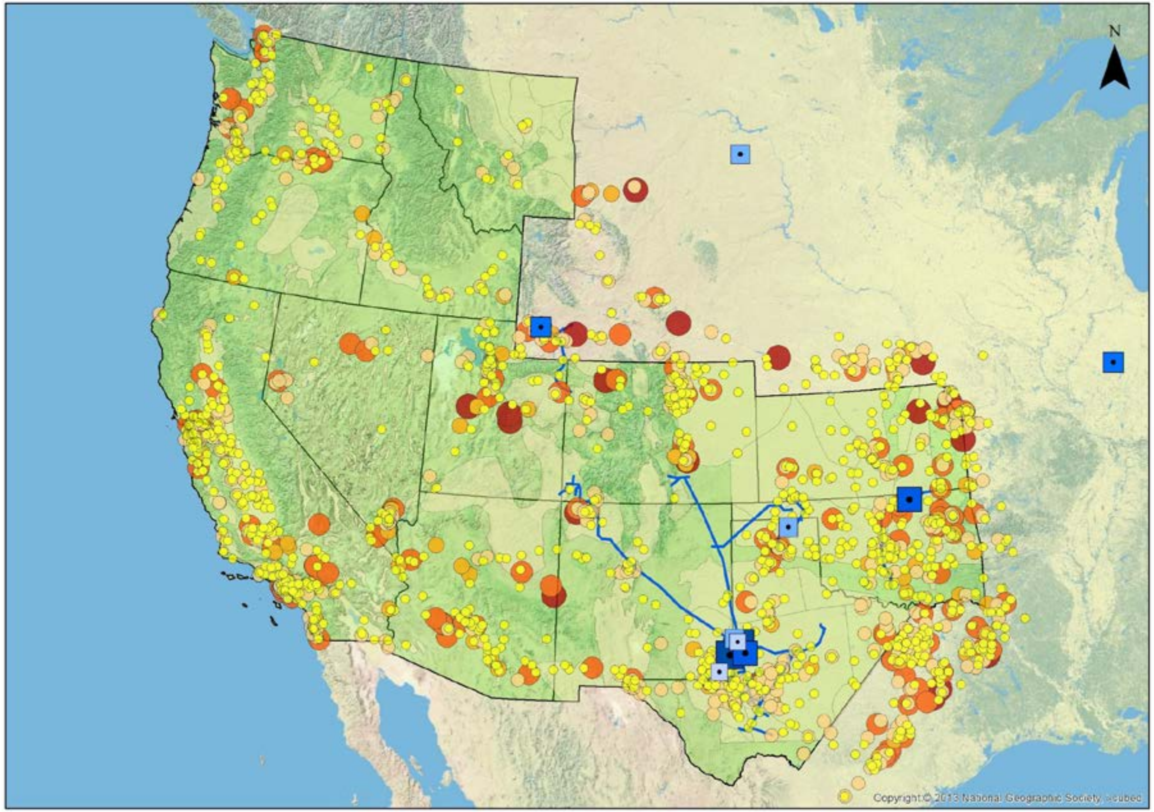
- **In the next two decades we need to mitigate (store) emissions while new technologies catch up both technology and infrastructure**
- **CCS/CCUS needed at scale of 6-8 Gt/year… Starting last year**
- **Also need to manage legacy CO_2 that has already been emitted (Direct Air Capture)**

Department of Energy Regional Initiatives to Accelerate CCUS Deployment (2019)



CUSP – Sources, Sinks and Transport

CO_2 emitted and sequestered (EPA GHGRP)



Legend

CO2 Sequestration GHGRP

EPA GHGRP Total CO2 sequestered (MMTCO2)

- 0.0 - 0.025
- 0.025 - 0.1
- 0.1 - 0.5
- 0.5 - 1.0
- 1.0 - 3.0

EPA GHGRP 2022

Total reported direct emissions (MMTCO2e)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 5
- 5 - 14

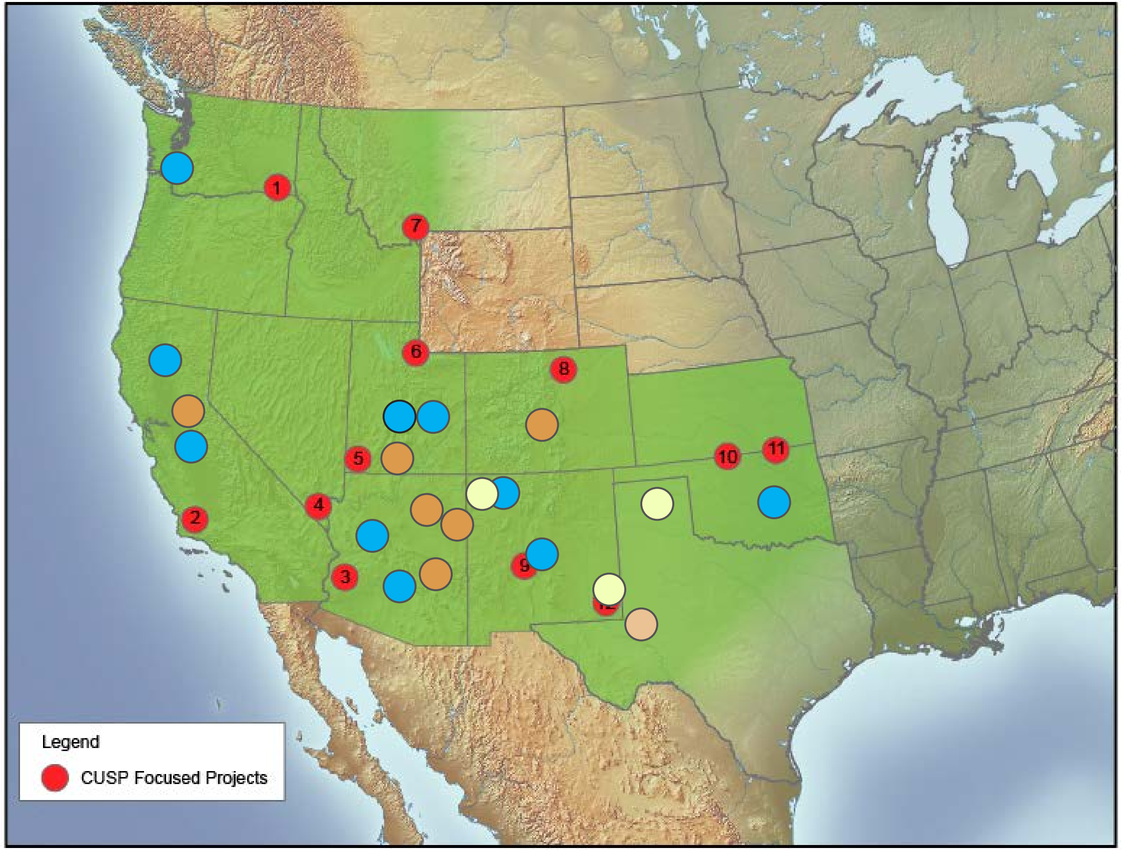
CO2 Pipeline (approx.)

CUSP

Adapted from
CCUS Map
EPA GHGRP

NATIONAL ENERGY TECHNOLOGY LABORATORY

CUSP 2024 Regional Footprint



Current footprint of CUSP related projects

- 2020 – 3 Projects CUSP funded
- 2021 – 12 Projects CUSP funded
- 2022-2023 – Associated projects Funded
- 2023 – Associated projects pending

- Includes development of five regional Storage Hubs
- **For a total of 39 CUSP related projects and 4 additional projects in contracting**

NATIONAL ENERGY TECHNOLOGY LABORATORY

So What does CCS Look Like?

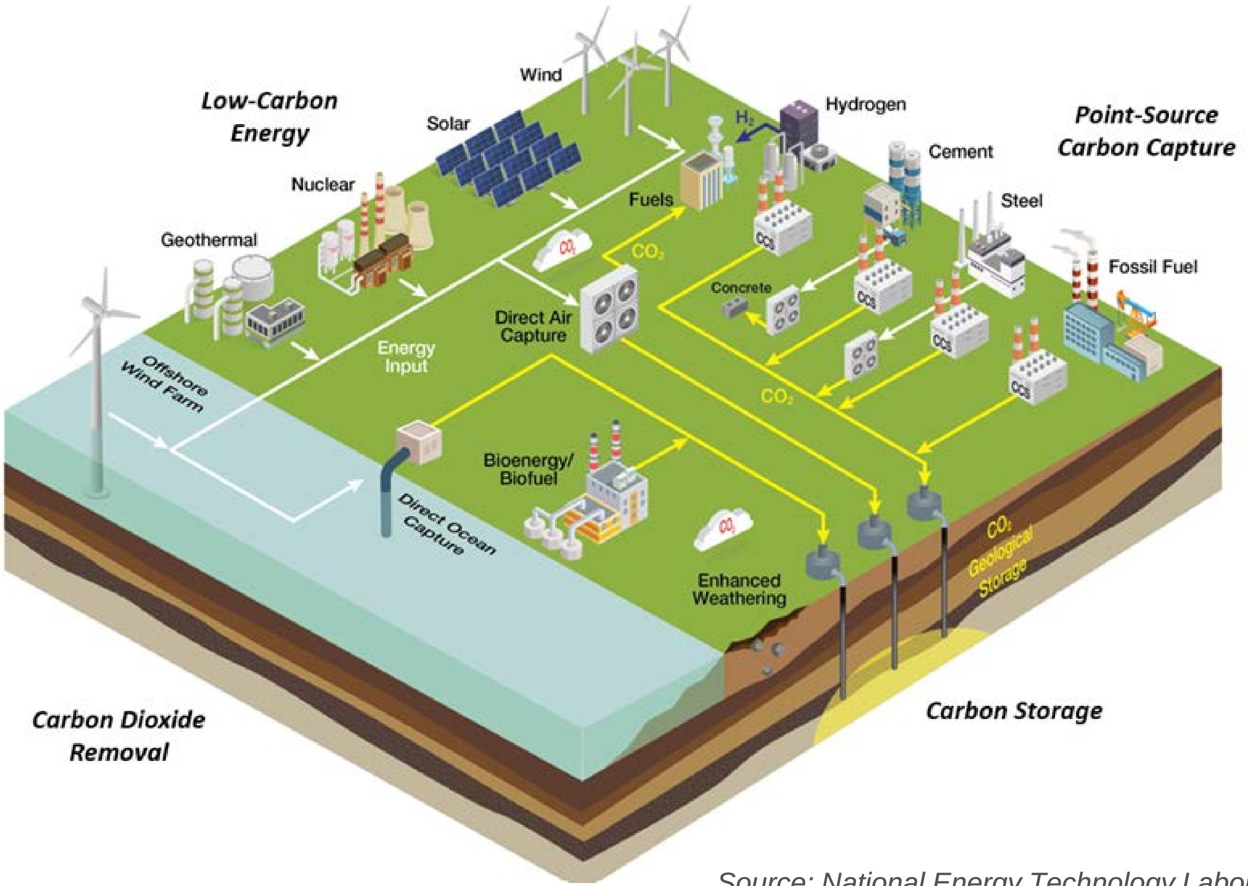
Carbon Capture – Industrial, Energy, DAC Sources

Point Sources

- Fossil Fuel Power Plants
- Refineries
- Cement & Steel Plants
- Hydrogen Production
- Ethanol

Capture Mechanisms

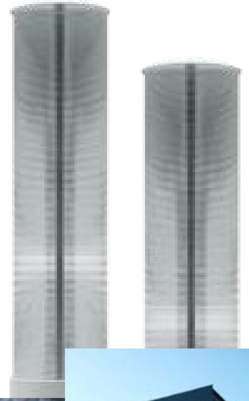
- Pre combustion
- Post combustion
- Direct Air Capture (DAC)



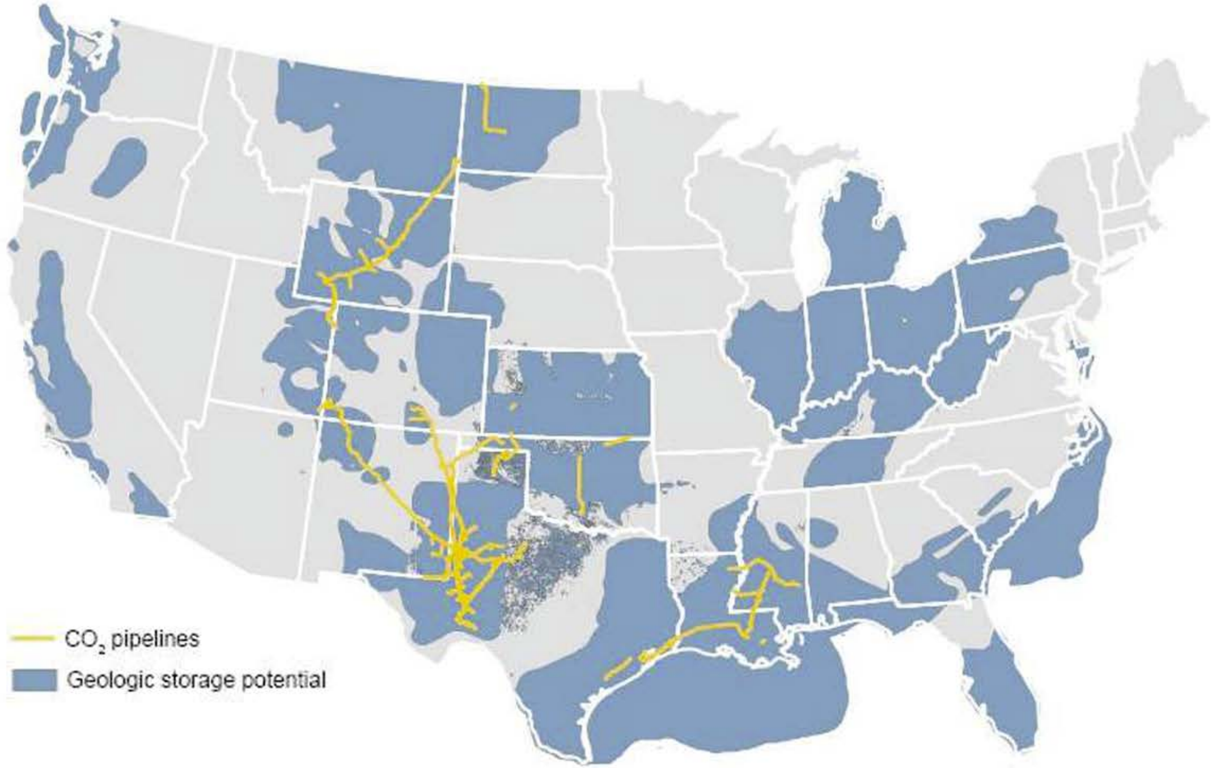
Source: National Energy Technology Laboratory

Carbon Capture: Carbon Dioxide Removal (CDR) aka Direct Air Capture (DAC)

- Essential piece of the plan to limit global warming
- Removes CO_2 from the atmosphere
- Several different technologies available: liquid solvent, solid sorbent, passive vs active, bipolar membrane electrodialysis, mineralization, weatherization, biochar, etc
- Several companies are at commercialization level: Climeworks, Carbon Capture, Heirloom, 1pointfive, many others

CO_2 Transport



- Current CO_2 pipeline infrastructure transports over 66 million metric tons of CO_2 per year – Great Plains Institute

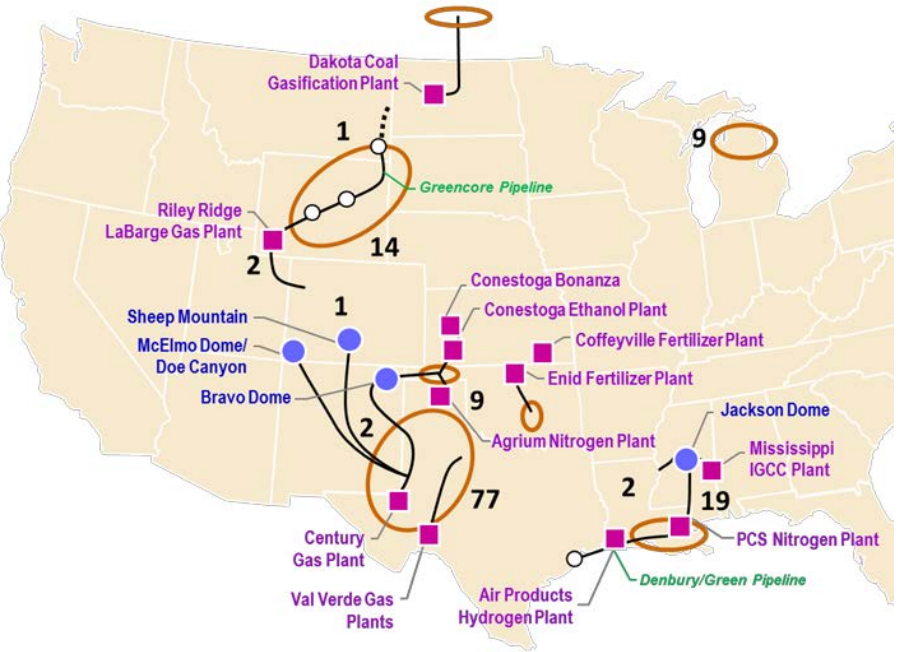
- New Mexico is one of the most highly connected states for the transportation of CO_2.

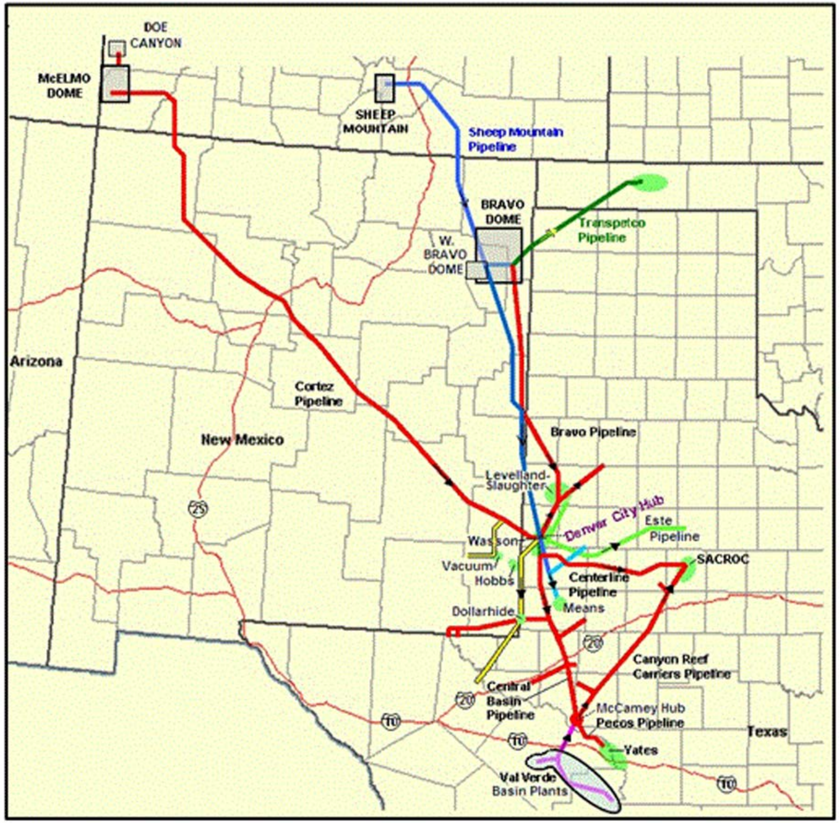
- Geologic storage potential in the state is estimated at over 26 Billion tonnes.

Sources: Bauer et al., "NATCARB."; Pipeline and Hazardous Materials Safety Administration, "Active CO_2 Pipelines in the NPMS."

Transport

U.S. CO_2 transport

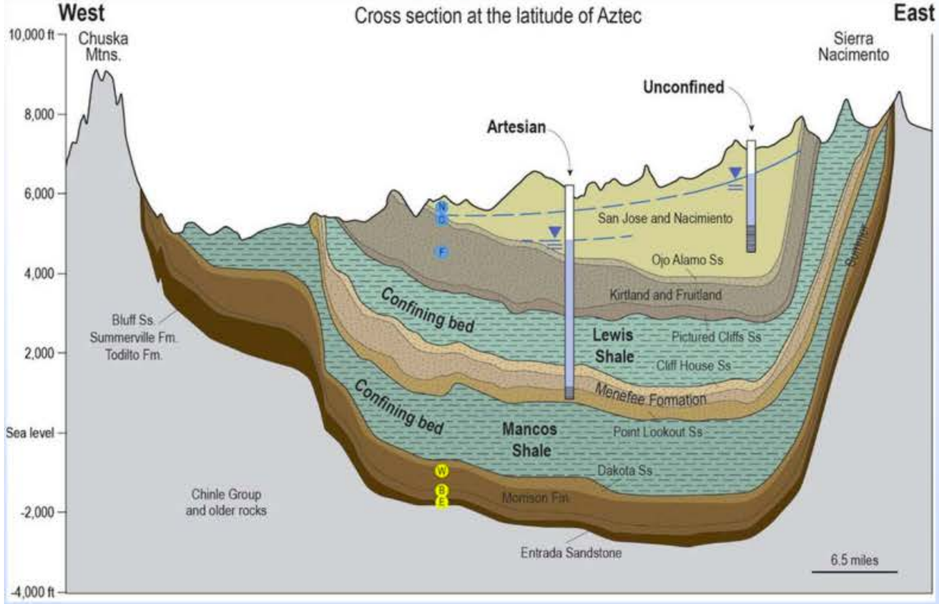




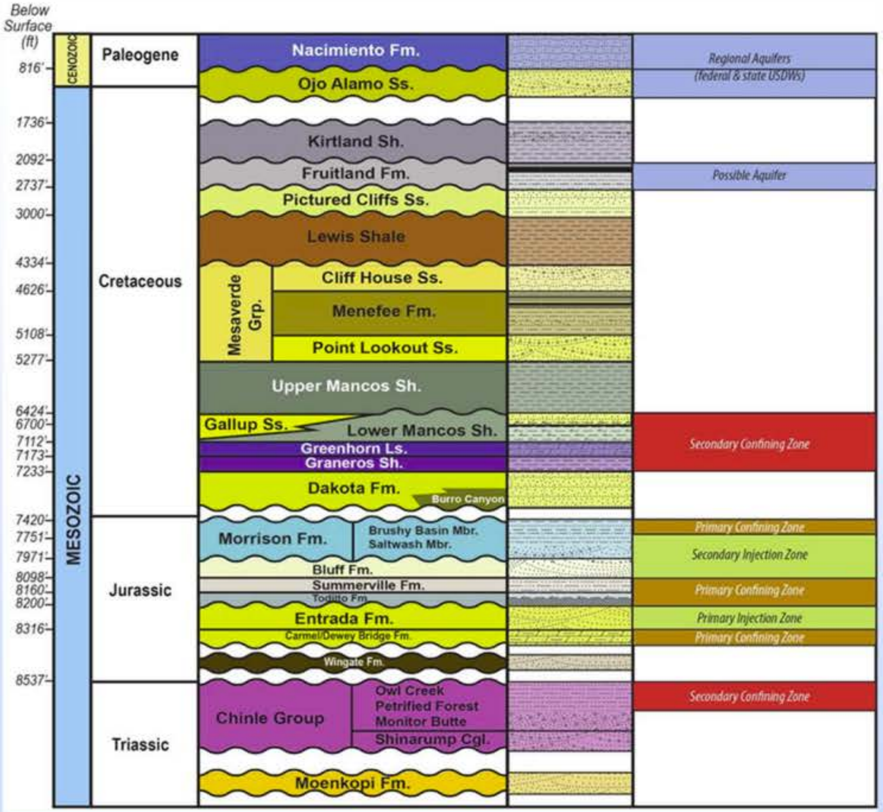
Once captured, CO_2 is compressed from a gas to a liquid or supercritical fluid and transported via pipeline

DOE/NETL-2014/1681 - A Review of the CO_2 Pipeline Infrastructure in the U.S.

San Juan Basin Geology - Example of Deep Storage

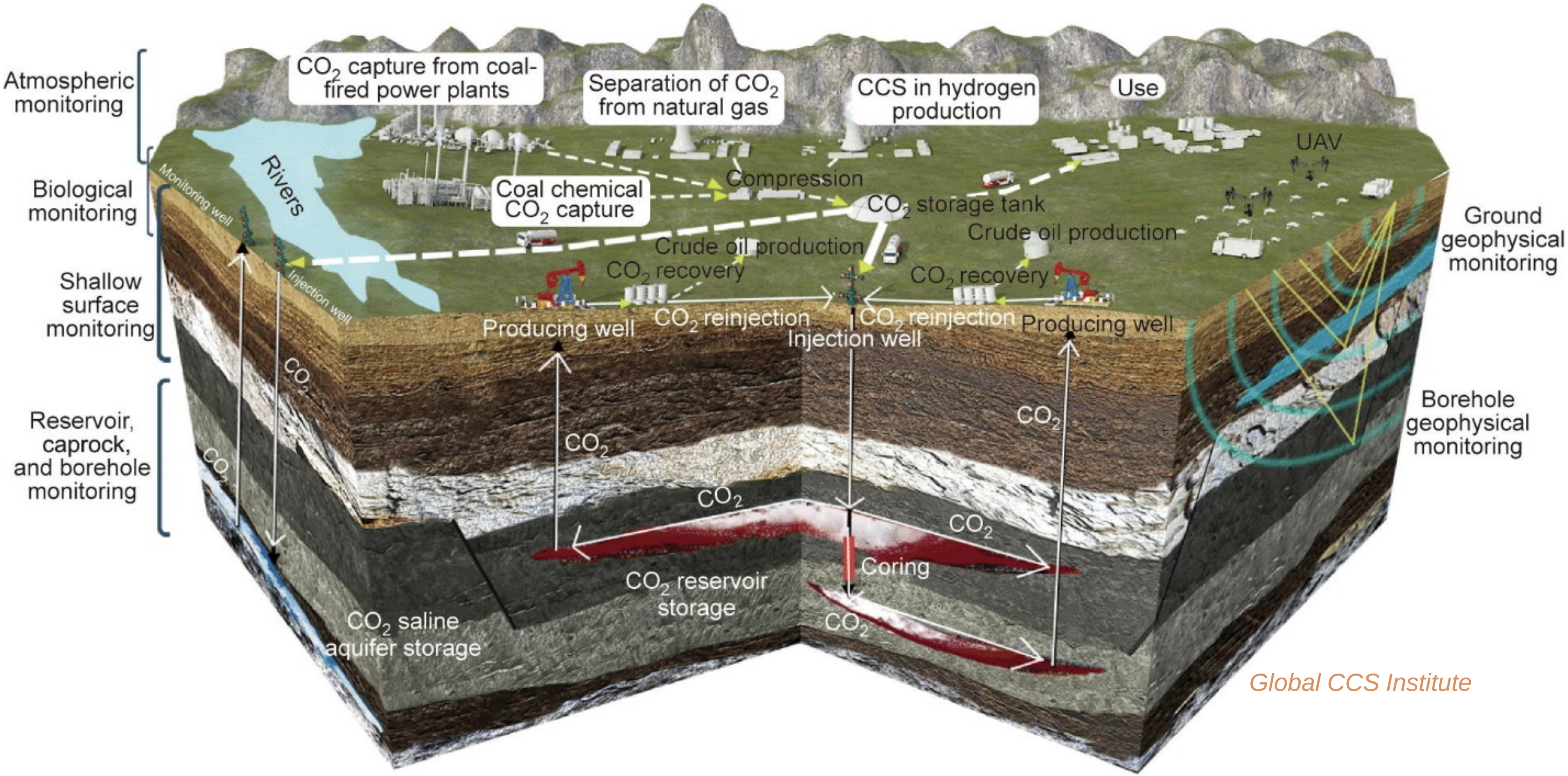


Schematic cross section of the San Juan Basin illustrating confining beds (blue units) and sandstone strata (brown, tan, and gray units).



Stratigraphic column for San Juan Basin

Storage: Robust Protections and Monitoring



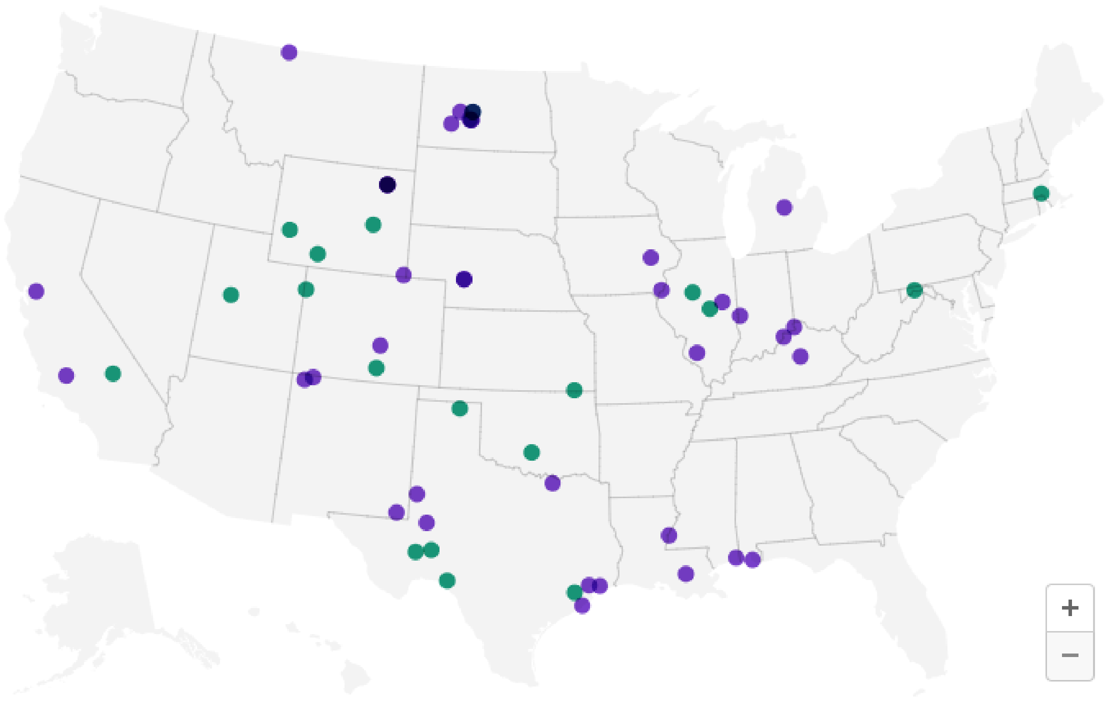
Global CCS Institute

State of CCUS Development

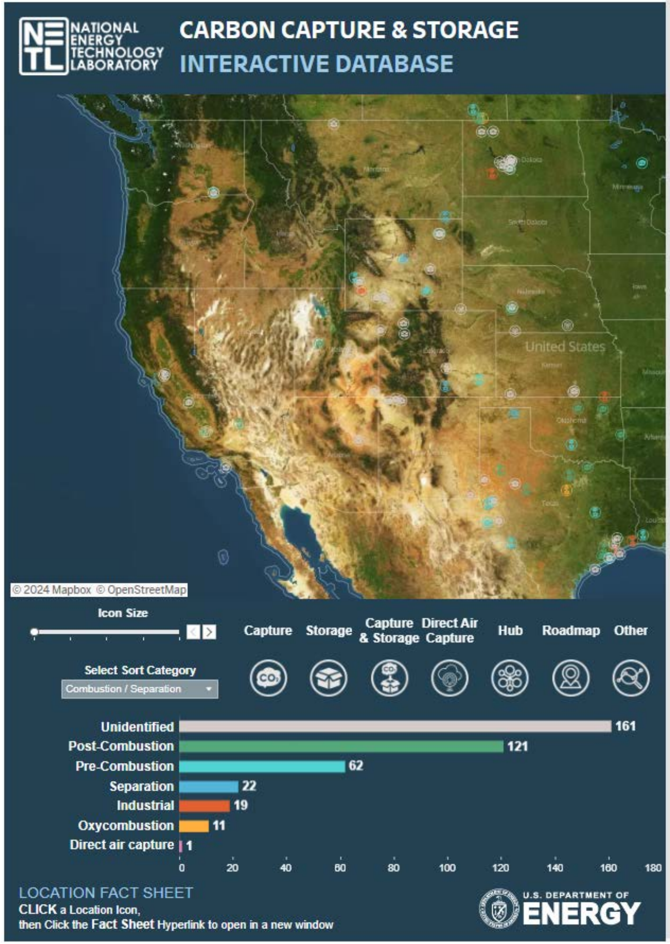
19 of the 58 carbon capture projects in the US are operational.

Active carbon capture and storage projects, identified by the Energy Department as of January 2023

Operational · In planning/development · Unknown



Source: National Energy Technology Laboratory CCS Database • Get the data • Download image • Download SVG



Currently 86 operational carbon capture projects globally

What is Needed for CCS and DAC in New Mexico?

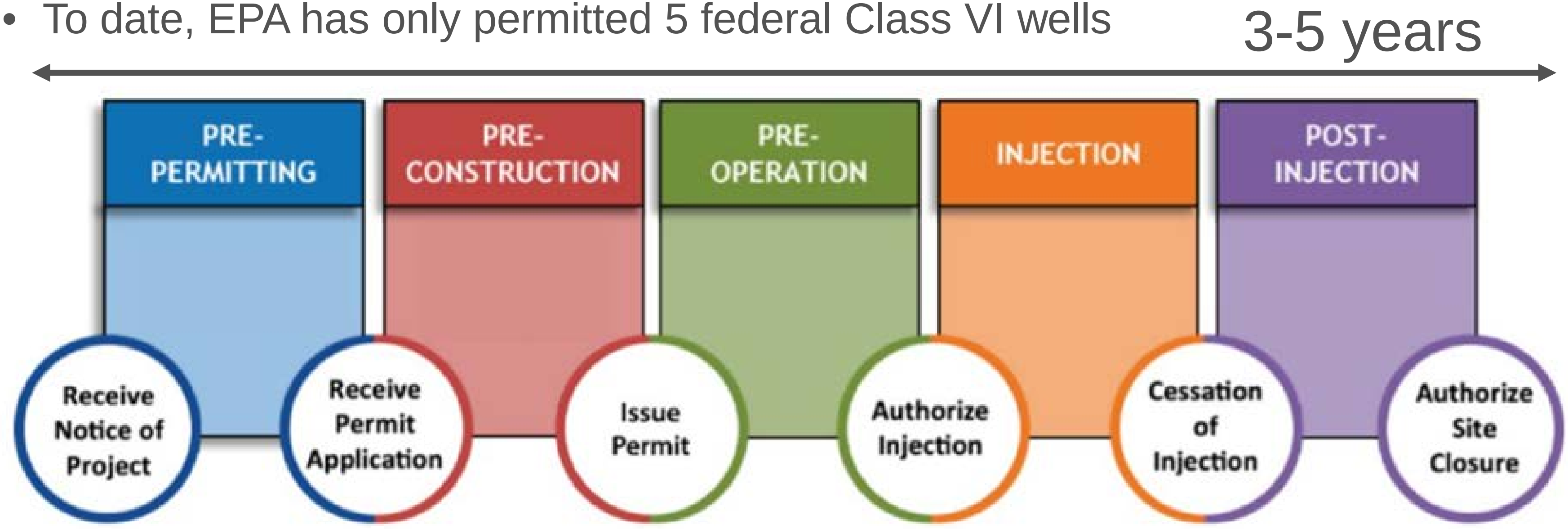
Economics and Industry Participation

- **Penalties (Stick)**
  - ~10 gigatons of CO_2/year needs to be removed to limit global warming to a maximum of 1.5°C by 2050.
  - IPCC, World Resources Institute, 2002; Philander, 2012; Ozkan, 2021; IEA, 2022; Zeeshan, 2023.
  - OECD Countries interested in carbon reduction usually apply penalties to emissions
- **Economics (Carrot) – US Only**
  - 45Q : $60 - $180 per ton of CO_2 stored
  - 12 years of tax credits – can pay for infrastructure
  - Creates jobs in new industry
  - Repurposes existing oil and gas workforce
  - Sticks will come to the US in the future

Pngegg.com

Permitting

- EPA currently has jurisdiction over Class VI wells (except in WY, ND, and LA)
- Timeline is 3-4 years to grant permit for 1 well
- To date, EPA has only permitted 5 federal Class VI wells

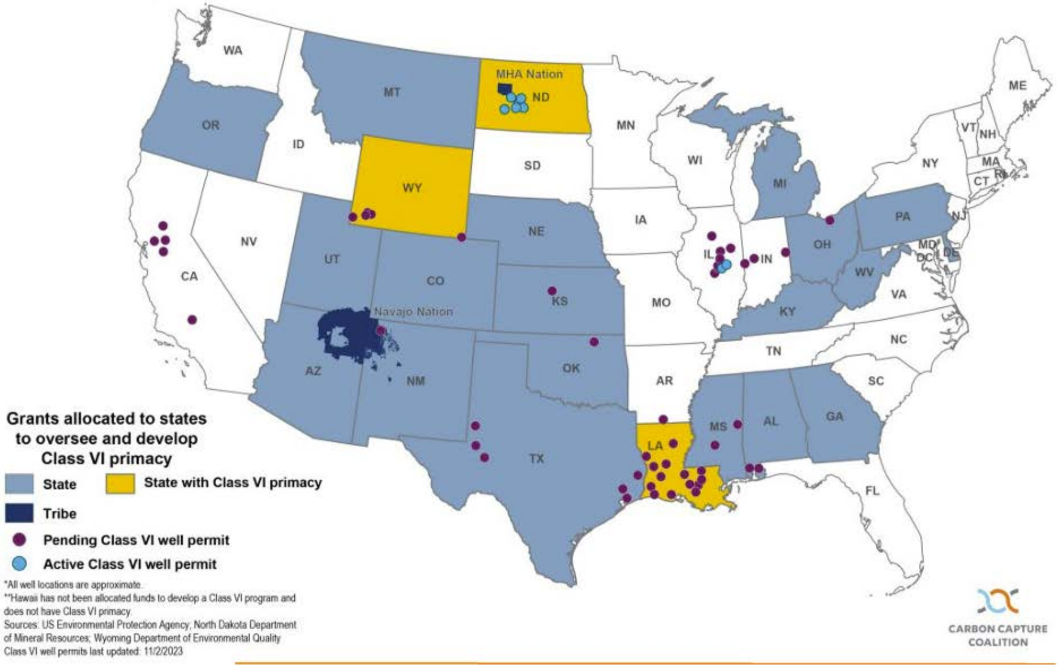


- Class VI Primacy – For a state or a Tribe to gain Class VI Primacy, **Proposed rules must meet or exceed EPA UIC standards**

Regulatory and Legislative Considerations

Primacy (Under way at NMERD)

- **Pore Space**
  - Ownership
  - Unitization
  - Plume migration
- **Liabilities and penalties**
  - Long term stewardship
  - Liability transfer and bonding
  - Induced seismicity
- **Rights of way and transport**
- **Fees and Administrative Costs**
- **Public Interest Policies**
  - Fair labor practices
  - Environmental justice
  - Project selection criteria



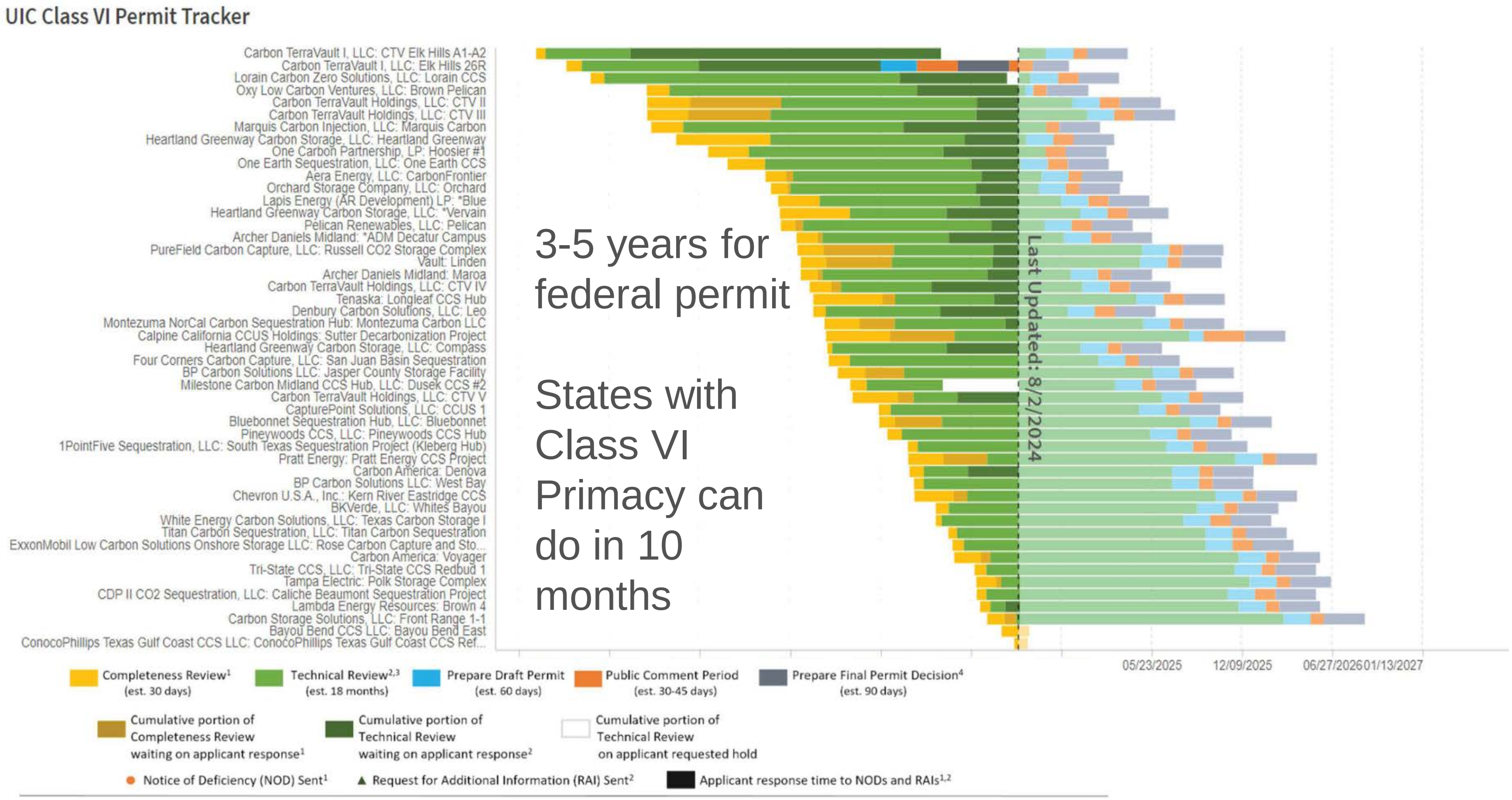
34 States or Tribes with EPA grants to seek primacy
Other states like California are also pursuing

Summary

1. Preventing the emission of CO_2 from the use of fossil fuels through direct carbon capture with storage (CCS) is essential to meeting climate goals
2. Removing the excess CO_2 in the atmosphere (CO2ppm) using carbon dioxide removal (CDR, such as direct-air-capture, mineralization, biochar, etc.) to prevent exceeding 1.5C warming and then reducing CO_2 to more reasonable levels can address legacy emissions and unmitigated future emissions
3. NM has ample resources to safely store CO_2 underground in the San Juan and Permian Basins.
4. CCS and CDR are billion dollar industries that have the potential to be trillion dollar industries by 2100.
5. Other states are investing in CCS and CDR.
6. CCS is already being implemented in NM (through Acid Gas Disposal and EOR)
7. Numerous projects underway for pure storage including Escalante, Federal Storage Hubs and DAC hubs
8. Community involvement is an essential part of the Class VI well permitting and selection of the appropriate technology to remove CO_2 at the source or from the atmosphere.

Supplemental Slides

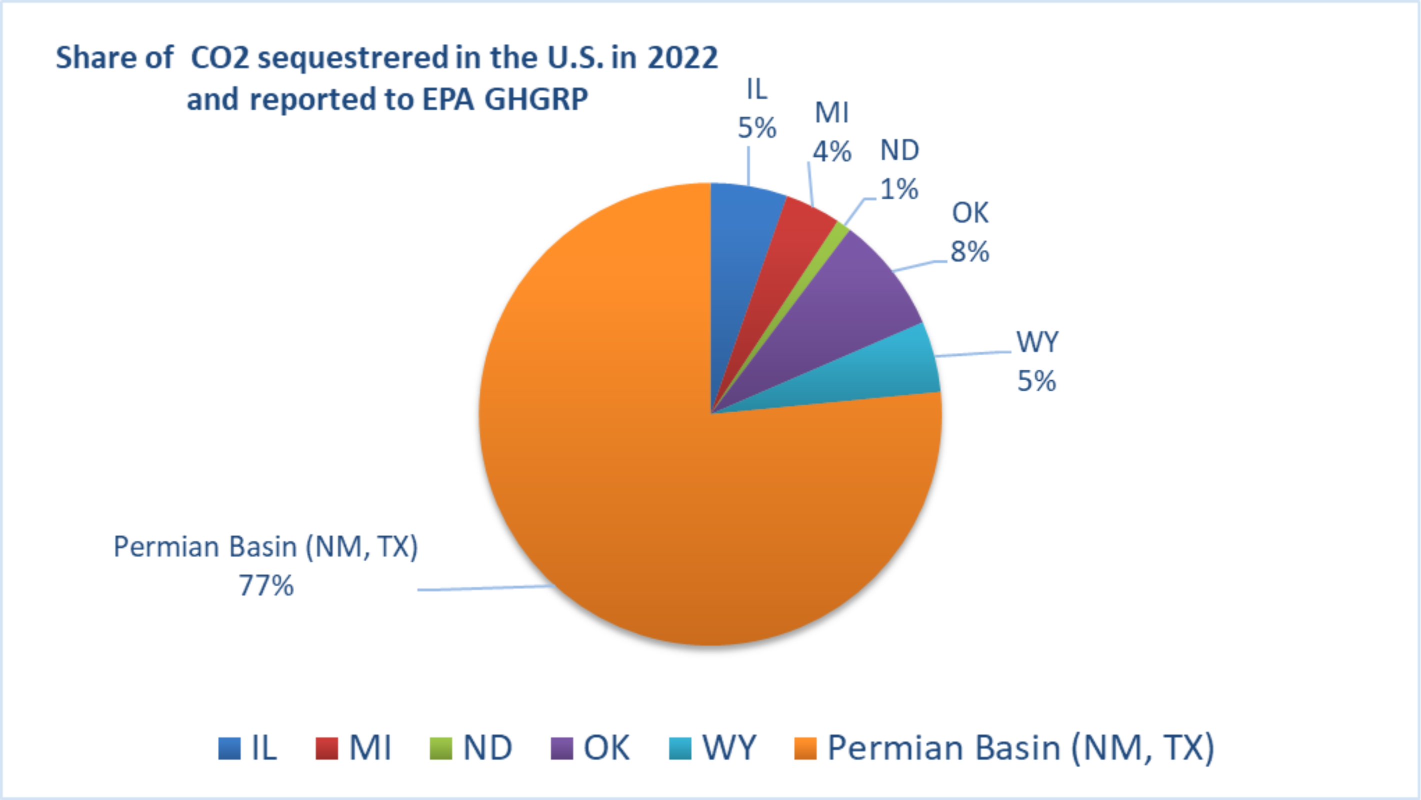
Permitting: EPA Class VI Permit Tracker



3-5 years for federal permit

States with Class VI Primacy can do in 10 months

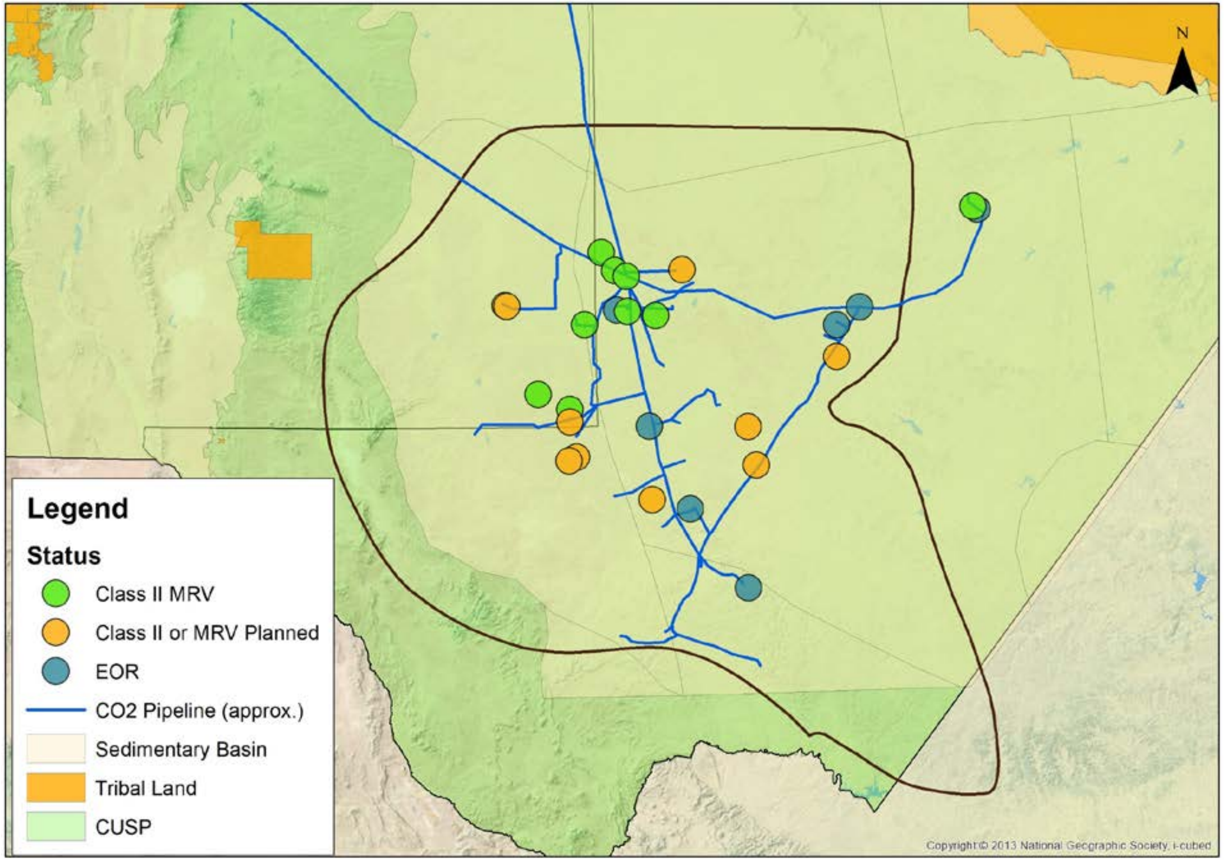
Where is CO2 Sequestered Today?



As of 8/18/2023, **76%** of the CO_2 sequestered in the US is in the Permian basin

Source: EPA GHGRP

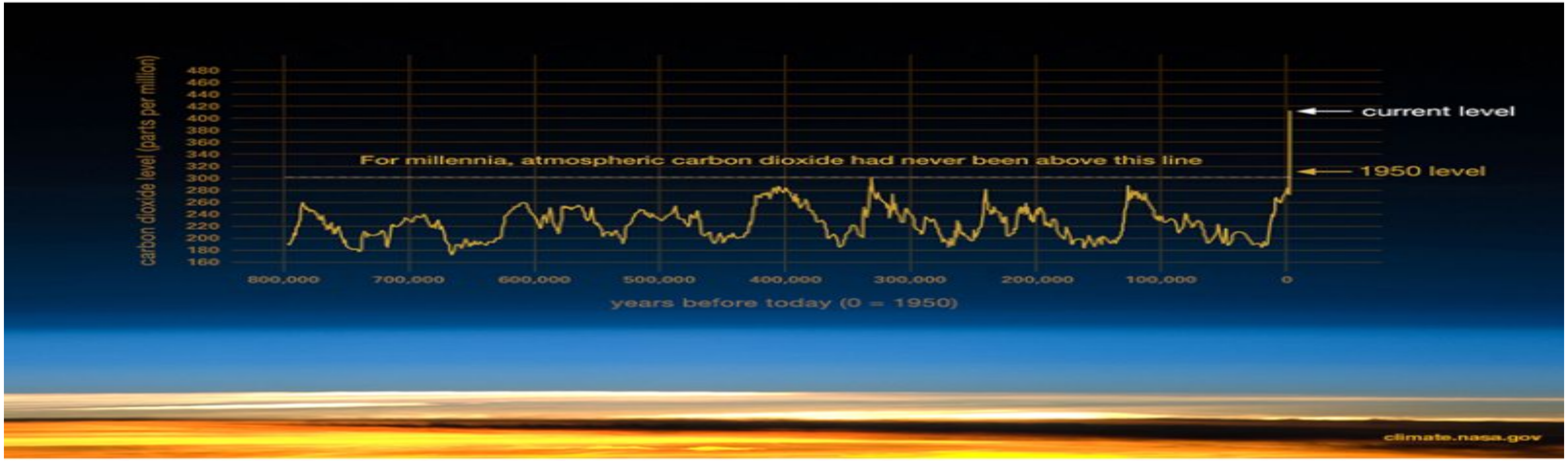
The majority through Class II wells in the Permian



- **EOR**
- **Class II or MRV planned**
- **Active Class II with MRV (45Q)**

CO_2 Emissions From Human Activity is Changing Our Atmosphere

- Carbon dioxide (CO_2) levels have never exceeded 300 parts per million (ppm) over the past 800,000 years. CO_2 levels stayed withing the range of 170 to 300 ppm (https://earth.org/data_visualization/a-brief-history-of-co2/)
- The rapid rise of CO_2 ppm to more than 400 ppm over the last 200 years is significant.
- Pre-industrial CO_2 levels were around 280 ppm and now they are at 422 ppm.



IPCC Working on Strategic Plans to Limit Global Warming

- According to the Intergovernmental Panel on Climate Change (IPCC) AR6 Summary for Policy Makers (https://www.ipcc.ch/sr15/chapter/spm/) there are four possible pathways to net zero by 2050 to limit global warming to 1.5C, including with a slight overshoot.
- Note CDR (including the use of DAC) and the capping of fossil fuel power plants and capturing of CO_2 in other sectors using CCS are essential parts of the overall plan. See IEA for estimated amounts of CCS and CDR needed by 2030 and 2050 to not exceed 1.5C warming. See Global emissions pathway characteristics below. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SPM3b-724x1024.png.

CO_2 Capture from Existing Sources and Removal by DAC with Sequestration are Essential

- According to the United States Geological Survey (USGS) 2013 report on the technically accessible storage capacity for CO_2 the:
- San Juan basin is estimated to have a technically accessible storage capacity for CO_2 of 740 million tons (mean value)
- Permian basin is estimated to have a technically accessible storage capacity for CO_2 of 59 gigatons (mean value).
- 60 gigatons of technically accessible storage capacity for CO_2 is 0.02 of the total capacity of 3 metric teratons in the US.
- See the USGS Carbon Dioxide Storage Resources Assessment Team. https://pubs.usgs.gov/fs/2013/3020/pdf/FS2013-3020.pdf