



The Carbon Utilization and Storage Partnership of the Western US

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August 4, 2021

NETL

The Changing Landscape

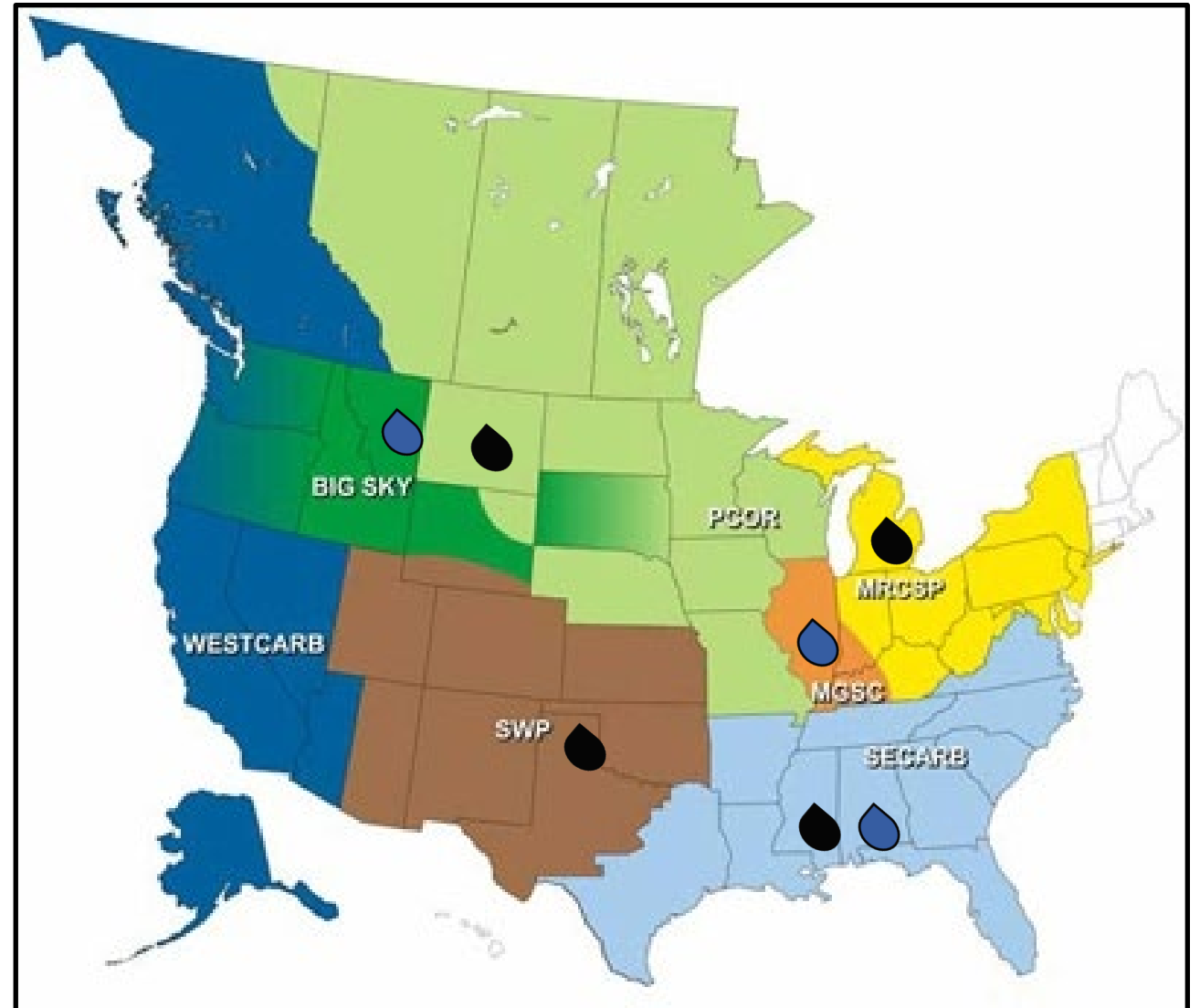
- Exxon Proposing \$100 Billion regional storage hub on the Gulf Coast
- Occidental Petroleum has a position statement that they will stop taking Natural CO₂ in the near future.
 - A large proportion of the 20 million metric tonnes of CO₂ delivered annually to the Permian (about 18 mmcf CO₂/tonne)
- Major industrial Investors such as Goldman-Sachs and Riverstone seeking Carbon Reductions/Neutrality
 - In response to investor pressure, these investment companies are looking for “greener” pastures
- Tax incentives and the potential for regulatory pressure have dramatically impacted the viability of CC(U)S projects
 - Green house gas reporting
 - 45Q tax credits

Some History of US Carbon Storage Research

- EOR has been doing this for years
 - Large literature and project base in US and Canada
- Regional Carbon Storage Partnerships (2003)
 - US DOE established regional partnership program to understand regional and national storage potential, technologies, and to perform demonstration projects
- CarbonSAFE (2016)
 - DOE program to promote large scale capture and storage for coal plants
- New Regional Initiative program (2019)
 - Doe doubled down on partnerships with focus on commercialization

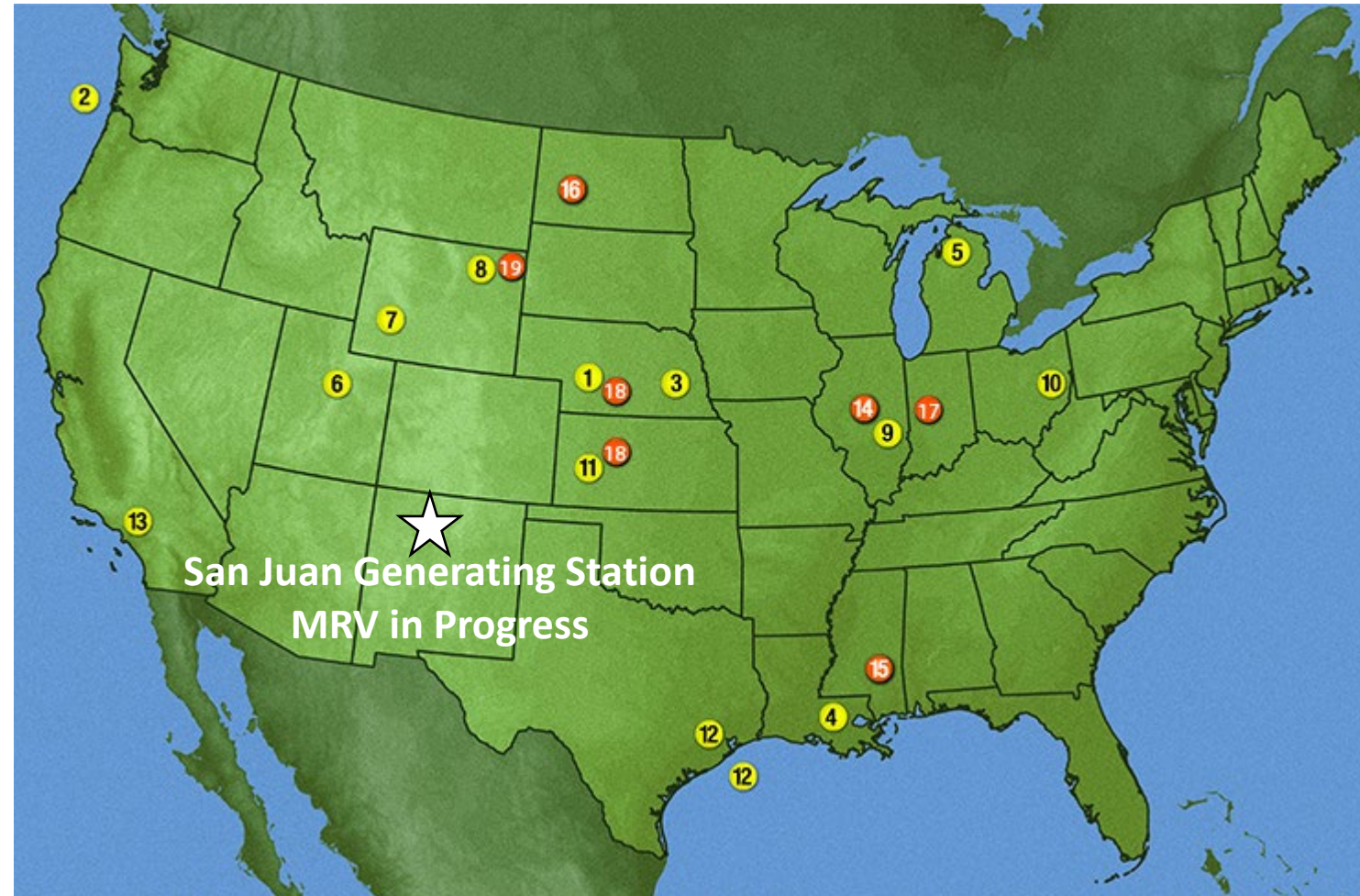
USA Case Studies for CCS (2003-2022)

- US Department of Energy Regional Carbon Sequestration Partnerships
 - Seven regional partnerships
- Each demonstrating injection of at least 1,000,000 metric tons of CO₂
- Four projects demonstrated storage in conjunction with EOR
- Developing “best practices” for utilizing captured CO₂

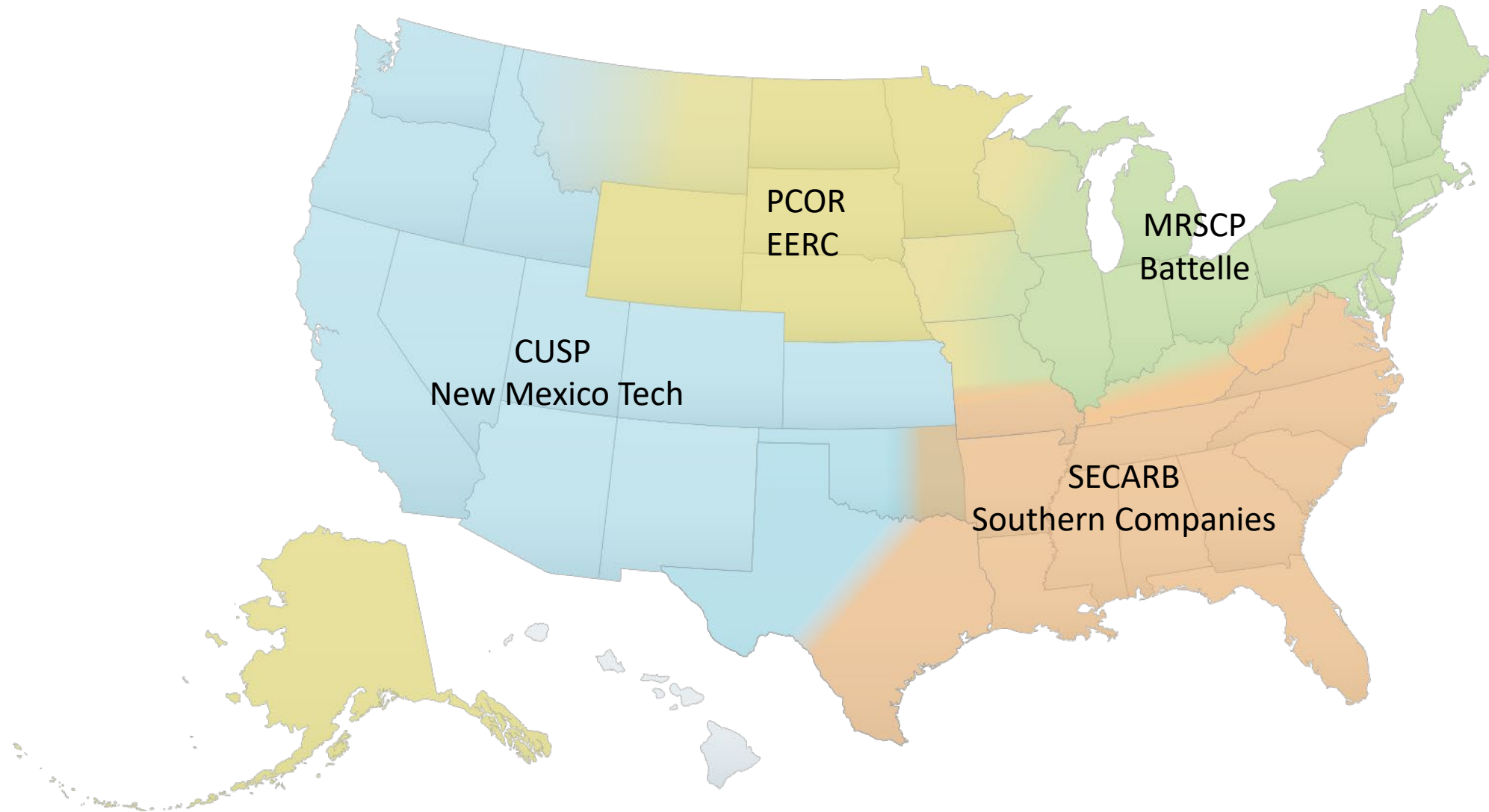


The Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Initiative

- Focused on development of geologic storage sites for the storage of 50+ million metric tons (MMT) of carbon dioxide (CO₂) from industrial sources.
- CarbonSAFE projects improve understanding of project screening, site selection, characterization, and baseline monitoring, verification, accounting (MVA), and assessment procedures
- Help determines information needed to submit appropriate permits and design injection and monitoring strategies for commercial-scale projects. (50+ MMT storage sites in anticipation of injection by 2026)

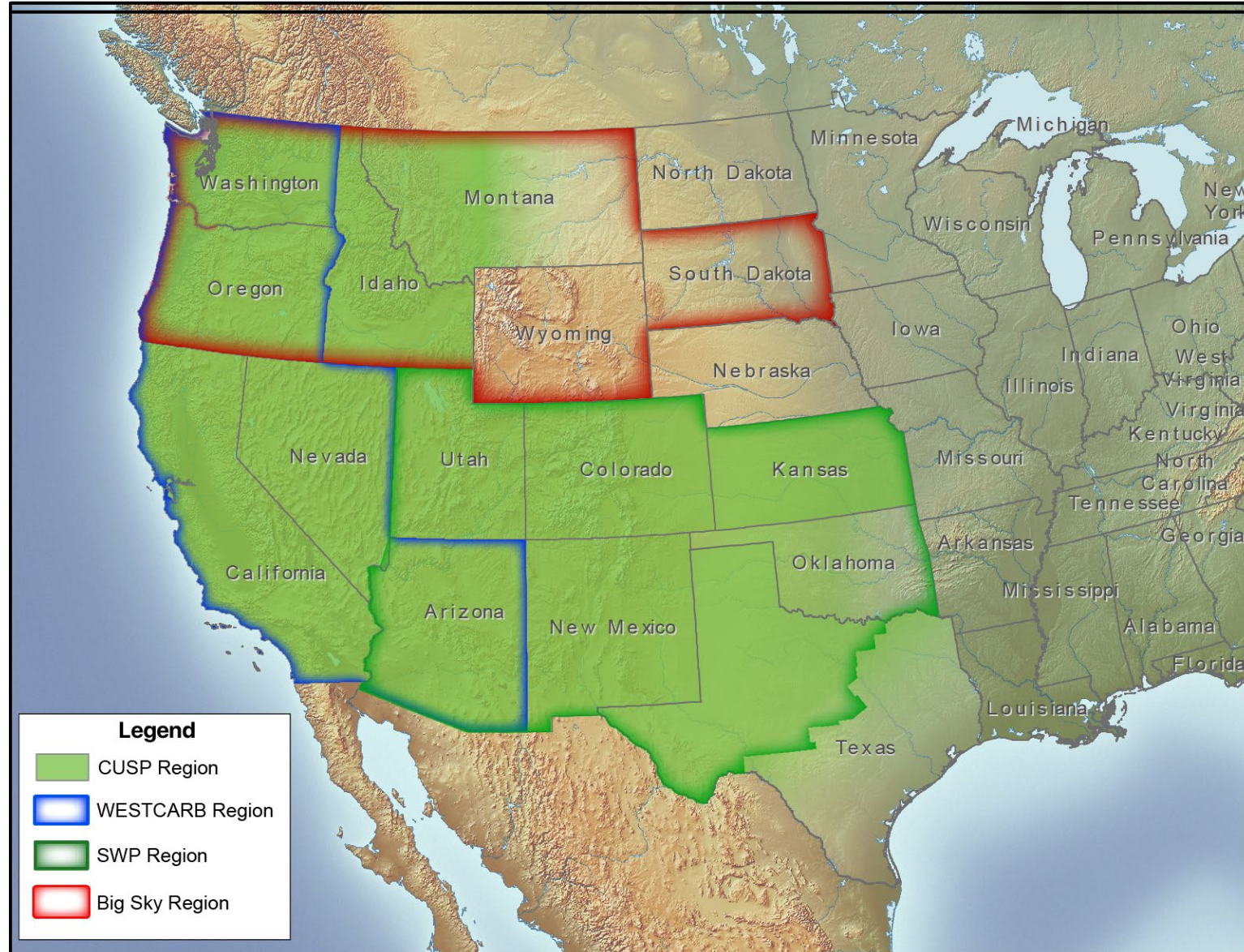


Regional Initiatives to Accelerate CCUS Deployment (2019-?)



Who is the CUSP?

- Parts of three of the original RCSPs: SWP, WESTCARB, and Big Sky
- States represented - through a survey, a university, or a research institute: AZ, CA, CO, ID, KS, NM, NV, MT, OK, OR, TX, UT, WA
- National Laboratories - Los Alamos, Pacific Northwest, and Sandia
- Additional collaboration with Indiana University for technical support (SIMCCS)
- Industry engagement: Schlumberger, Bright Energy, EDP, and Enchant NM. Other states will be bringing in more interested parties

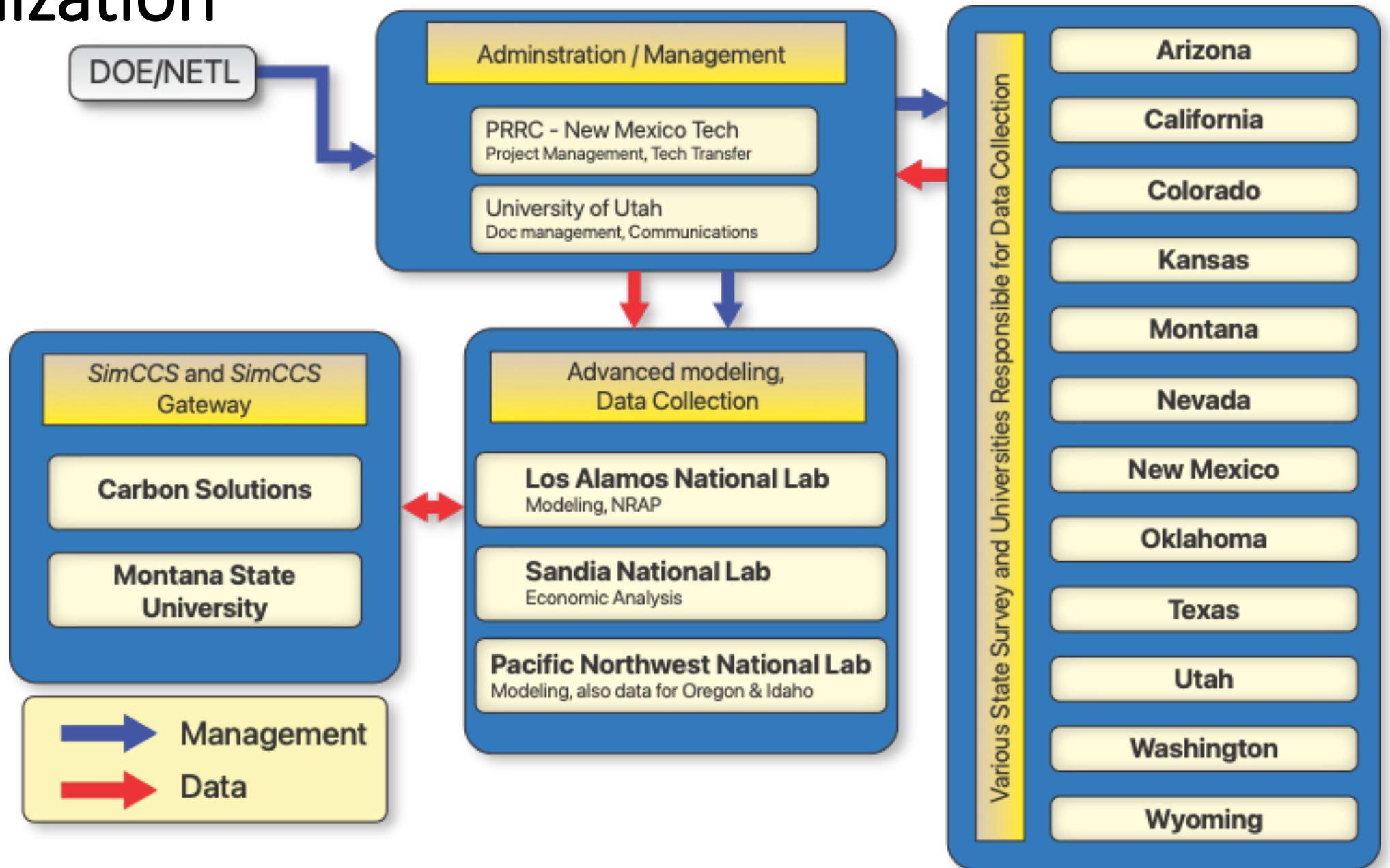


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Organization



Regional Storage is Diverse

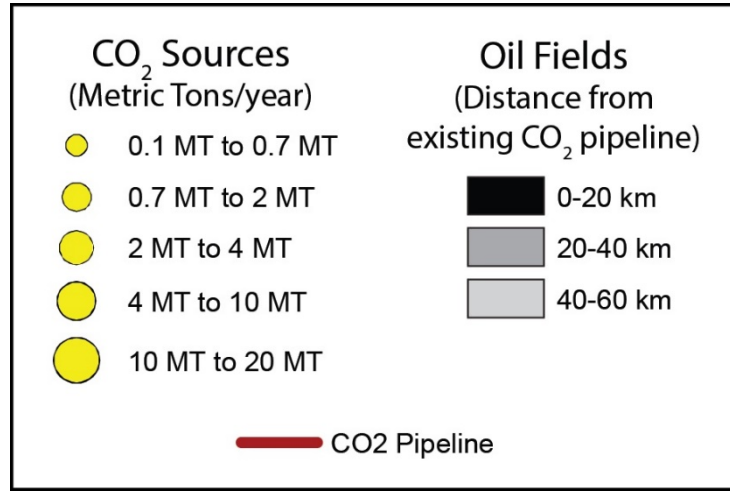
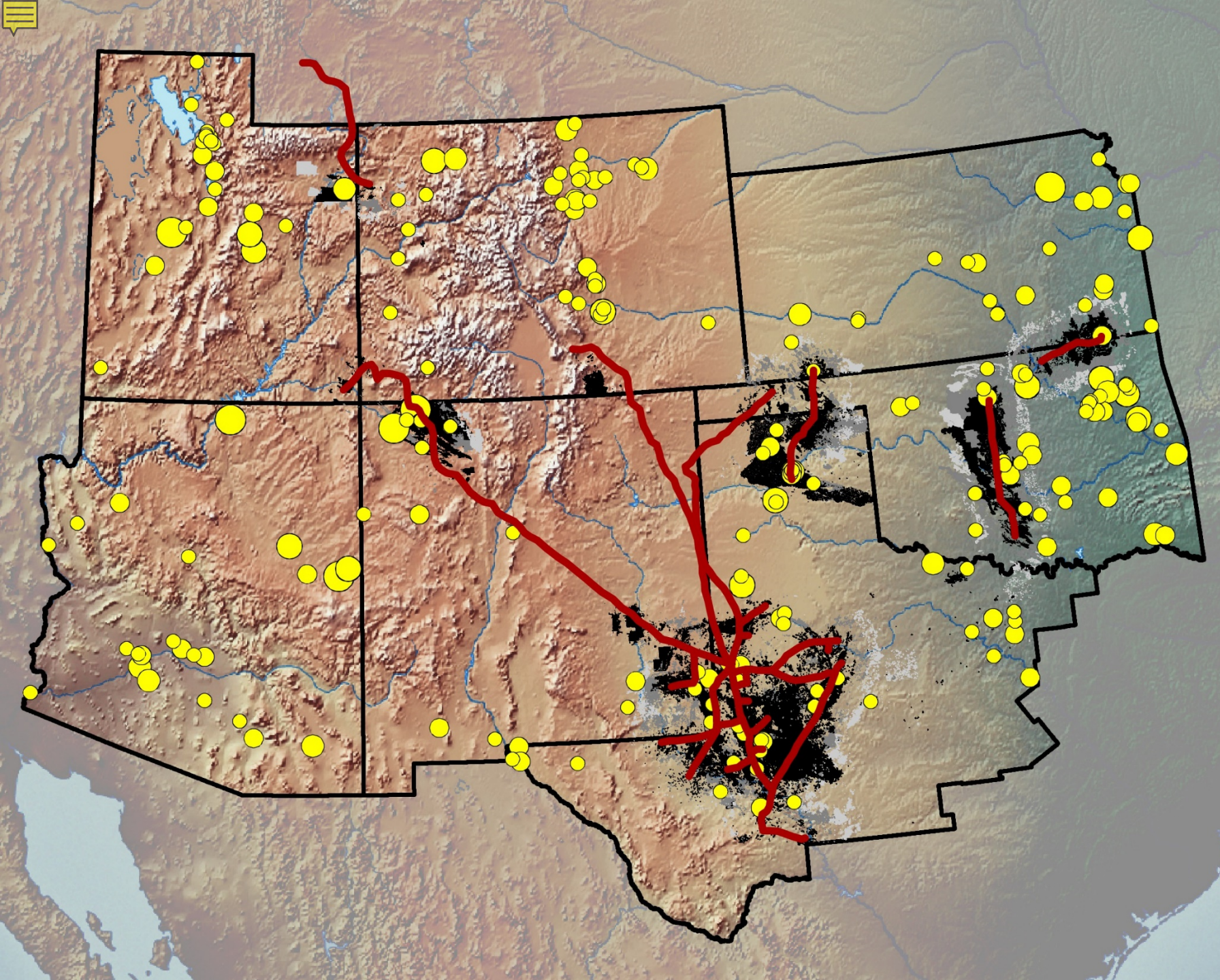
Basalts



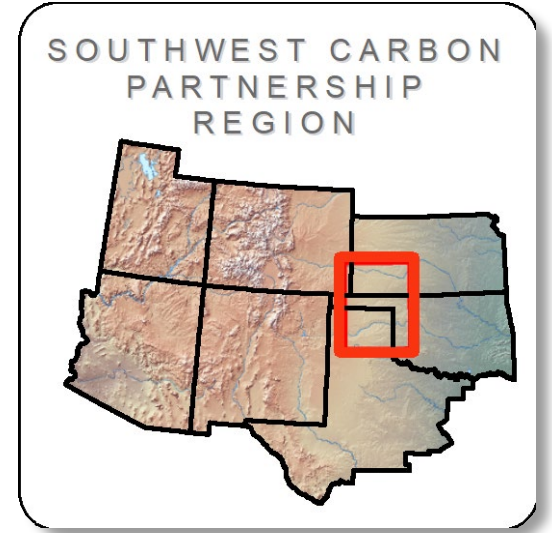
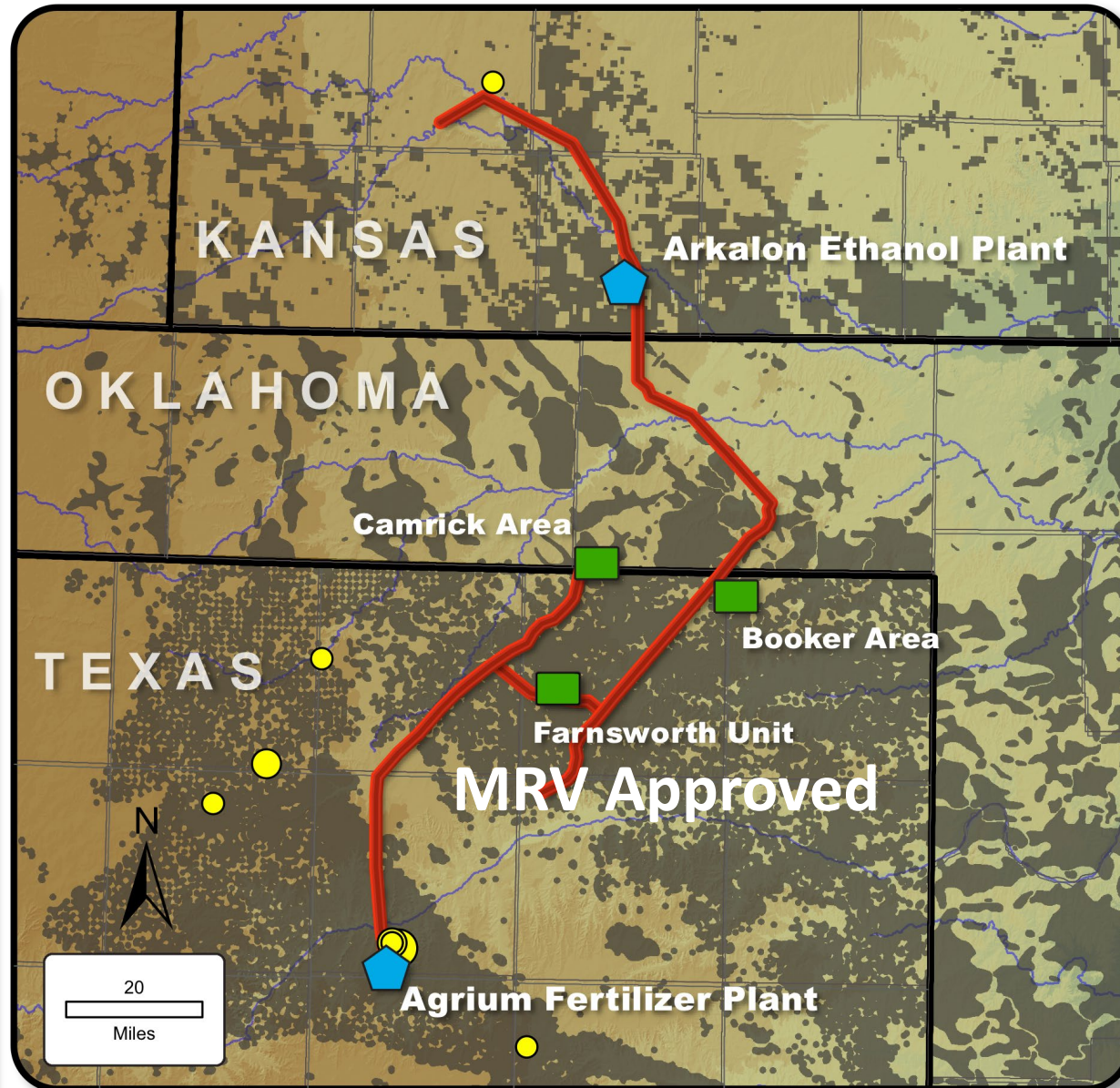
Oil and Gas basins

Saline Aquifers

Proven EOR Potential and Infrastructure



Anthropogenic Supply:
500-600,000
Metric tons
CO₂/year supply



Legend

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

Other CO₂ 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

Programmatic Goals of The Carbon Utilization and Storage Partnership For the Western USA (CUSP)

- Accelerate onshore CCUS technology deployment in the Western Region of the United States.
- Coordinate capabilities and experience within (and outside of) CUSP region to accelerate CCUS deployment in four key activities:
 - Addressing key technical challenges;
 - Facilitating data collection, sharing and analysis;
 - Evaluating regional infrastructure;
 - Promoting regional technology transfer.

CUSP – Original Scope of Work (2019)

- Focus on collecting, synthesizing, and using existing data sets.
- Data to 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 assessing, updating, augmenting, and verifying data used in data analysis and modeling

- Geological storage complexes (saline, stacked storage, ROZs)
- CO₂ emission sources
- Existing infrastructure

Strong emphasis on technology transfer and outreach

CUSP – Expanded Scope of Work (2020)

- While maintaining original scope and duration for atlas work (3 years) we added funds to each organization to cover tech transfer and education in the subsequent 2 years
- A portion of the new funds were set aside to support the Smart Initiative
- Funds set aside to jumpstart 45Q ready projects in the region
 - Farnsworth EOR project conversion to storage focus – **Perdure Petroleum** – Ion Conjunction with SWP team
 - Provide support for MRV planning at CarbonSAFE III San Juan Project – **Enchant Energy** – In conjunction with CarbonSafe San Juan team
 - Red Hills and Metropolis separation facilities, Permian basin – **Lucid Energy**

Progress and Current Status of Project

- Looking at Sources, Sinks, transportation pathways both existing and potential
- Have identified existing and several potential regional hubs
- Beginning process of refining Atlas style data and converting older static databases into self updating data sources
- Working towards integrating machine learning tools such as SimCCS to analyze results
- The project team has done an initial survey of the region for opportunities and issues related to those opportunities
- **Funding has been regular:**
 - ~\$6million (including cost-share) in 2019, 2020, and now in 2021
 - With the second round of funding we selected three companies to assist with MRV planning

Outreach

- The CUSP project has developed a website for dissemination of CCS/CCUS materials to the general public and more detailed geologic storage and economic data/analysis information to industry and stakeholders
- Educational videos are being developed to expand upon the information contained on the website; these will cover the many technical aspects and states within the CUSP region

The screenshot displays the CUSP West website. At the top right is the CUSP West logo and the text "CUSP West". Below this is a navigation menu with "About", "Team", "Contact Us", and "Member Area". A dropdown menu is open under "Team", showing "CUSP Partner States". The main heading reads "Carbon Utilization and Storage Partnership of the Western United States". On the left, a blue sidebar contains the text "Carbon Utilization and Storage Partnership (CUSP)" and "CUSP is a Department of Energy-funded Regional Initiative established to accelerate onshore CCUS technology deployment in the Western Region of the United States." The central part of the page features a map of the Western United States with a green overlay indicating the CUSP region. Various logos are placed on the map, including PNNL, DRI, Stanford University, ARIZONA GEOLOGICAL SERVICE, MONTANA STATE UNIVERSITY, MINES, Los Alamos, Sandia National Laboratories, UT, and CARBON SOLUTIONS LLC. A legend at the bottom left of the map shows a green square labeled "CUSP Region". On the right side, a vertical menu lists "About CUSP", "Partner States", "Projects", "Resources", "Links", and "FAQ".

Industry Advisory Board

- The CUSP project has called on a select group of energy sector representatives to advise the team on how best to engage and communicate with industry and other stakeholders, for the purpose of advancing CCS in the western USA
- The CUSP Industry Advisory Group has been formed and consists of members from:
 - State regulatory agencies
 - CO₂ emitters
 - CO₂ capture and transport companies
 - Oil/Gas operators
 - Policy think tanks



CO₂ CAPTURE

Large (>25,000 metric tons), stationary emission sources (power plants, cement factories, ethanol plants, etc) are fitted with special hardware to capture and concentrate produced CO₂, where it is then transported to a site for utilization and/or storage.

CO₂ TRANSPORT

Captured and concentrated liquid phase CO₂ is gathered for conveyance to a long-term storage site. The most economical form of CO₂ transport is by pipeline. For new capture-to-storage sites, CO₂ pipelines must be constructed along rights-of-way, often requiring significant legal and regulatory negotiations.

CO₂ STORAGE

Captured liquid phase CO₂ is transported to a utilization or storage site via pipeline. The CO₂ is injected into deep geologic formations. Over time,

Carbon Utilization and Storage Partnership

What is the Carbon Utilization and Storage Partnership (CUSP)? CUSP is a Department of Energy-funded Regional Initiative established to accelerate onshore CCUS technology deployment in the Western Region of the United States. The CUSP project is a research consortium of all or parts of 13 states, consisting of organizations throughout the western United States including academia, government agencies, national laboratories, and industry.

The Main Objectives of the CUSP Initiative

• Addressing Key Technical Challenges

The project will expand the understanding of storage in stacked and unconventional formations, with emphasis on optimizing storage and reducing uncertainty.

• Facilitating Data Collection, Sharing, and Analysis

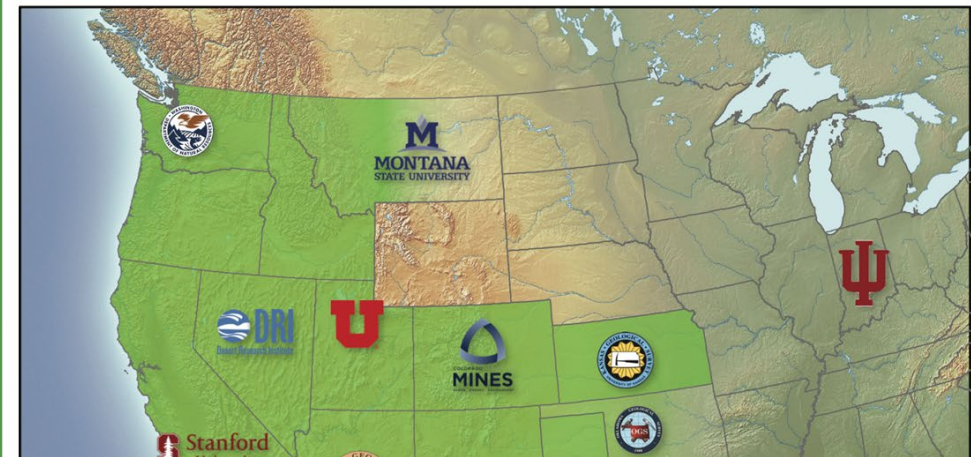
The project will consolidate and update the disparate and outdated datasets to improve the understanding of CO₂ injection, containment and economic feasibility.

• Evaluating Regional Infrastructure

The project will evaluate the requirements of a transportation network needed to deliver the captured CO₂ from the sources to the utilization and storage sites.

• Promoting Regional Technology Transfer

The project will engage, inform and educate CCUS stakeholders to facilitate technology transfer and the advancement of CCUS projects in the region.



2020 Case Study – Perdure Petroleum

- Perdure Petroleum operates the Farnsworth Unit, a CO₂ Enhanced Oil Recovery field in Ochiltree County, Texas
- The Farnsworth Unit has been injecting anthropogenic CO₂ from the Agrium fertilizer plant at Borger, Texas and the Arkalon ethanol plant at Liberal, Kansas
- Perdure plans to continue CO₂ EOR operations in the western half of the Farnsworth Unit, with likely expansion to EOR and storage in the eastern half of the unit
- The Perdure MRV plan for the Farnsworth Unit relies heavily on the work conducted by the Southwest Carbon Partnership, one of the NETL Regional Carbon Sequestration Partnerships



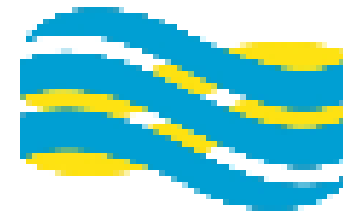
2020 Case Study – Enchant Energy



- Enchant Energy is part of the NETL CarbonSAFE initiative that will demonstrate that the storage complex in San Juan County, New Mexico can accelerate the deployment of CCS technology at the San Juan Generating Station (SJGS)
- Enchant Energy plans to retrofit the San Juan Generating Station, San Juan County, New Mexico with 6-7 MMT/yr CO₂ capture technology and locally store more than 2 MMT/yr CO₂
- Project is currently in the Characterization phase, with an upcoming stratigraphic test well; an EPA UIC Class VI permit application is being developed in parallel to the geologic characterization.

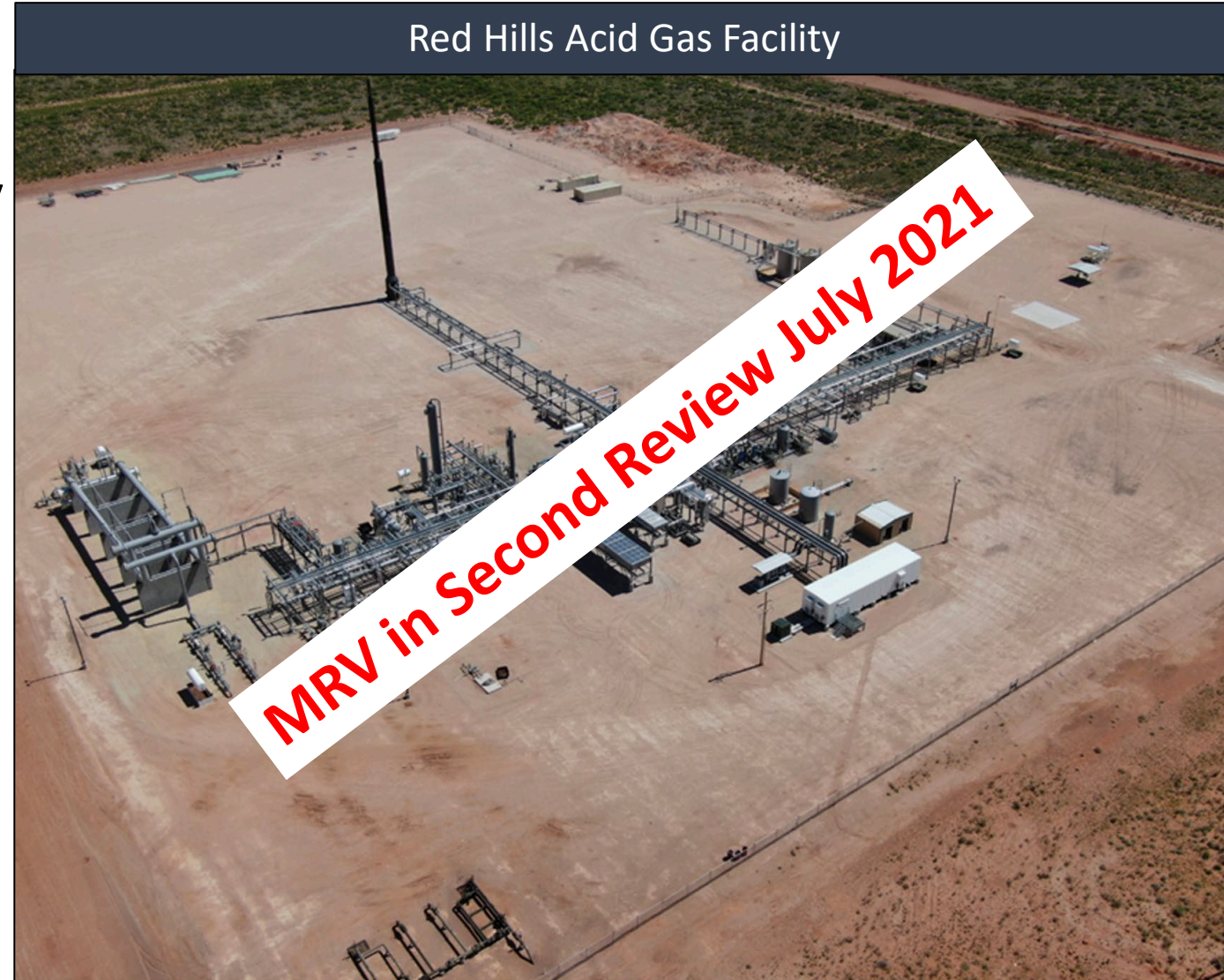


2020 Case Study – Lucid Energy



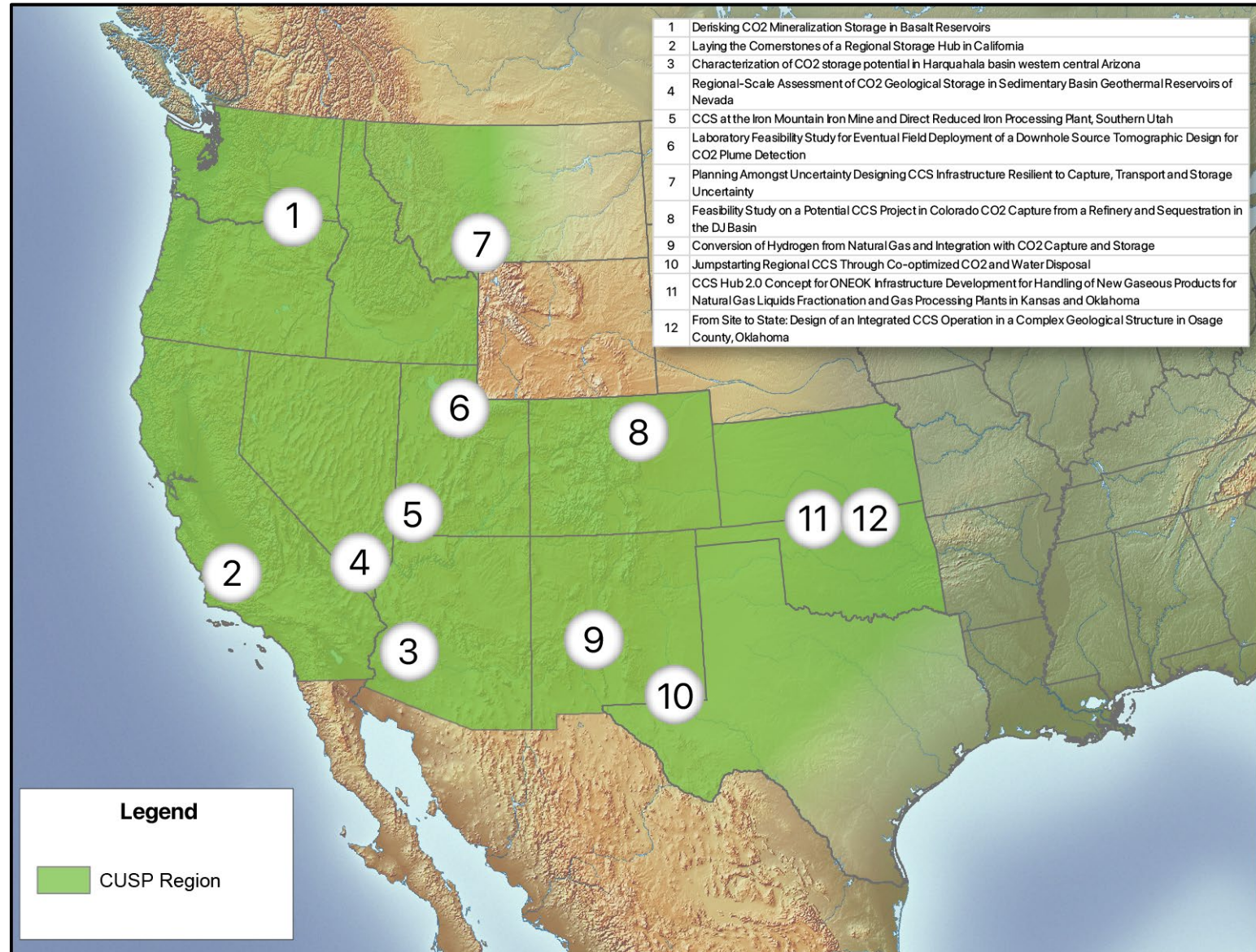
LUCID
ENERGY GROUP

- Lucid operates acid gas treating and disposal facilities at its Red Hills gas processing plant complex and Dagger Draw processing plants in Lea and Eddy County, New Mexico, respectively
- The Red Hills facility compresses and injects H₂S and CO₂ concentrations in the raw sour gas it receives into the facility
- Roughly 50% of Lucid's CO₂ emissions are from vented CO₂ resulting from Amine Treating
- Capturing, sequestering and storage of vented CO₂ is the most economic option to capture 45Q tax credits and impact Lucid's carbon footprint
- Additional CO₂ capture likely with proven economics



Selected 2021 Portfolio

- Internally selected by management team, the advisory board will assist if future funding is given
- 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 CO2 as Geothermal working fluid
- Includes development of regional Storage Hubs

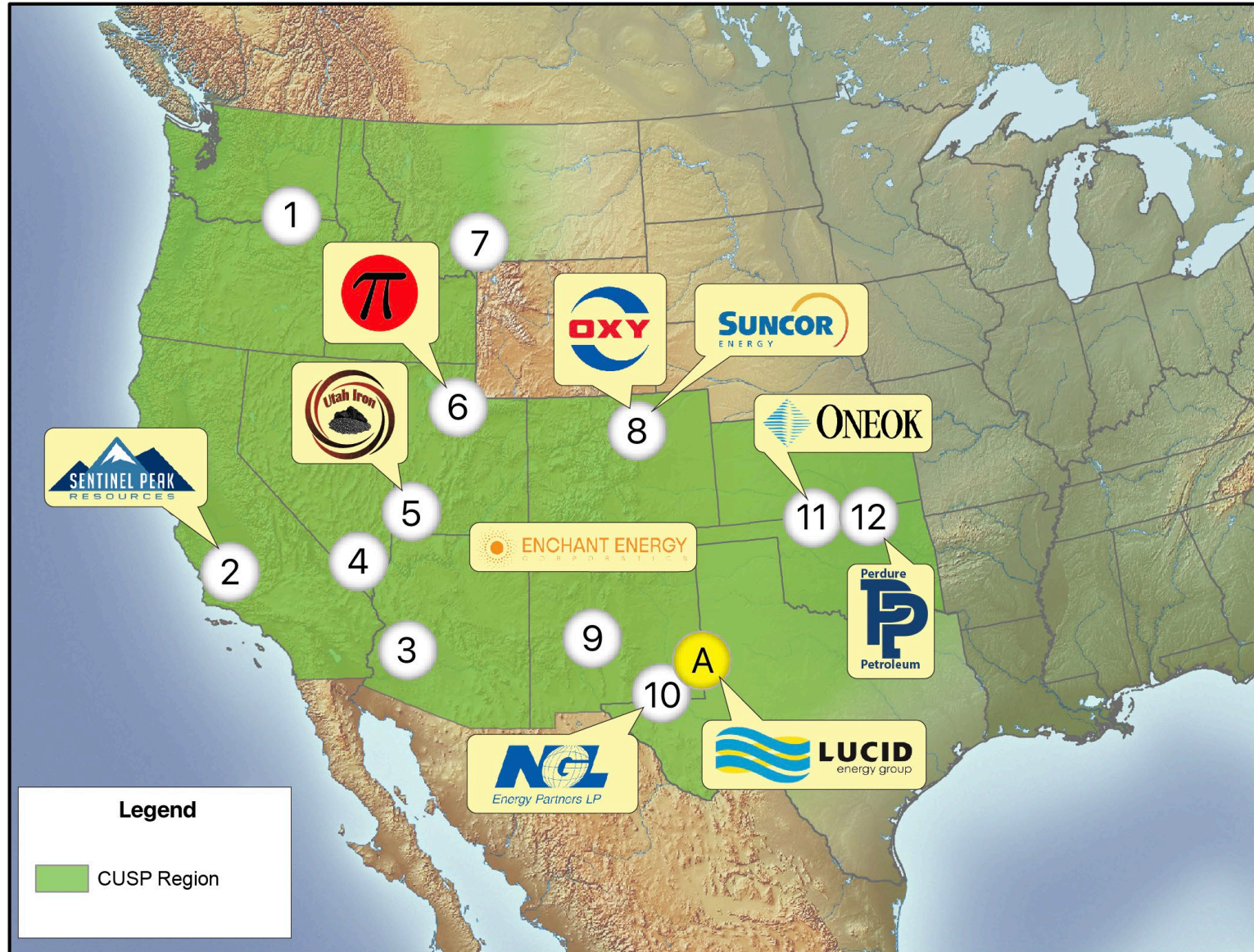


Selected 2021 Portfolio

- Industry engagement
 - Lucid Energy
 - Enchant Energy
 - Oxy Low Carbon Ventures
 - Sentinel Peak Resources
 - Perdure Petroleum
 - Suncor Energy
 - ONEOK
 - Utah Iron LLC
 - NGL Energy Partners
 - Paulsson Inc
 - And other interests...

**Carbon
America**

Schlumberger



Selected 2021 Portfolio

De-risking CO₂ Mineralization Storage in Basalt Reservoirs

This project seeks to address research gaps crucial to derisking and demonstrating commercial scale basalt storage, and to provide critical information to key stakeholders and developers seeking CO₂ storage opportunities in our region, and beyond.

Laying the Cornerstones of a Regional Storage Hub in California

This project seeks to accelerate the implementation of a shovel-ready pilot project by Sentinel Peak Resources to capture, transport, and store 70,000 tCO₂/yr from steam generation for thermal oil recovery, including supporting a Class VI well permit application.

CUSP Focused Project proposal: Characterization of CO₂ storage potential in Harquahala basin, western central Arizona

This project proposes multiple phases of work, including evaluation of existing seismic and gravity, that will eventually lead to testing of the Harquahala basin for CO₂ storage potential

Selected 2021 Portfolio

Regional-Scale Assessment of CO₂ Geological Storage in Sedimentary Basin Geothermal Reservoirs of Nevada

The objectives of the proposed effort are to: 1) perform a regional-scale assessment to fill a data gap of critical information related to CCUS technologies to mitigate CO₂ emissions in Nevada, and 2) to develop an approach to regionally assess the potential that using CO₂ geological storage in sedimentary basin geothermal reservoirs may have for increasing the states capability for CCUS.

CCS at the Iron Mountain Iron Mine and Direct Reduced Iron Processing Plant, Southern Utah

This project will seek to deploy a commercial-scale carbon capture and storage site at or near its Iron Mountain iron mine, near Cedar City, Utah, so that the project partners can build an iron processing plant near the mine, which will produced CO₂ as a by-product

Laboratory Feasibility Study for Eventual Field Deployment of a Downhole Source Tomographic Design for CO₂ Plume Detection

This project will seek to develop a thorough design plan for both laboratory and field-scale testing (feasibility study) of a novel seismic tomography technology to significantly improve CO₂ plume monitoring

Selected 2021 Portfolio

Planning Amongst Uncertainty: Designing CCS Infrastructure Resilient to Capture, Transport, and Storage Uncertainty

The overarching aim of this project is to develop a CCS infrastructure design model that will endogenously account for uncertainty throughout the CCS supply chain, with a particular focus on storage uncertainty.

Feasibility Study on a Potential CCUS Project in Colorado: CO2 Capture from a Refinery and Sequestration in the DJ Basin

This project seeks to: 1) assess the technology and economic feasibility of capturing CO2 from a refinery by Suncor; 2) study transport by CSM; 3) sequestering the purified CO2 to a nearby saline aquifer in Colorado by Oxy; 4) evaluate sequestration by CO2-EOR opportunities in conventional and unconventional reservoirs by CSM and 5) develop monitoring and verification program by CSM.

Conversion of Hydrogen from Natural Gas and Integration with CO2 Capture and Storage

This project will seek to generate lab-scale data for the conversion and clean-up of hydrogen from natural gas taking into account contaminants introduced with produced water used as a process stream.

Selected 2021 Portfolio

Jumpstarting Regional CCUS Through Co-optimized CO₂ and Water Disposal

This project has an overall goal of developing and formalizing a new and novel approach to accelerate commercial-scale CCUS, complementing existing approaches, including Class VI CO₂ storage, CO₂-enhanced oil recovery (CO₂-EOR), and acid gas injection.

CCUS 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

This study aims to identify potential CO₂ reservoirs for long-term saline storage or Enhanced oil Recovery (EOR) in the area surrounding ONEOK natural gas liquids fractionation plants near Bushton, KS, and Medford, OK, as well as several gas processing plants in Oklahoma that emit ~1M tonnes of CO₂ per annum.

From Site to State: Design of an Integrated CCUS Operation in a Complex Geological Structure in Osage County, Oklahoma

This project will work with Perdure Petroleum LLC, a major CO₂-EOR operator in Oklahoma, to develop the plan for a Class IV permit application for sequestration into the Arbuckle formation at their existing CO₂-EOR site in Osage County.

2021 Portfolio - Timeline

- Industry engagement
 - Lucid Energy
 - Enchant Energy
 - Oxy Low Carbon Ventures
 - Sentinel Peak Resources
 - Perdure Petroleum
 - Suncor Energy
 - ONEOK
 - Utah Iron LLC
 - NGL Energy Partners
 - Paulsson Inc
 - And other interests...

**Carbon
America**

Schlumberger

Task	Title	2019		2020				2021				2022				2023				2024					
		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4		
Project CUSP_short_2021_0602		[Timeline bar]																							
1	Project Management and Planning	[Timeline bar]																							
1.1	Update Project Management Plan	[Timeline bar]																							
2	Addressing Key Technical Challenges	[Timeline bar]																							
2.1	Expand characterization of stacked and unconventional storage	[Timeline bar]																							
2.2	Develop collaborations for key technologies	[Timeline bar]																							
2.3	Collaborate with industrial partners for monitoring/verification strategies	[Timeline bar]																							
2.4	Development & validation of risk assessment/mitigation strategies for CCUS sites	[Timeline bar]																							
3	Facilitating Data Collection, Sharing, and Analysis	[Timeline bar]																							
3.1	Engaging with national laboratories	[Timeline bar]																							
3.2	Apply NRAP tools to assess geologic risks	[Timeline bar]																							
3.3	Provide synthesized data to DOE's machine learning initiative	[Timeline bar]																							
4	Evaluating Regional Infrastructure	[Timeline bar]																							
4.1	Catalog, map, and evaluate extant and near-term CO2 distribution network	[Timeline bar]																							
4.2	Identify and add rights-of-way for new pipelines (main lines and otherwise).	[Timeline bar]																							
4.3	Regulatory/policy impact assessment	[Timeline bar]																							
4.4	Economic assessment	[Timeline bar]																							
4.5	Focused scenario analysis	[Timeline bar]																							
4.6	Develop regional readiness indices	[Timeline bar]																							
5	Promoting Regional Technology Transfer	[Timeline bar]																							
5.1	Development of regional readiness indices maps	[Timeline bar]																							
5.2	Technology transfer forums	[Timeline bar]																							
5.3	Targeted network development	[Timeline bar]																							
5.4	Support DOE	[Timeline bar]																							
P1	Derisking CO ₂ Mineralization Storage in Basalt Reservoirs	[Timeline bar]																							
P2	Laying the Cornerstones of a Regional Storage Hub in California	[Timeline bar]																							
P3	Characterization of CO ₂ storage potential in Harquahala basin western central Arizona	[Timeline bar]																							
P4	Regional-Scale Assessment of CO ₂ Geological Storage in Sedimentary Basin Geothermal Reservoirs of Nevada	[Timeline bar]																							
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P9	Conversion of Hydrogen from Natural Gas and Integration with CO ₂ Capture and Storage	[Timeline bar]																							
P10	Jumpstarting Regional CCS Through Co-optimized CO ₂ and Water Disposal	[Timeline bar]																							
P11	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	[Timeline bar]																							
P12	From Site to State: Design of an Integrated CCS Operation in a Complex Geological Structure in Osage County, Oklahoma	[Timeline bar]																							

Take Aways

- The CUSP is actively seeking opportunities to help companies access 45Q
- Has experience in generating CO2 storage models, MRV applications, and in engaging with stakeholders
- Has databases of useful information necessary to create robust geologic models, flow models, and economics
- Has access to Intelligent computer applications and National Lab products which can optimize connecting sources and syncs, and long range development and economic analyses of projects
- **Funding has been regular...**
 - ~\$6million in 2019, 2020, and now in 2021
 - Full allotment of DOE funds used for 2021 selected project
 - If additional funds given in Future will select an additional 5-10 projects in the region

CUSP Members



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NATIONAL LABORATORY

