# Carbon Capture, Utilization and Storage

Brian J. McPherson

*September 21, 2022*

EGI Energy & Geoscience Institute AT THE UNIVERSITY OF UTAH

THE UNIVERSITY OF UTAH

## Acknowledgements:

Utah Science, Technology and Research (USTAR) Initiative
U.S. Department of Energy
National Energy Technology Laboratory


DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

NATIONAL ENERGY TECHNOLOGY LABORATORY

EGI Energy & Geoscience Institute AT THE UNIVERSITY OF UTAH

THE UNIVERSITY OF UTAH

Acknowledgements:

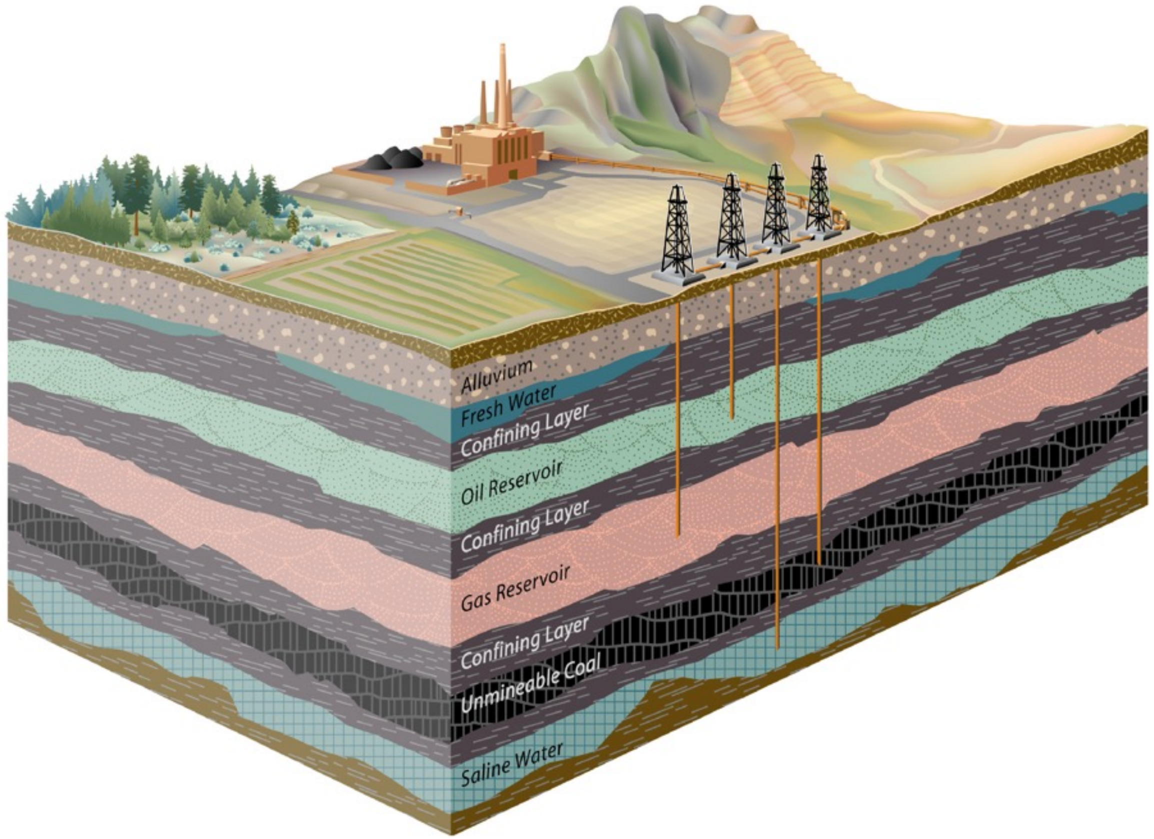
$CO_2$ Scholars at the University of Utah!

Energy & Geoscience Institute
AT THE UNIVERSITY OF UTAH

# Motivation: Energy and Climate

- **Carbon neutral energy: How fast can we get there?**
- Manage societal impact
- Technology impact
- Assure stability of the transition
- Adapt to a changing environment
- Manage unavoidable damages

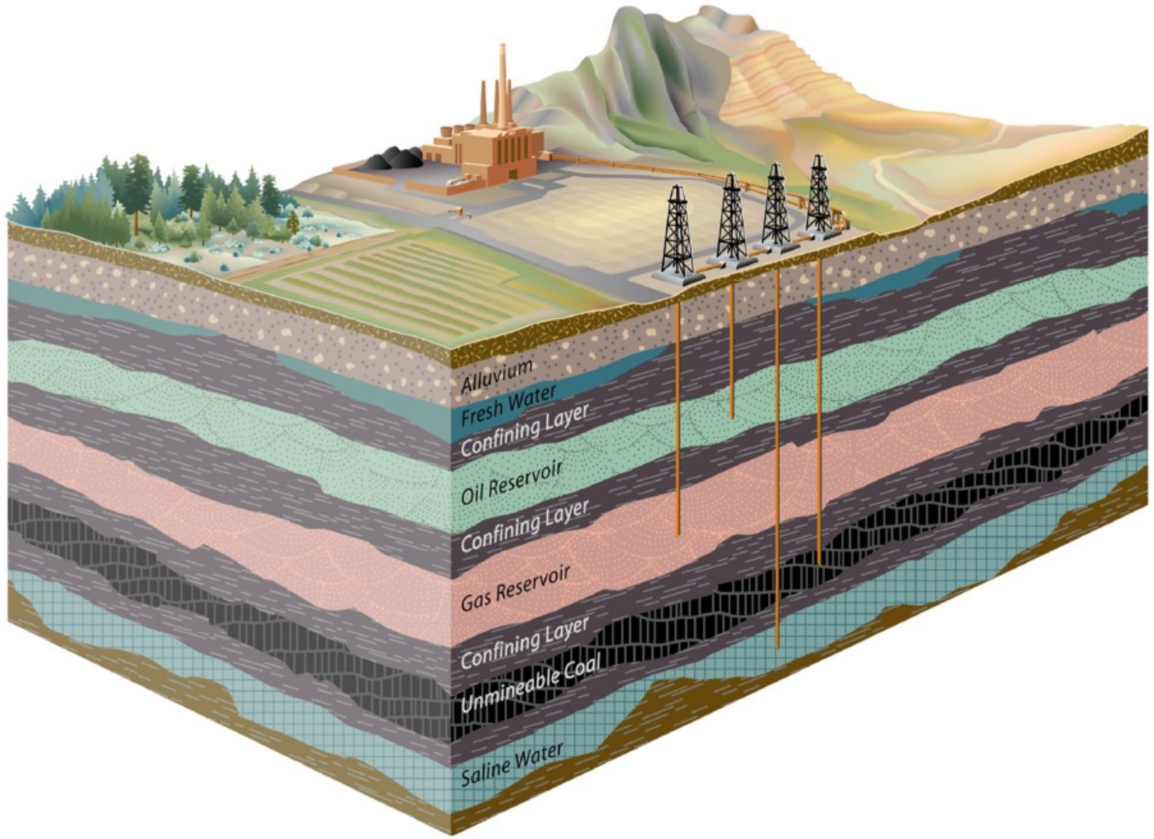
# EGI's approach targets translating national goals to local/regional goals, needs, & expectations.




**National Goal:** Rapid transition to carbon neutral energy economies

**Local Goals/Needs:?**

# Targeting transitional energy (carbon-neutral, but still fossil-fuel-based) is a strategy to accelerate deployment of new technologies.




**National Goal:** Rapid transition to carbon neutral energy economies

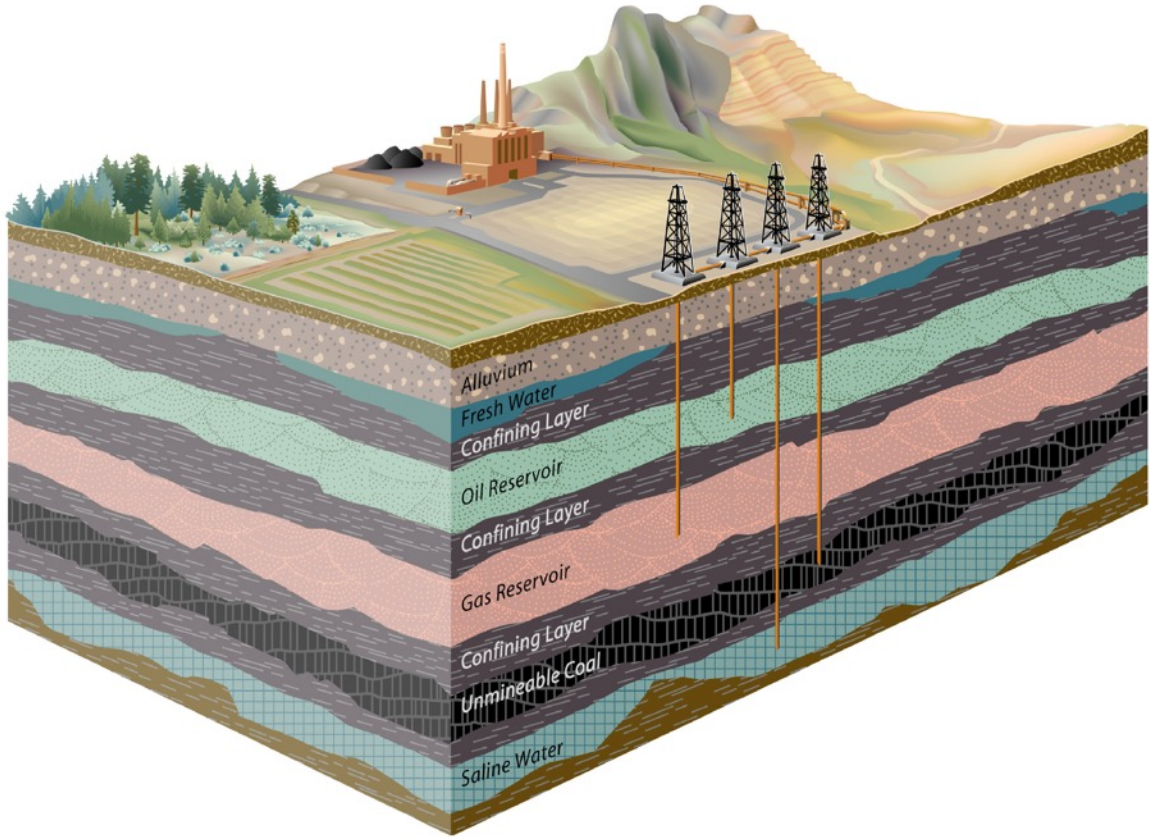
**Local Goals/Needs:?**

**Why $CO_2$?** Capturing $CO_2$ is essential for decades even with rapid deployment of renewables.

**Why highlight symbiosis?** Energy systems are interdependent. Exploiting the symbiosis accelerates deployment.

THE UNIVERSITY OF UTAH™

# Any regional strategy must identify near-term opportunities that are consistent with long-term goals.




**National Goal:** Rapid transition to carbon neutral energy economies

**Local Goals/Needs:?**

**Why $CO_2$?** Capturing $CO_2$ is essential for decades even with rapid deployment of renewables.

**Why highlight symbiosis?** Energy systems are interdependent. Exploiting the symbiosis accelerates deployment.

**Coupling Commercial-Scale Storage to DAC is Essential**

THE UNIVERSITY OF UTAH™

# EGI's Goal: $CO_2$ Storage for the Energy Transition

## Strengths

- Existing/proven technology
- Can capture $CO_2$ at the source - high concentrations/efficient
- Vast amounts of storage potential
- Vast amounts of $CO_2$ sources near storage sites
- $CO_2$-EOR – improves oil field economics with additional recovery
- Substantial existing geologic data to leverage in region
- Helps save jobs at FE power plants
- Largest near-term impact on decarb compared to other options
- Other pollutants removed than just $CO_2$ – Sox, NOx, etc

## Weaknesses

- 3-5 year permitting duration for class VI
- Economically challenged with current subsidies/tax credits
- Viable storage sites need identified
- Not as "green" as other decarb options
- Potential of induced seismicity or leakage to aquifer or atmosphere
- $CO_2$-EOR creates additional fossil fuels and therefore additional $CO_2$
- Landowner safety concern near storage sites

## Opportunities

- 45Q Expansion
- Additional tax credits or subsidies
- Natural gas separation/acid gas injection – Class II – quicker permitting; lots of these sources in the region
- State primacy to expedite permitting (WY; AZ 1- VI application)
- Synergies with other decarb options like bioenergy, hydrogen, DAC
- Capture technologies improving
- Storage hubs to improve economics and permitting logistics; piggybacking off federally supported 1st movers
- Trunklines to improve economics

## Threats

- Renewables expand quicker than expected
- Increasingly shuttered FE power plants
- No expansion of 45Q or additional subsidies/tax credits
- Environmental push back – Seen as prolonging FE usage
- Ambiguity around pore space rights
- Pushback elsewhere in country (mid-west) to proposed $CO_2$ pipeline expansion efforts

# Direct Air Capture

## Need scalable technologies for $CO_2$ drawdown

- **Removal from biomass via photosynthesis**
  - ***Low cost, but limited scale***
- **Removal from ocean water**
  - ***Low concentration 1 : 25,000***
- **Removal from air (direct air capture or DAC)**
  - ***1 : 2,500, well mixed reservoir***

### Direct air capture can

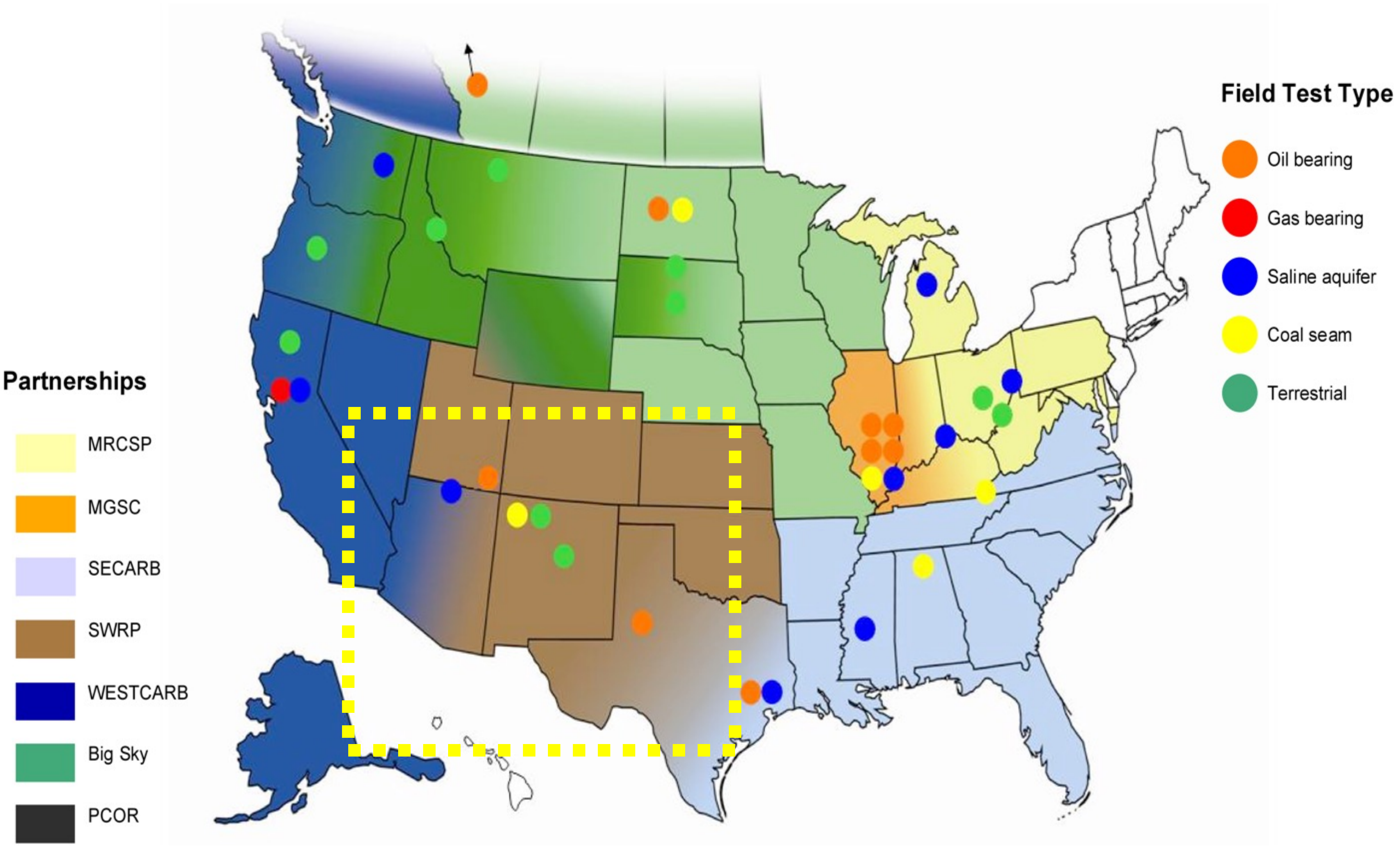
- close the carbon cycle
- deliver $CO_2$ for large scale sequestration
- enable renewable energy to fulfill energy needs over the long-term

THE UNIVERSITY OF UTAH™

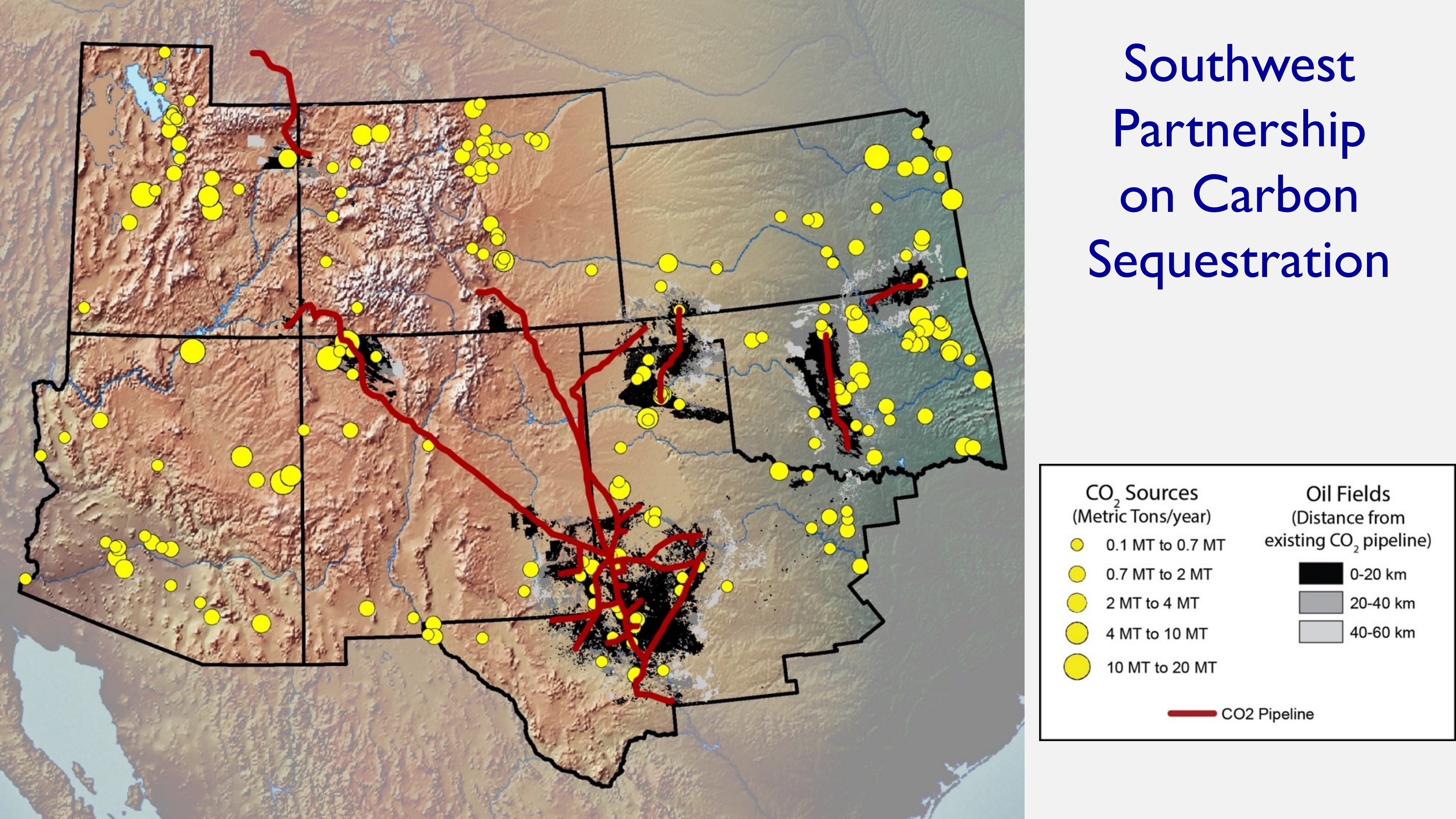
# EGI and DAC (Collaboration - ASU)


- Mechanical trees are a thousand times more effective at removing $CO_2$ waste from the air than a planted tree.
- Passive Direct Air Capture (DAC) of $CO_2$ is a practical, affordable and rational means to address the existential threat of global warming.
- A dozen trees can remove one ton of $CO_2$ per day.
- EGI's role: subsurface storage

# Southwest Partnership on Carbon Sequestration



# Southwest Partnership on Carbon Sequestration



# Southwest Partnership: Phase 3

- The SWP's Phase 3 project is a large-scale EOR-CCUS test
- General Goals:
  - One million tons CO2 injection
  - Optimization of storage engineering
  - Optimization of monitoring design
  - Optimization of risk assessment
- Blueprint for CCUS in western U.S.

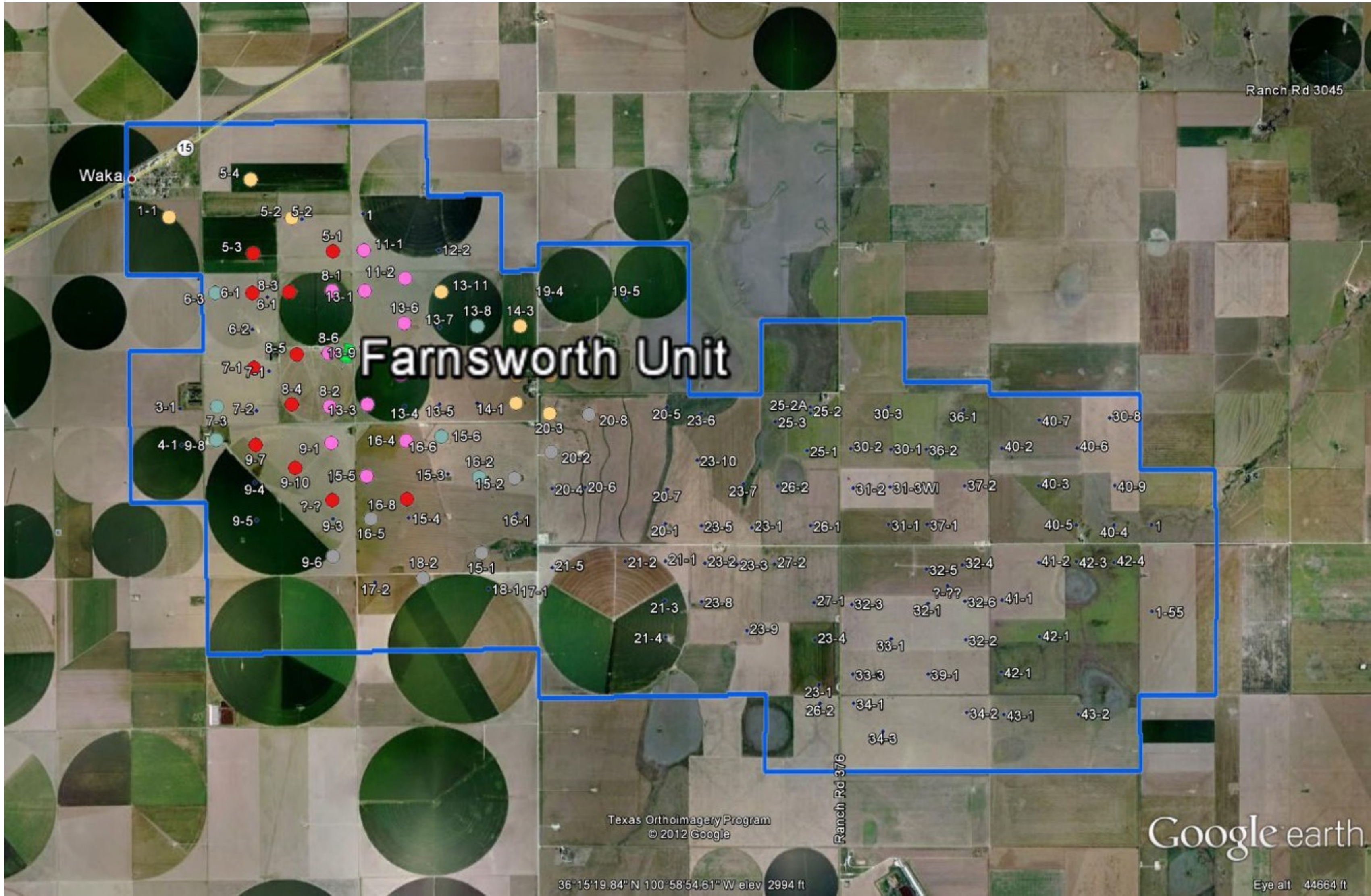
# Southwest Partnership: Phase 3

- Farnsworth field was discovered in 1955.
- About 100 wells were completed by the year 1960.
  - The field was unitized in 1963 with Unocal as operator.
  - Water injection for secondary recovery started in 1964.

| Property | Value |
|---|---|
| Initial water saturation | 31.4% |
| Initial reservoir pressure | 2218 PSIA |
| Bubblepoint Pressure | 20-150 PSIA |
| Original Oil in Place (OOIP) | 120 MMSTB (60 MMSTB west-side) |
| Drive Mechanism | Solution Gas |
| Primary Recovery | 11.2 MMSTB (9.3%) |
| Secondary Recovery | 25.6 MMSTB (21.3%) |

# SWP FIELD SITE: THE FARNSWORTH UNIT

- Farnsworth is located in actively farmed lands
- At present the west half of the unit is being converted to $CO_2$ EOR
- East half of the unit is waiting on capital for infrastructure and available $CO_2$



# $CO_2$ Sources

Anthropogenic $CO_2$ Supply:

~100,000 Metric tons $CO_2$/year

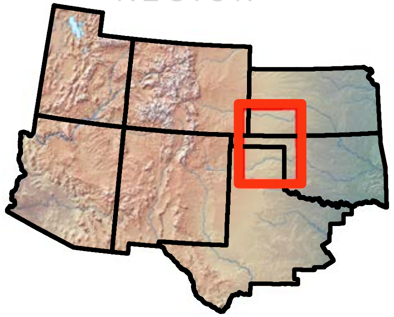

**Legend**

- Utiilization & Storage
- Carbon Capture
- Transportation
- Oil Fields

**Other $CO_2$ Sources**

- 0.1 to 0.7 MT/yr
- 0.7 to 1.8 MT/yr
- 1.8 to 4 MT/yr
- 4 to 10 MT/yr
- 10 to 20 MT/yr

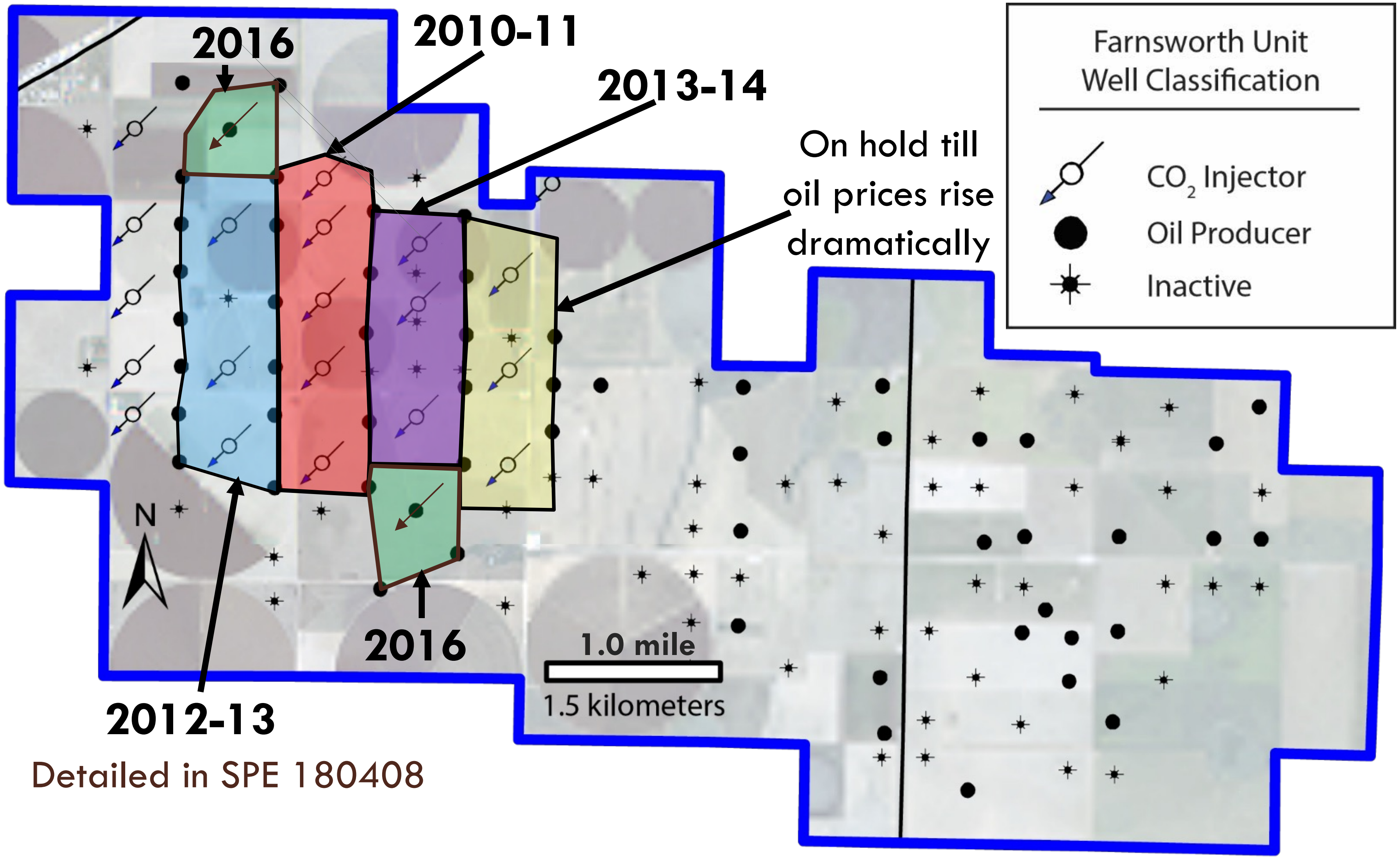
http://www.conestogaenergy.com/arkalon-ethanol




www.agrium.com

THE UNIVERSITY OF UTAH™

# ACTIVE AND PLANNED $CO_2$ PATTERNS




Detailed in SPE 180408

# Accomplishments: MVA

## Significant Achievements

The MVA technologies deployed by the SWP are targeted to provide the data necessary to track the location of $CO_2$ in the study area, including migration, type, quantity and degree of $CO_2$ trapping. Monitoring data is used to facilitate simulation and risk assessment, particularly with respect to USDWs, the shallow subsurface, and atmosphere.

### Detecting $CO_2$ and/or brine outside Reservoir:

- Groundwater chemistry (USDW)
- Soil $CO_2$ flux
- $CO_2$ & $CH_4$ Eddy Towers
- Aqueous- & Vapor-Phase Tracers
- Self-potential (AIST)
- Distributed Sensor Network (Ok. State)

### Tracking $CO_2$ Migration and Fate:

- *In situ* pressure & temperature
- 2D/3D seismic surveys
- VSP/Cross-well seismic
- Passive/micro seismic
- Fluid chemistry (target reservoir)
- Aqueous- & Vapor-Phase Tracers
- Gravity surveys & MagnetoTelluric (AIST)

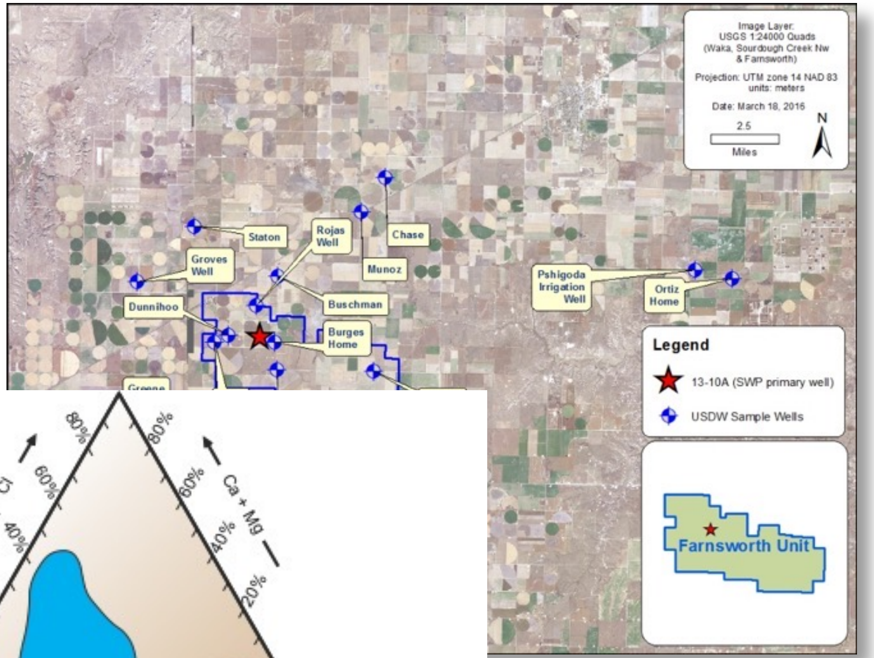
**MVA relational database**

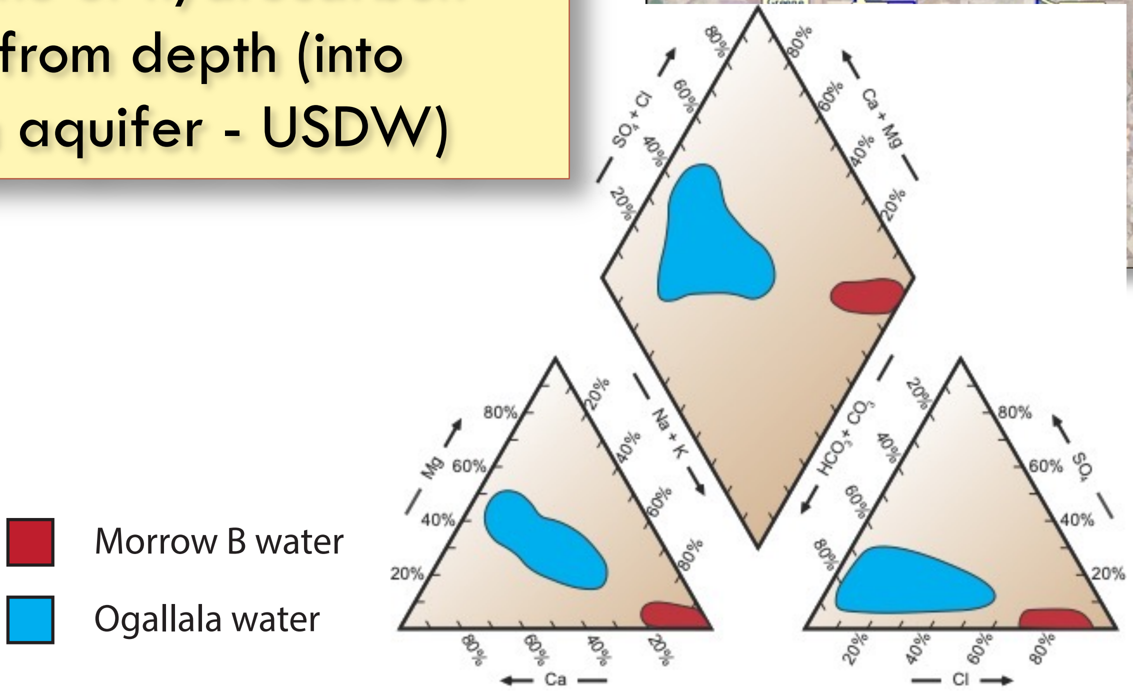
- All SWP non-seismic MVA data in one central location
- Collection of related tables that can be readily queried
- Efficient, Fast
- Complex searching
- Web ready
- Secure

# Accomplishments: MVA

## Selected Progress: USDW monitoring

- Technology validates spatial and temporal sampling to monitor USDW for potential leakage. No Indication of $CO_2$, brine or hydrocarbon leakage from depth (into Ogallala aquifer - USDW)

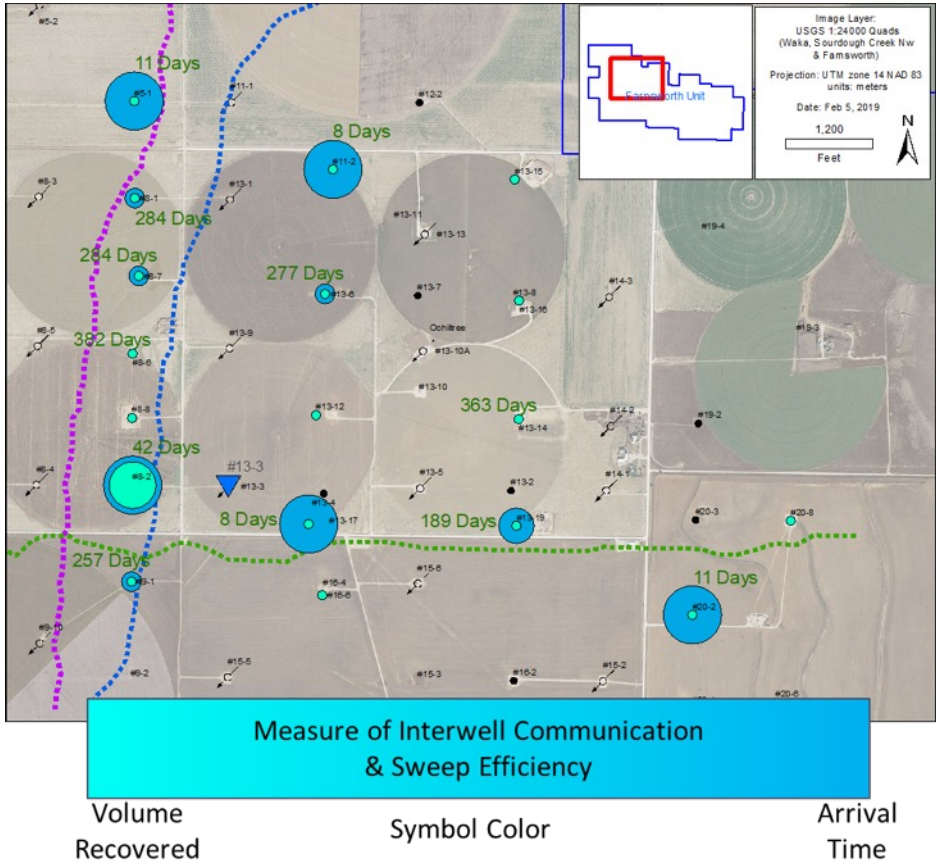


# Accomplishments:  MVA

## Selected Progress: Reservoir tracers (aqueous)

- Aqueous-phase tracer slugs (Naphthalene sulfonates) were injected into 5 well patterns to successfully evaluate fluid velocities, interwell connectivity and identify and characterize  significant reservoir heterogeneities.
- The injection into FWU #13-3 yielded results indicating significant preferential fluid flow along two adjacent faults.
- Relative tracer recovery along (FWU #8-2 and FWU #20-2) and across faults (FWU #9-1) indicate variable transmissive versus sealed characteristics
- Vapor-phase tracer injection into FWU #13-3 yields similar results, indicating similar flow behavior for water and $CO_2$ at least in this area of the reservoir.

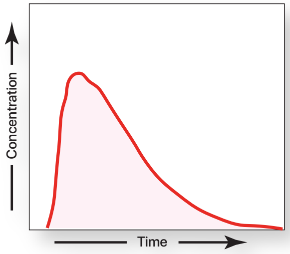


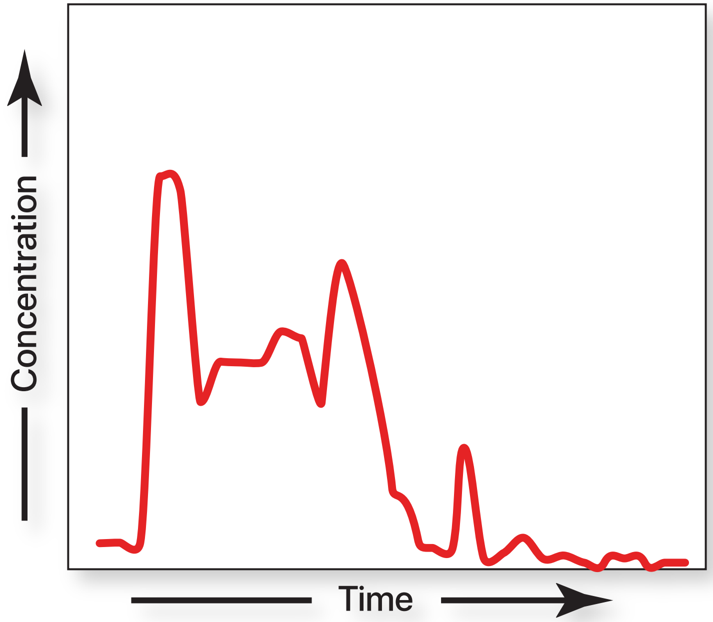
# Accomplishments: MVA

## Selected Progress: Tracers - Aqueous and Vapor

### For Characterization

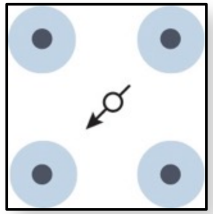
- Well-to-well communication (directions & velocities)
- Reservoir continuity or compartmentalization
- Fracture volume and extent
- Identify and interpret significant faults and/or barriers to flow

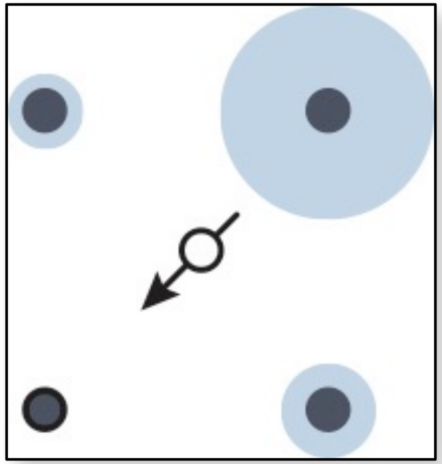



### For Monitoring

- Tracers as analogs of $CO_2$
- Constrain & calibrate flow models and simulations; predict the fate of the injected $CO_2$
- Monitor tracer leakage to USDW and/or atmosphere as analogue for $CO_2$/brine leakage





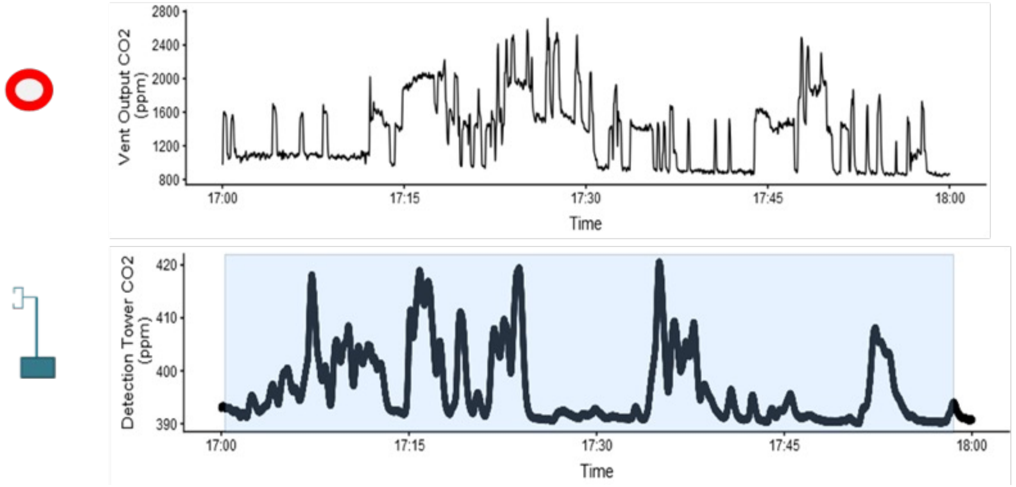
THE UNIVERSITY OF UTAH™

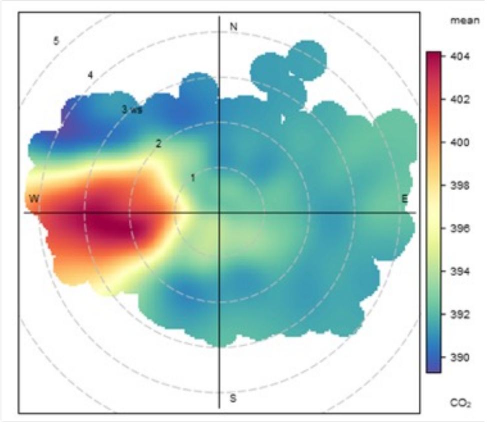
# Accomplishments: MVA

## Selected Progress: $CO_2$ surface & atmospheric flux

- Use a known, consistent $CO_2$ source to develop detection, location, and quantification methods
- Bench experiments, concurrent source measurements, and machine learning methods

Source Location

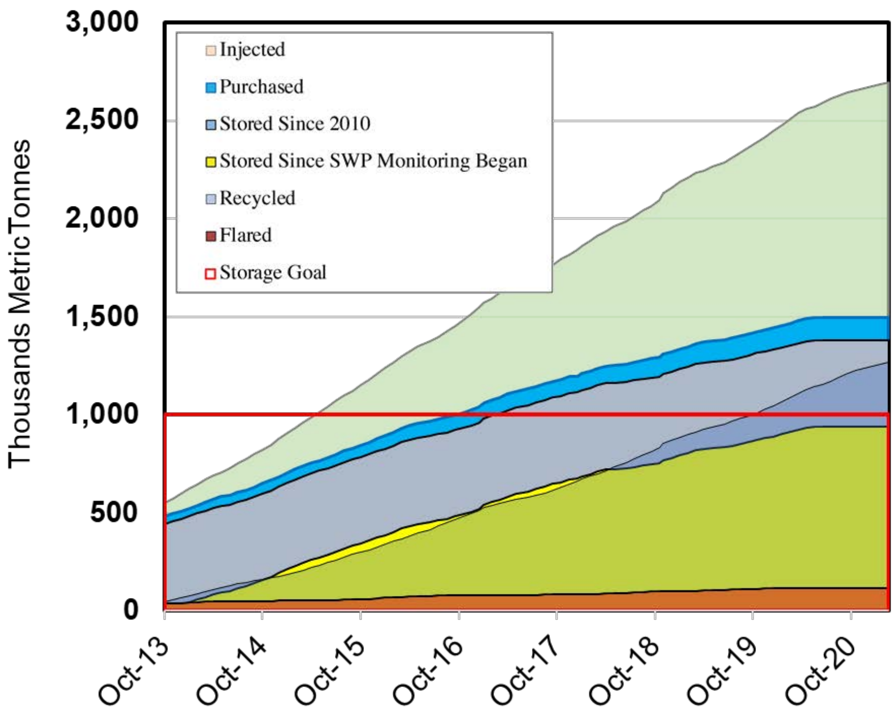




THE UNIVERSITY OF UTAH™

# Accomplishments: MVA

## Selected Progress: Fluid accounting

- Provided to SWP by Chaparral Energy and Perdure Petroleum
- Daily or Monthly values of $CO_2$ Purchased, Injected, Produced (Recycled) and Flared
- SWP has not yet accomplished the project goal of 1,000,000 metric tonnes of $CO_2$ injected (since 2013).
- Since 2010, over 2.5 million metric tonnes of $CO_2$ have been injected.
- Approximately of the purchased $CO_2$ 50% has been stored.
- 47% has been recycled.
- Purchase and storage rates have slowed as recycling has increased and field expansion has stalled (due to low price of oil).



# Accomplishments: MVA

## Selected Progress: Microseismic Array

- Sixteen level borehole array - deployed in Dec 2018 (FWU #13-10).
- Twenty surface seismic stations – deployed in July 2019.
- Aid in characterizing the stability and storage of the $CO_2$ in the reservoir.
- Analysis of both borehole and surface microseismic is starting and will continue to end of project.


THE UNIVERSITY OF UTAH™

# Carbon Utilization Storage Partnership

CUSP West — Carbon Utilization and Storage Partnership of the Western USA

- Focus is on collecting, synthesizing, and use of existing data sets. Purpose of data is to improve coverage, accuracy, and granularity of existing data (e.g. NATCARB) for western US. To improve understanding of storage systems and carbon sources.
- Data will be incorporated into analytical and optimization models to evaluate CCUS potential and readiness. Goals include:
  - Identifying best prospects for commercial CCUS
  - Quantifying potential economic impacts
  - Developing Readiness Indices (w/ SimCCS) to identify best areas for short-term, mid-term, and long-term CCUS projects

State organizations will assess, update, augment, and verify data used in data analysis and modeling

- geological storage complexes (saline, stacked storage, ROZs)
- $CO_2$ emission sources
- existing infrastructure

Strong emphasis on technology transfer

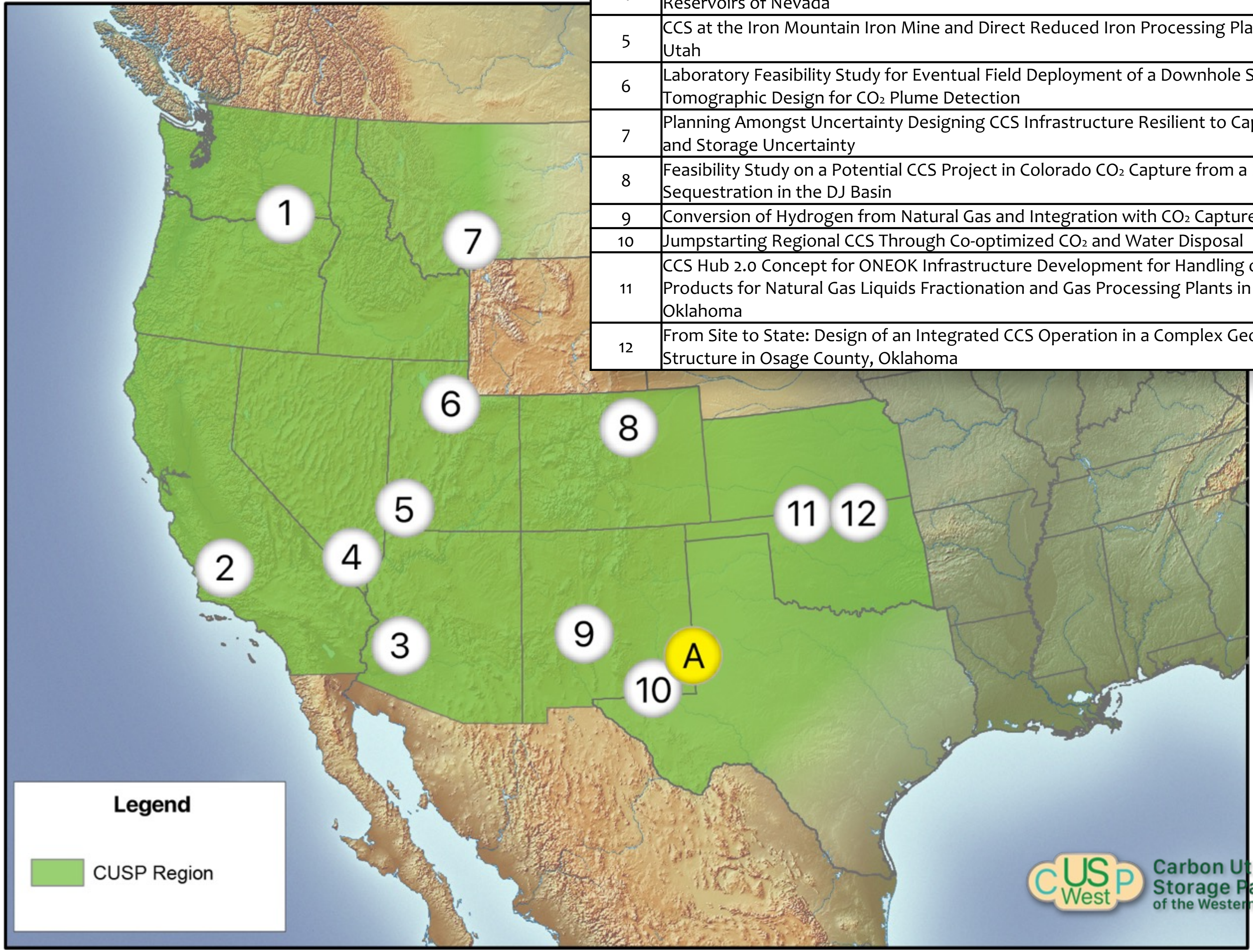

*CUSP Member States & Organizations*

THE UNIVERSITY OF UTAH™

# Carbon Utilization Storage Partnership

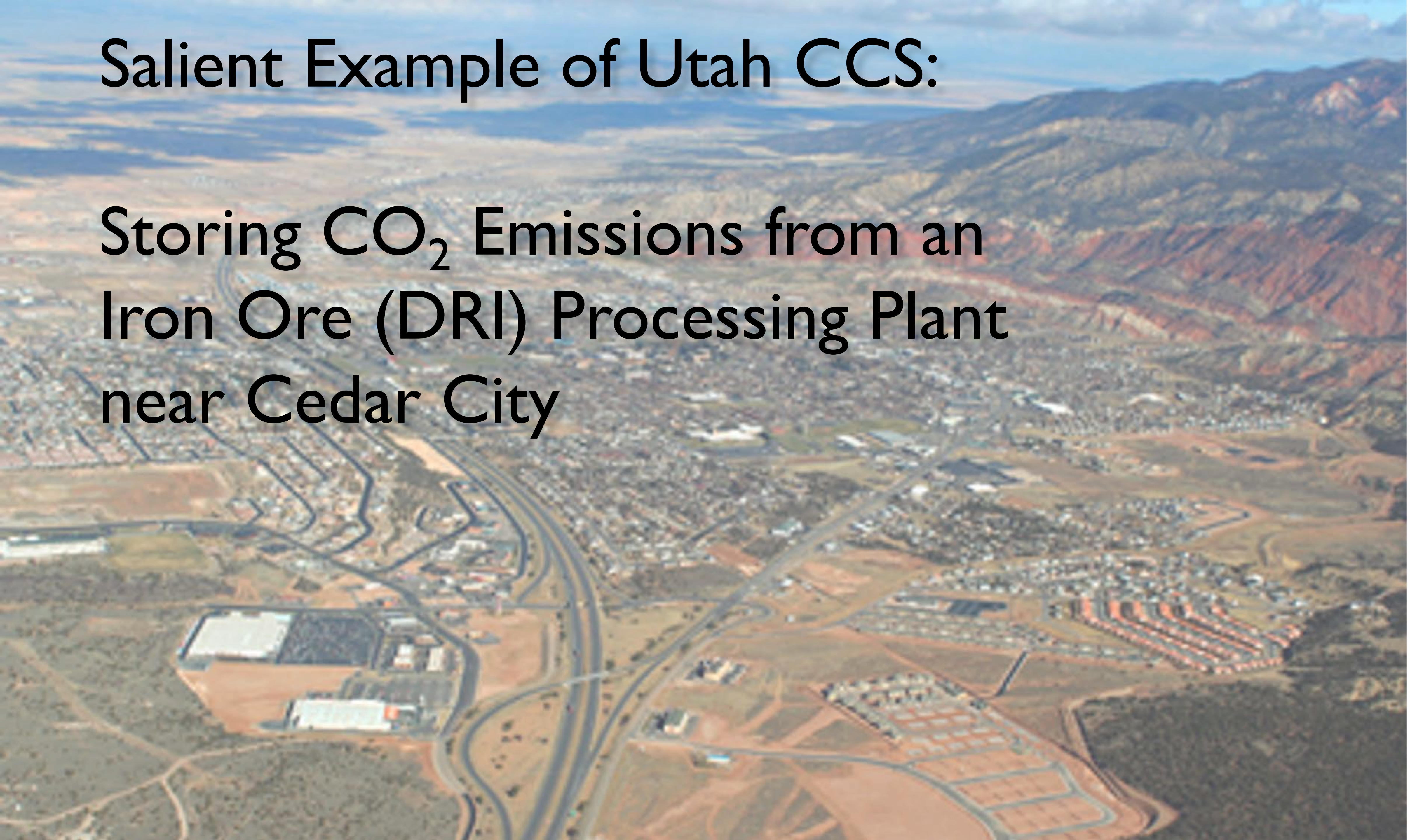
- Portfolio in 2nd year
- Most projects have industry partners and target injection in 1-3 years
- Includes a unique study for injection into basalts
- Includes bench scale work on the use of $CO_2$ as Geothermal working fluid
- Includes development of two regional Storage Hubs

| | |
|---|---|
| A | Lucid Acid Gas Injection Project |
| 1 | De-risking $CO_2$ Mineralization Storage in Basalt Reservoirs |
| 2 | Laying the Cornerstones of a Regional Storage Hub in California |
| 3 | Characterization of $CO_2$ storage potential in Harquahala basin western central Arizona |
| 4 | Regional-Scale Assessment of $CO_2$ Geological Storage in Sedimentary Basin Geothermal Reservoirs of Nevada |
| 5 | CCS at the Iron Mountain Iron Mine and Direct Reduced Iron Processing Plant, Southern Utah |
| 6 | Laboratory Feasibility Study for Eventual Field Deployment of a Downhole Source Tomographic Design for $CO_2$ Plume Detection |
| 7 | Planning Amongst Uncertainty Designing CCS Infrastructure Resilient to Capture, Transport and Storage Uncertainty |
| 8 | Feasibility Study on a Potential CCS Project in Colorado $CO_2$ Capture from a Refinery and Sequestration in the DJ Basin |
| 9 | Conversion of Hydrogen from Natural Gas and Integration with $CO_2$ Capture and Storage |
| 10 | Jumpstarting Regional CCS Through Co-optimized $CO_2$ and Water Disposal |
| 11 | CCS Hub 2.0 Concept for ONEOK Infrastructure Development for Handling of New Gaseous Products for Natural Gas Liquids Fractionation and Gas Processing Plants in Kansas and Oklahoma |
| 12 | From Site to State: Design of an Integrated CCS Operation in a Complex Geological Structure in Osage County, Oklahoma |



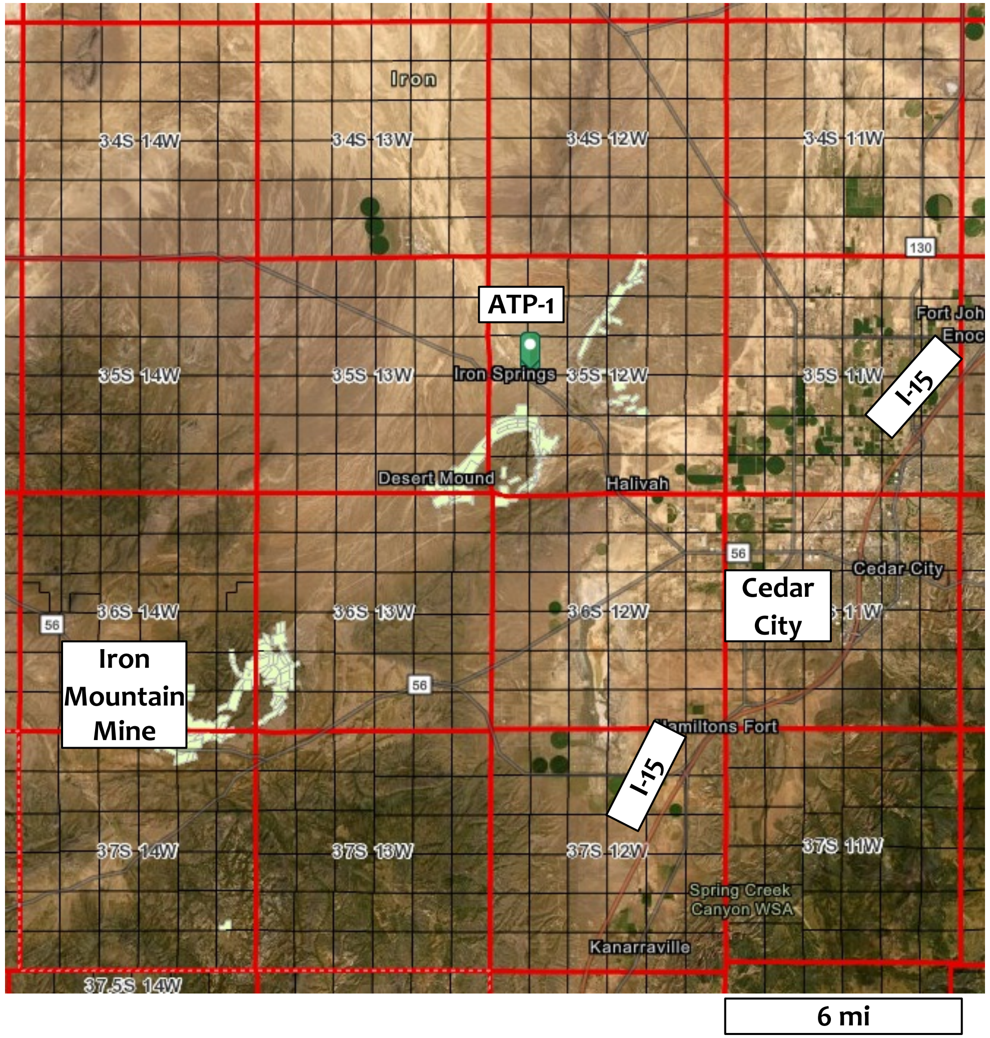
# Salient Example of Utah CCS:

## Storing $CO_2$ Emissions from an Iron Ore (DRI) Processing Plant near Cedar City



# Utah CCS: Iron Mountain Subsurface Characterization

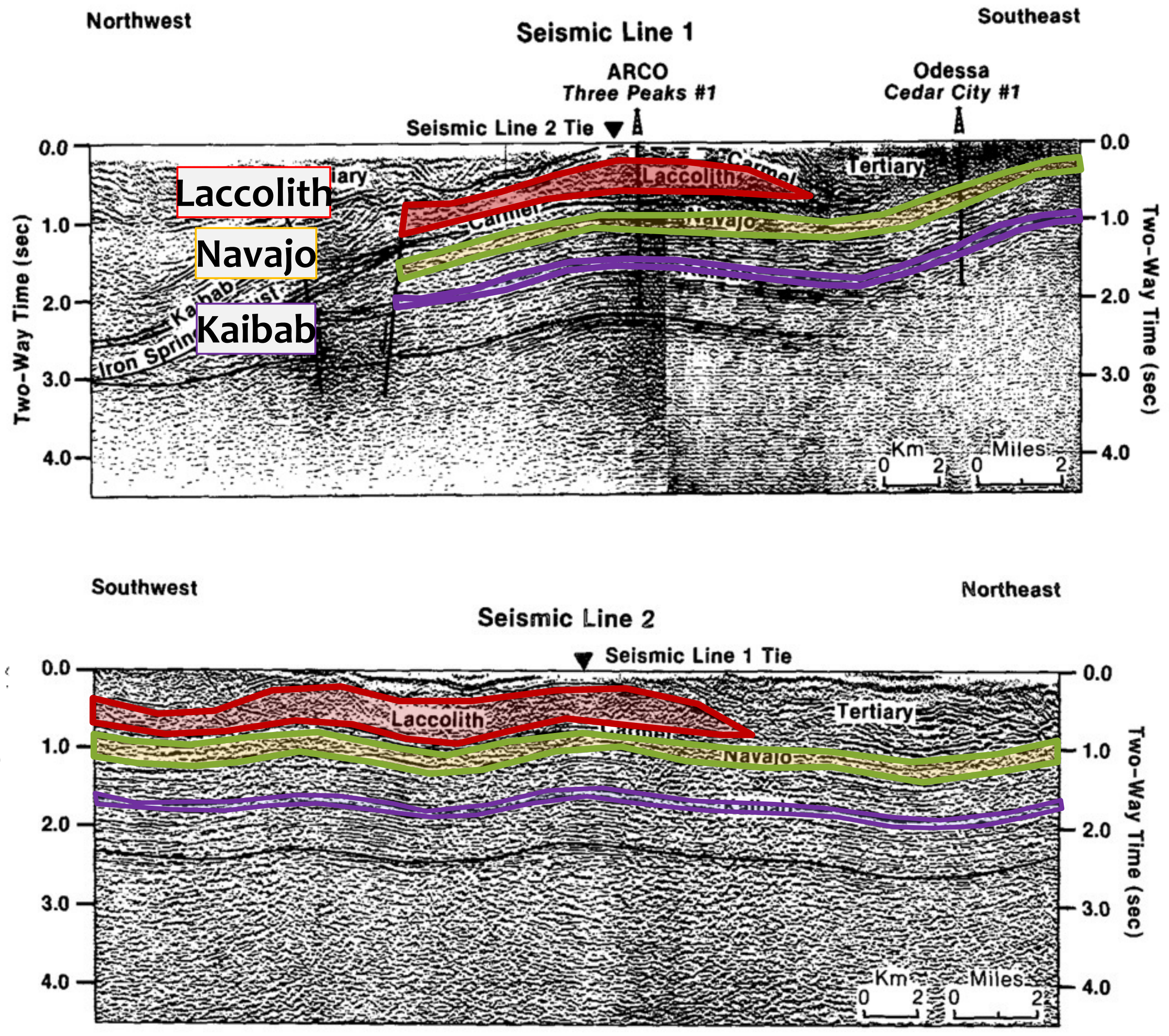
- Commercial-scale carbon capture and storage near Iron Mountain iron mine
- Located near Cedar city, UT
- Evaluating the potential to store 500,000 metric tons of $CO_2$ generated from Direct Reduced Iron (DRI) process
- Potential storage formation is the Navajo Sandstone
- Leverage 45Q tax credits for economic viability



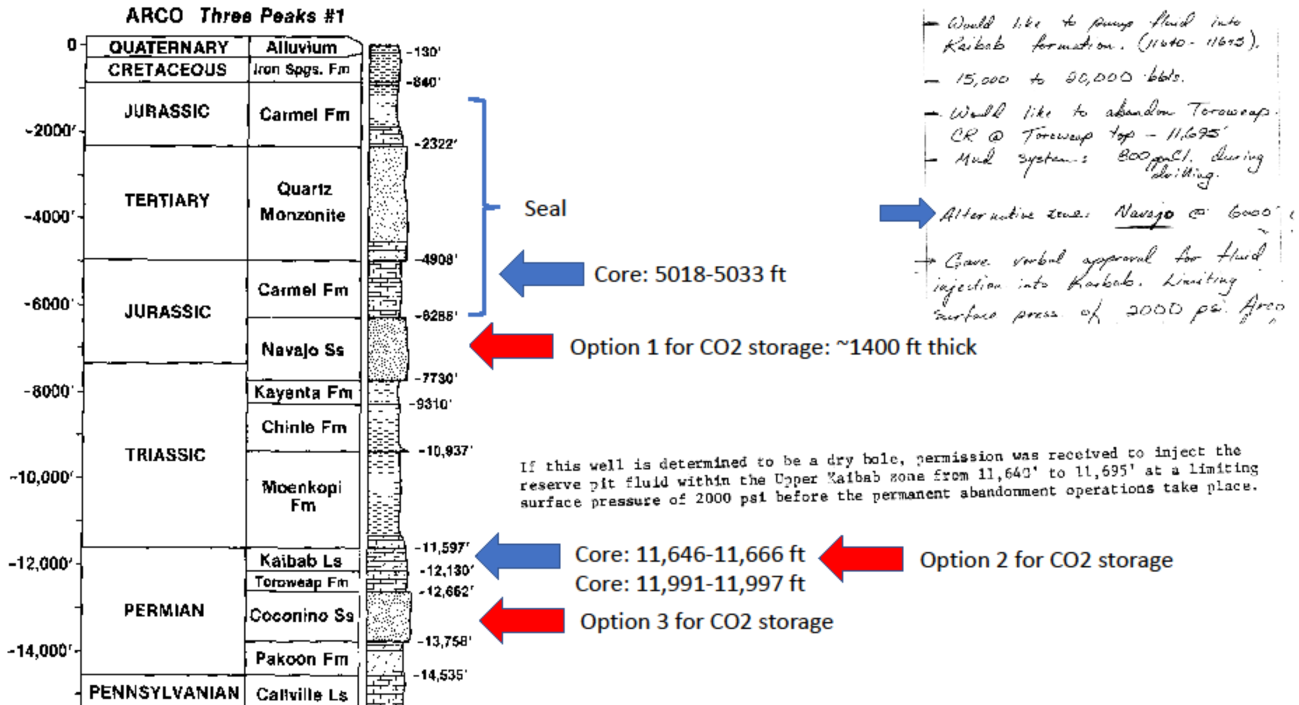

Source: https://blm-egis.maps.arcgis.com/apps/webappviewer

# Utah CCS: Iron Mountain Subsurface Characterization

- Primary CCS target is the Navajo Sandstone at 6200ft
- Secondary CCS target is the Kaibab Limestone at 11,600 ft




Van Kooten, 1988

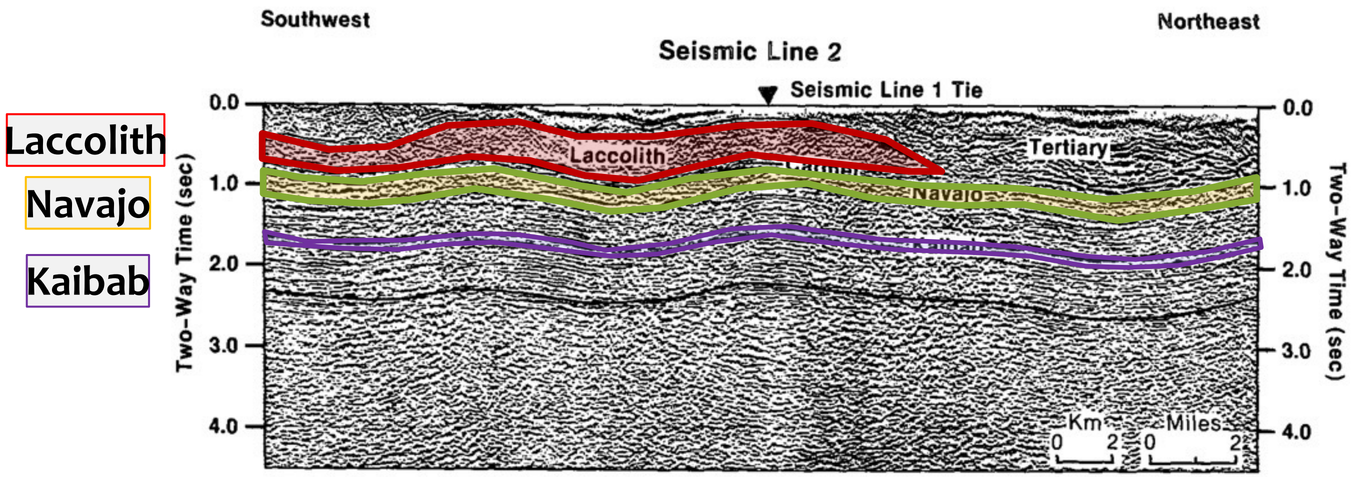



If this well is determined to be a dry hole, permission was received to inject the reserve pit fluid within the Upper Kaibab zone from 11,640' to 11,695' at a limiting surface pressure of 2000 psi before the permanent abandonment operations take place.

# Utah CCS: Iron Mountain Subsurface Characterization

- Big Issues:
- Accurate Forecast of Storage Capacity (resource)
- Maximize economic benefit to operator (45Q)
- But: Minimize Risk (esp. pressure buildup and seismic activity)
- Tremendous focus on

**Uncertainty Quantification** (data and algorithms as sources of uncertainty)




Van Kooten, 1988

# 45Q

- What might motivate industry stakeholders to implement CCS?

# What is 45Q?

- 45Q is a part of the US tax code heavily modified in 2017 by a bipartisan congress and signed into law by the President
  - Modified slightly in 2021 Omnibus to extend deadline to start projects
  - Most recently modified by 2022 Inflation Reduction Act
- 45Q provides tax credits for geologic storage of Carbon Oxides ($CO_2$)
  - Originally up to $35/tonne of $CO_2$ stored in EOR or other uses, **now $60/tonne**
  - Originally up to $50/tonne of $CO_2$ stored in other formations, **now $85/tonne**
  - Originally DAC fell under the other categories, **Added DAC credit of $180/tonne**
- 45Q is designed to jumpstart carbon storage projects in the US
  - Foundation of the idea is in enabling "clean coal"
  - Geologic storage of carbon is perceived as a needed solution to address climate change

# Efforts to make 45Q more effective

***2020-2021 CATCH Act incorporated in IRA***

- Increase Credits up to $85 per tonne for saline storage and $60 per tonne for EOR, **included in IRA**
- Eliminate or reduce thresholds for project size, **included in IRA**

***2021-2022 ACCESS Act incorporated in IRA***

- Make the tax credit directly payable, **first five years allowed in IRA, 12 years if a tax-exempt organization**
- Extend duration of credit by 10 years, **further extended to 2033**

- **Also included:**
  - **Expanded transferability to taxpayers outside of operational partners**

# Why might companies be interested in 45Q?

- Economic benefits of tax credit can be substantial
  - 1 tonne of CO2 is approximately 18 mmcf of gas
  - 1 million tonnes per year from each of 4 gas plants in San Juan, for example
  - **Under 2022 rules this could generate a tax credit of $50 -85 million per year per plant if the $CO_2$ were stored**
- Other tangible benefits of reducing carbon emissions
  - Stored $CO_2$ does not count as emissions for EPA or State reporting purposes
  - Reduces $CO_2$ footprint of the company
  - Reduces exposure to carbon taxes or emissions penalties which could be imposed by state or federal entities
- Sustainability of operations for oil and gas producers
  - Improved public perception of operations
  - Reduced economic risk from future regulatory or policy changes

# Motivation: Energy and Climate

- **Carbon neutral energy: How fast can we get there?**
- Manage societal impact
- Technology impact
- Assure stability of the transition
- Adapt to a changing environment
- Manage unavoidable damages

EGI Energy & Geoscience Institute AT THE UNIVERSITY OF UTAH