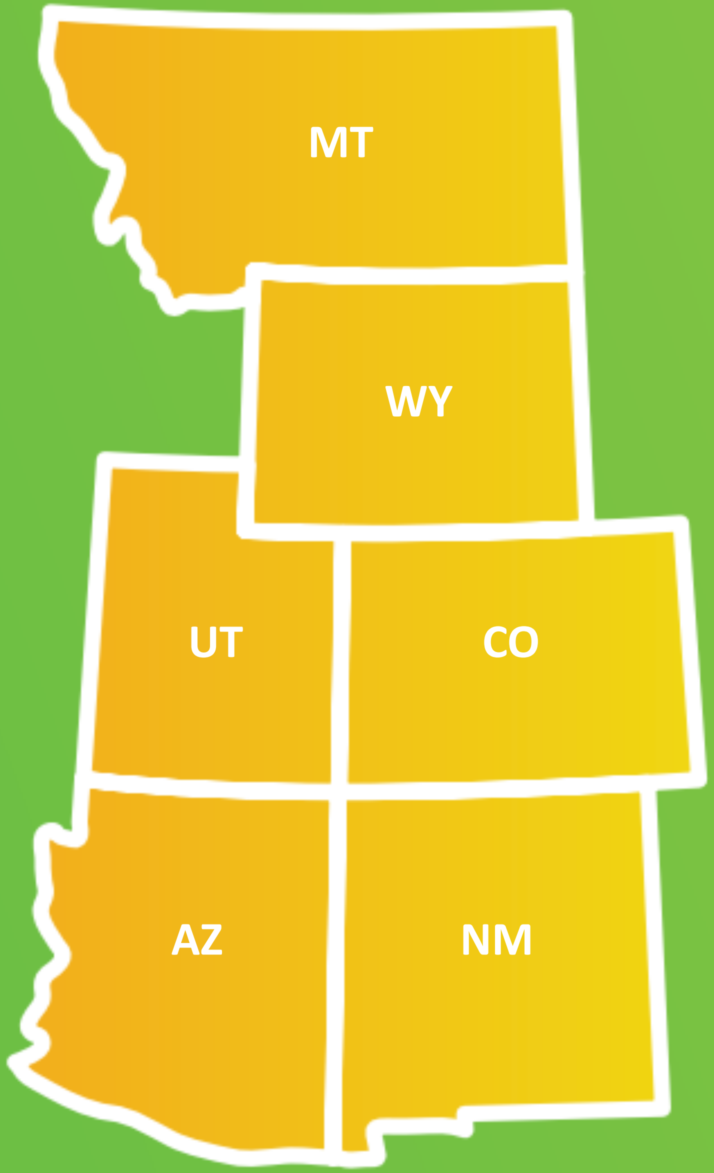
I-WEST

Seminar Series

June 7, 2023

LA-UR-23-26099



I-WEST provides Intermountain West states with data, tools, and information for energy transition planning

- Place-based approaches focus on the unique geographical, environmental, and demographic attributes of the region
- Technology-neutral approach leverages opportunities across numerous symbiotic energy economies
- Integrated approaches to assessing technology readiness in tandem with societal readiness for a just and equitable energy transition
- Community engaged research and coalition building to encourage regional partnerships

I-WEST

TODAY'S SEMINAR

Pathways to CO_2 Utilization and Storage for the Intermountain West Region

Dr. Derek Vikara

National Energy Technology Laboratory

Dr. Bailian Chen

Los Alamos National Laboratory

Featuring data and key findings
from the I-WEST Phase One report

I-WEST

Intermountain West Energy Sustainability & Transitions

On the road to carbon neutrality in the Intermountain West

Phase One Final Report
December 2022

LA-UR-22-32428

Version 1

Please enter your questions in the chat and stay on for Q&A at the end.

Overview of the Pathways to CO_2 Utilization and Storage for the Intermountain West Region

I-WEST Seminar Series
June 7, 2023

Derek Vikara[1] and Bailian Chen[2]

[1]National Energy Technology Laboratory (NETL), NETL support contractor
[2]Los Alamos National Laboratory

I-WEST Team

ASU

UW
School of Energy Resources

THE UNIVERSITY OF UTAH

NM

SAN JUAN COLLEGE

COLORADO SCHOOL OF MINES

RESOURCES for the FUTURE

NEW MEXICO TECH
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MONTANA STATE UNIVERSITY

Los Alamos NATIONAL LABORATORY
Lead Organization

U.S. DEPARTMENT OF ENERGY
Sponsor

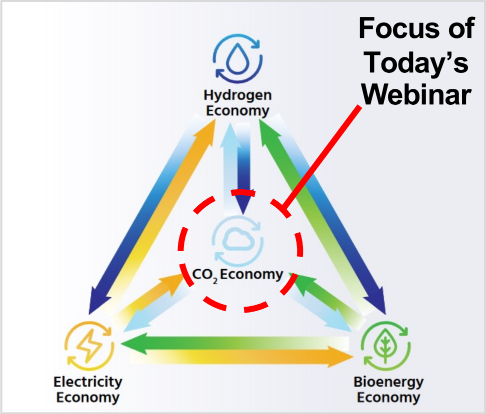
I-WEST Overview: the Road To Carbon Neutrality in the Intermountain West

Objectives

- Develop a regional, stakeholder-informed technology “roadmap” for a sustainable and equitable transition to carbon neutral.
- Facilitate regional coalitions to implement and deploy the roadmap.

Place-based Approach

- Prioritize regional attributes and societal readiness first and technologies second.
- Explicitly consider the non-technological aspects of a region—policy landscape, revenue and jobs, workforce, equity, and energy and environmental justice.
- Consider the interplay of multiple technology pathways that support the growth of symbiotic economies.



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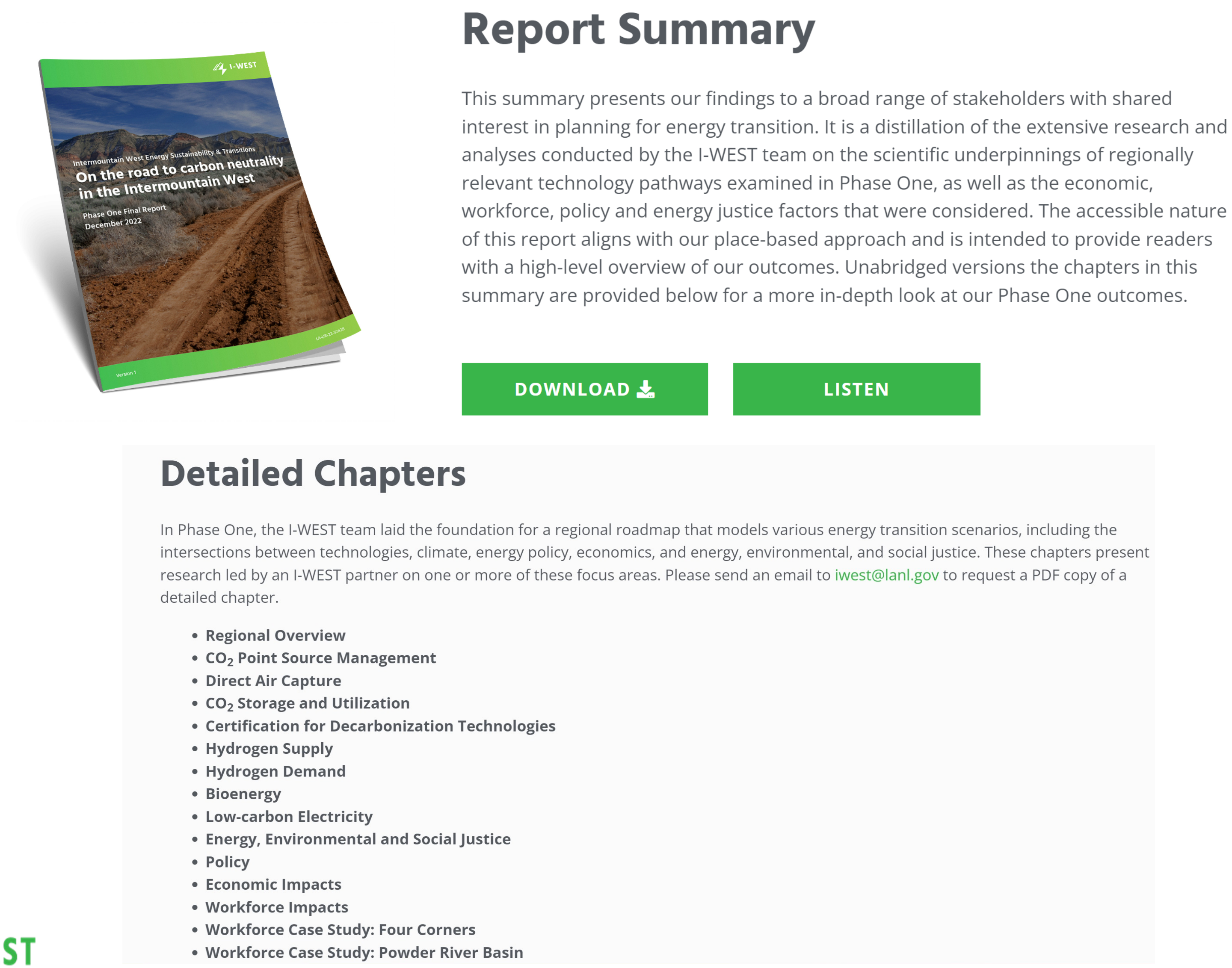
Phase I Final Report Available Online

https://iwest.org/phase-one-final-report/



Report Summary

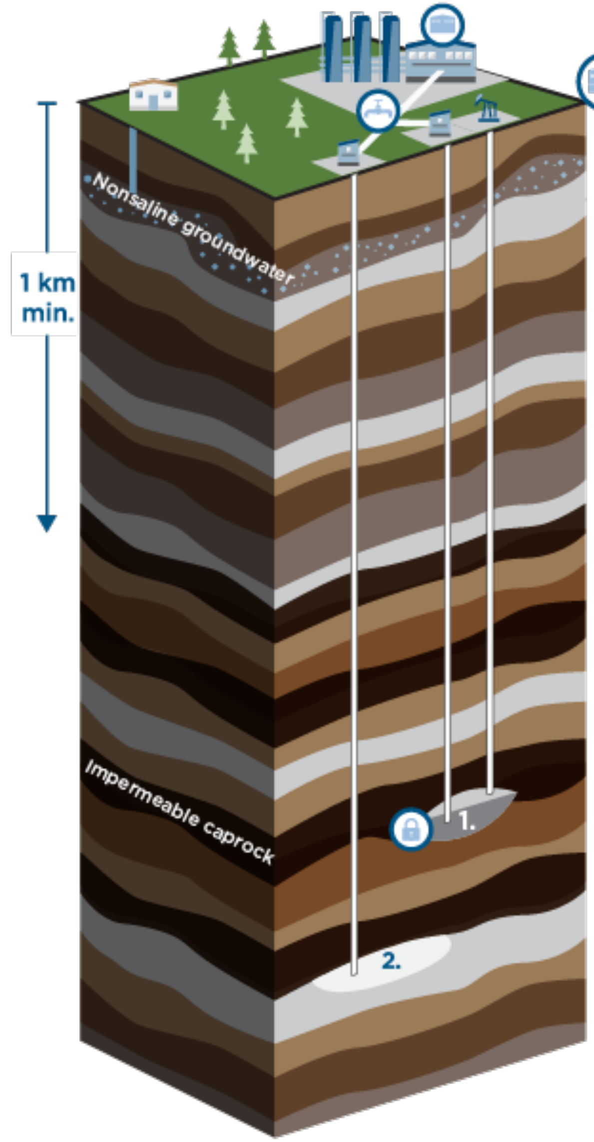
This summary presents our findings to a broad range of stakeholders with shared interest in planning for energy transition. It is a distillation of the extensive research and analyses conducted by the I-WEST team on the scientific underpinnings of regionally relevant technology pathways examined in Phase One, as well as the economic, workforce, policy and energy justice factors that were considered. The accessible nature of this report aligns with our place-based approach and is intended to provide readers with a high-level overview of our outcomes. Unabridged versions the chapters in this summary are provided below for a more in-depth look at our Phase One outcomes.

Detailed Chapters

In Phase One, the I-WEST team laid the foundation for a regional roadmap that models various energy transition scenarios, including the intersections between technologies, climate, energy policy, economics, and energy, environmental, and social justice. These chapters present research led by an I-WEST partner on one or more of these focus areas. Please send an email to iwest@lanl.gov to request a PDF copy of a detailed chapter.

- **Regional Overview**
- **CO_2 Point Source Management**
- **Direct Air Capture**
- **CO_2 Storage and Utilization**
- **Certification for Decarbonization Technologies**
- **Hydrogen Supply**
- **Hydrogen Demand**
- **Bioenergy**
- **Low-carbon Electricity**
- **Energy, Environmental and Social Justice**
- **Policy**
- **Economic Impacts**
- **Workforce Impacts**
- **Workforce Case Study: Four Corners**
- **Workforce Case Study: Powder River Basin**

Carbon Capture, Utilization, and Storage (CCUS) Overview



CAPTURE
Capturing CO_2 from industrial and energy-related processes.

TRANSPORT
Transporting CO_2 by pipeline.

STORAGE
1. CO_2-EOR.
2. Dedicated storage.

USE
- Feedstock for fuels, chemicals, and materials.

Benefits of CCUS

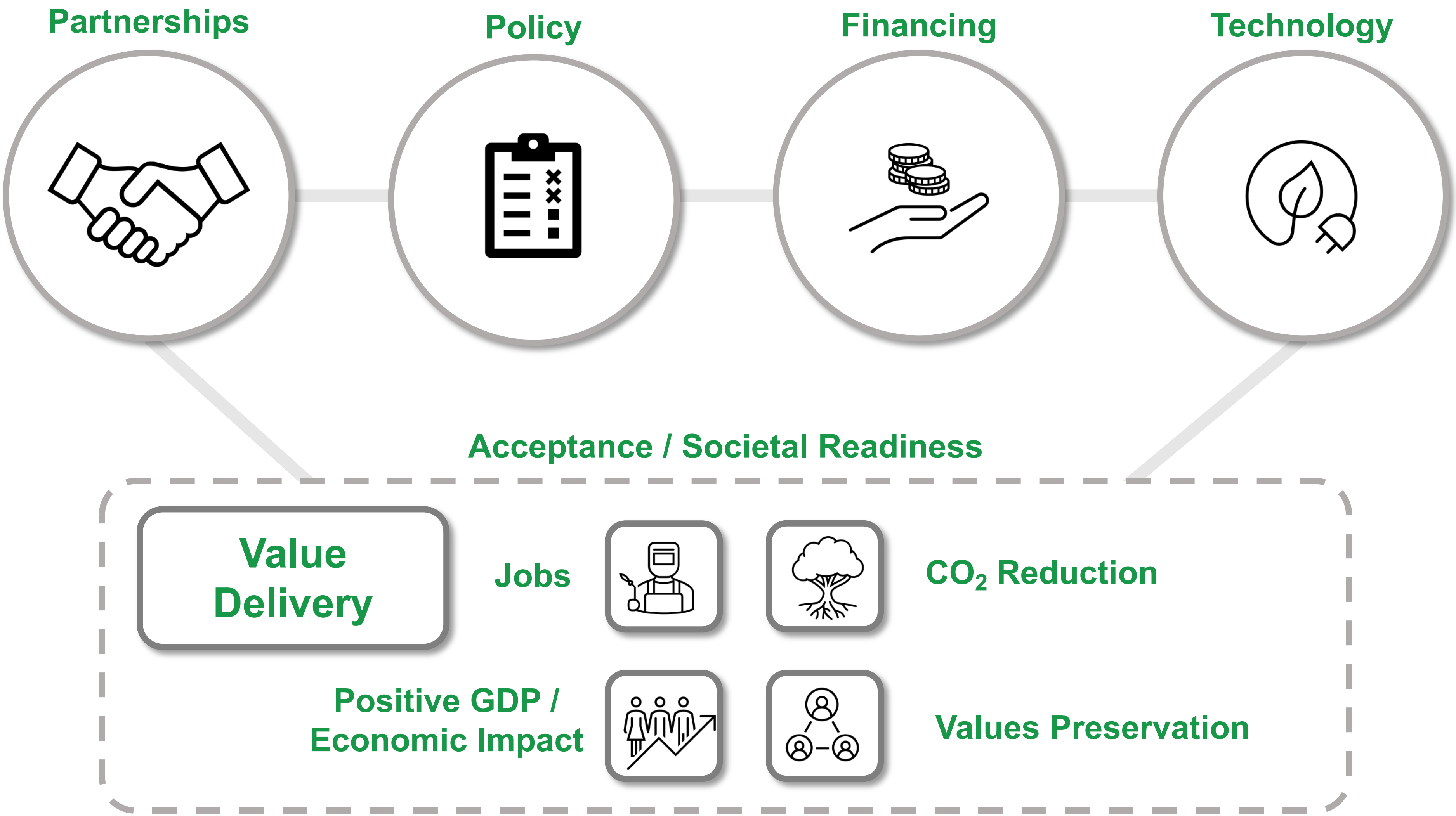
- ✓ Value chain component technologies are largely matured.
- ✓ Offers deep decarbonization potential for power and industrial point sources.
- ✓ Critical technology for achieving net-zero pathways.
- ✓ Has linkages with emerging industries such as hydrogen, bioenergy, and atmospheric CO_2 removal.

Regulating CCUS in the U.S.

- U.S. EPA enforces regulations associated with CO_2 injection in the subsurface under its Underground Injection Control (UIC) Program.
- UIC sets minimum technical criteria for the permitting, site characterization, corrective action (if necessary), financial responsibility, well construction, operation, monitoring, well plugging, post-injection site care (PISC), and site closure for the purposes of protecting underground sources of drinking water.

Picture from the Alberta Energy Regulator Website:
https://www.aer.ca/providing-information/by-topic/carbon-capture

Enabling Mechanisms for CCUS



Partnerships

Policy

Financing

Technology

Acceptance / Societal Readiness

Value Delivery

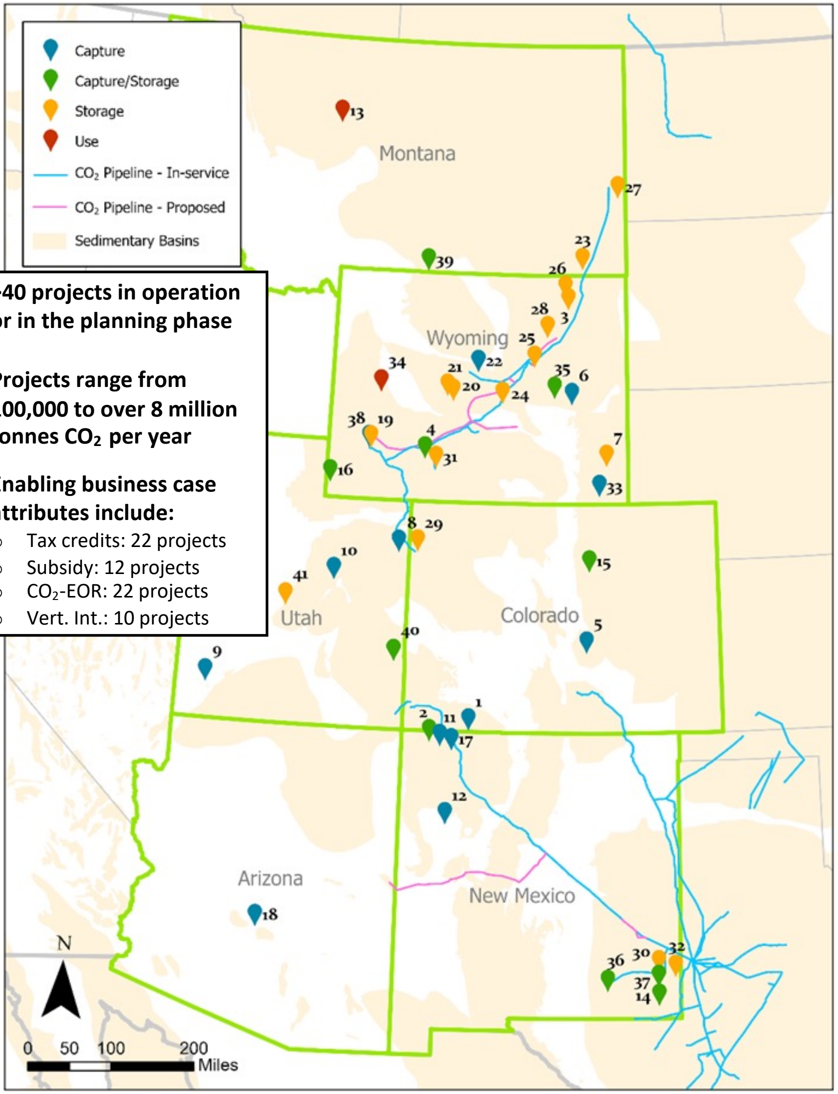
Jobs

CO_2 Reduction

Positive GDP / Economic Impact

Values Preservation

CCUS Is Ramping Up in the I-WEST Region



- **>40 projects in operation or in the planning phase**
- **Projects range from 100,000 to over 8 million tonnes CO_2 per year**
- **Enabling business case attributes include:**
  - Tax credits: 22 projects
  - Subsidy: 12 projects
  - CO_2-EOR: 22 projects
  - Vert. Int.: 10 projects

Project Name	Tax Credit	Grant Funding	Regulatory Requirement or Benefit	Pipeline Quality Requirement	Enhanced Oil Recovery	Vertically Integrated
1) Coyote Clean Power Project	🟧				🟩	
2) CarbonSAFE New Mexico: San Juan Basin	🟧	🟨			🟩	🟥
3) CarbonSAFE Wyoming: Dry Forks Station	🟧	🟨			🟩	🟥
4) Jim Bridger Plant Capture	🟧	🟨	🟦		🟩	
5) LH CO_2MENT Colorado Project	🟧	🟨				
6) Project Blue Bison (Blue Hydrogen)	🟧	🟨				
7) Eastern Wyoming Sequestration Hub	🟧	🟨				
8) Bonanza Power Plant CCS Project	🟧					
9) CCS at Iron Mountain Iron Mine	🟧		🟦			🟥
10) Utah Blue Ammonia	🟧					
11) Libertad Energy Project - Hydrogen	🟧					
12) Escalante H_2 Power Project	🟧					
13) Montana Renewables - Renewable Diesel						
14) Red Hills Acid Gas	🟧			🟪		🟥
15) Commerce City Refinery	🟧		🟦		🟩	
16a) North Shore Energy - Clean H_2	🟧	🟨				
16b) Project Phoenix	🟧	🟨				
17) Big Navajo Hydrogen Pilot Project		🟨				
18) MechanicalTree - DAC	🟧	🟨				
19) Shute Creek Gas Processing Facility	🟧		🟦		🟩	
20) Big Sand Draw Oil Field CO_2-EOR					🟩	
21) Beaver Creek Oil Field CO_2-EOR					🟩	
22) Lost Cabin Gas Processing Facility	🟧				🟩	
23) Bell Creek Oil Field CO_2-EOR					🟩	
24) Grieve CO_2-EOR					🟩	
25) Salt Creek CO_2-EOR					🟩	
26) Gas Draw CO_2-EOR					🟩	
27) Cedar Creek Anticline CO_2-EOR					🟩	
28) Hartzog Draw CO_2-EOR					🟩	
29) Rangely Weber Sand Unit CO_2-EOR					🟩	
30) Vacuum CO_2-EOR					🟩	
31) Patrick Draw Monell CO_2-EOR					🟩	
32) Hobbs CO_2-EOR	🟧				🟩	
33) Wyoming Hydrogen Demonstration Pilot	🟧	🟨				
34) Jonah Energy - Green H_2 through Power to Gas		🟨				
35) Dave Johnson Power Plant capture	🟧				🟩	
36) Eddy County, NM Acid Gas Injection				🟪		🟥
37) Lea County, NM Acid Gas Injection				🟪		🟥
38) Shute Creek Acid Gas Injection				🟪		🟥
39) EBET2 001 Acid Gas Injection				🟪		🟥
40) Lisbon Unit D-716 Acid Gas Injection				🟪		🟥
41) Providence Fed 24-4 CO_2-EOR					🟩	🟥

For project-level info: https://iwest.org/current-regional-initiatives/

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CCUS Examples From the I-WEST Region

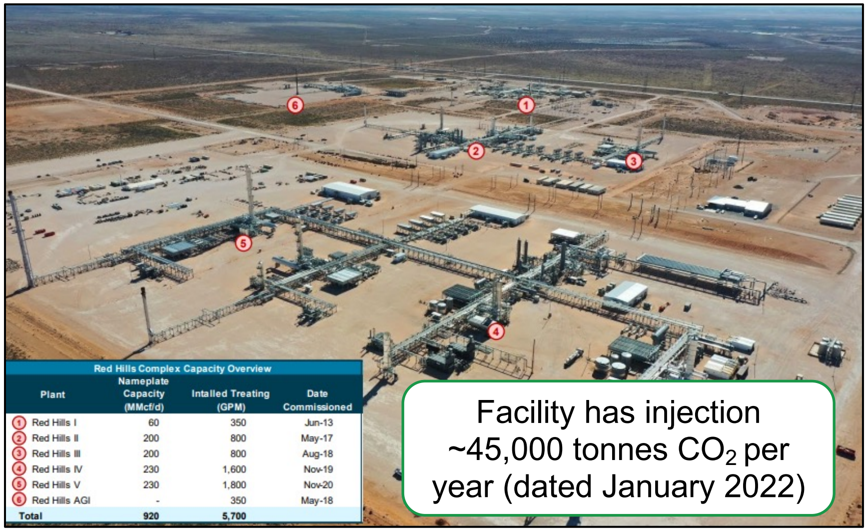
Red Hills Acid Gas Facility

Lucid Energy Group

Red Hills V gas processing facility in Lea County, New Mexico -capacity of 230 MMcf/d

Facility compresses and injects H_2S and CO_2 concentrations in the raw sour gas it receives into the facility.

- 87% CO_2 / 12% H_2S mixture.
- UIC Class II wells.
- MRV plans in place for tracking stored volumes.
- 45Q tax credits improve economics.
- Storage reduces Lucid's overall carbon footprint.



Red Hills Complex Capacity Overview

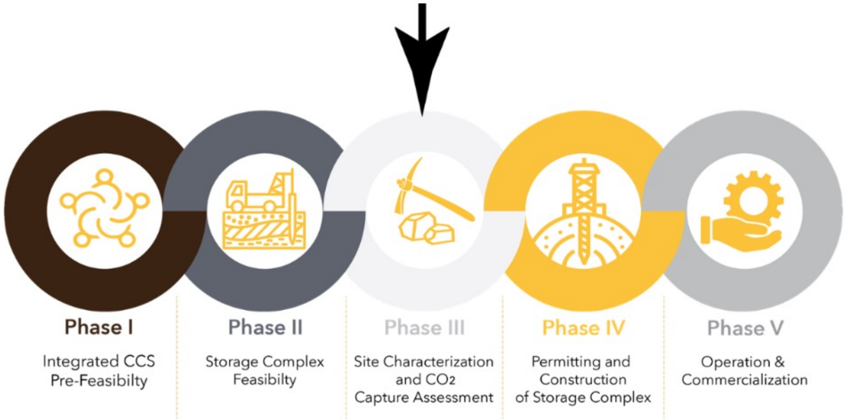
Plant	Nameplate Capacity (MMcf/d)	Intalled Treating (GPM)	Date Commissioned
① Red Hills I	60	350	Jun-13
② Red Hills II	200	800	May-17
③ Red Hills III	200	800	Aug-18
④ Red Hills IV	230	1,600	Nov-19
⑤ Red Hills V	230	1,800	Nov-20
⑥ Red Hills AGI	-	350	May-18
Total	920	5,700	

Facility has injection ~45,000 tonnes CO_2 per year (dated January 2022)

Image from CUSP website: https://www.cuspwest.org/wp-content/uploads/2022/08/Lucid-Energy-Group-Red-Hills-AGI-Overview.pdf

CarbonSAFE Wyoming

University of Wyoming



Phase I
Integrated CCS Pre-Feasibilty

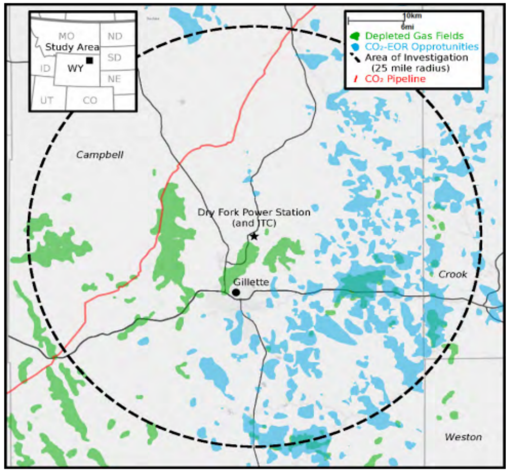
Phase II
Storage Complex Feasibilty

Phase III
Site Characterization and CO2 Capture Assessment

Phase IV
Permitting and Construction of Storage Complex

Phase V
Operation & Commercialization

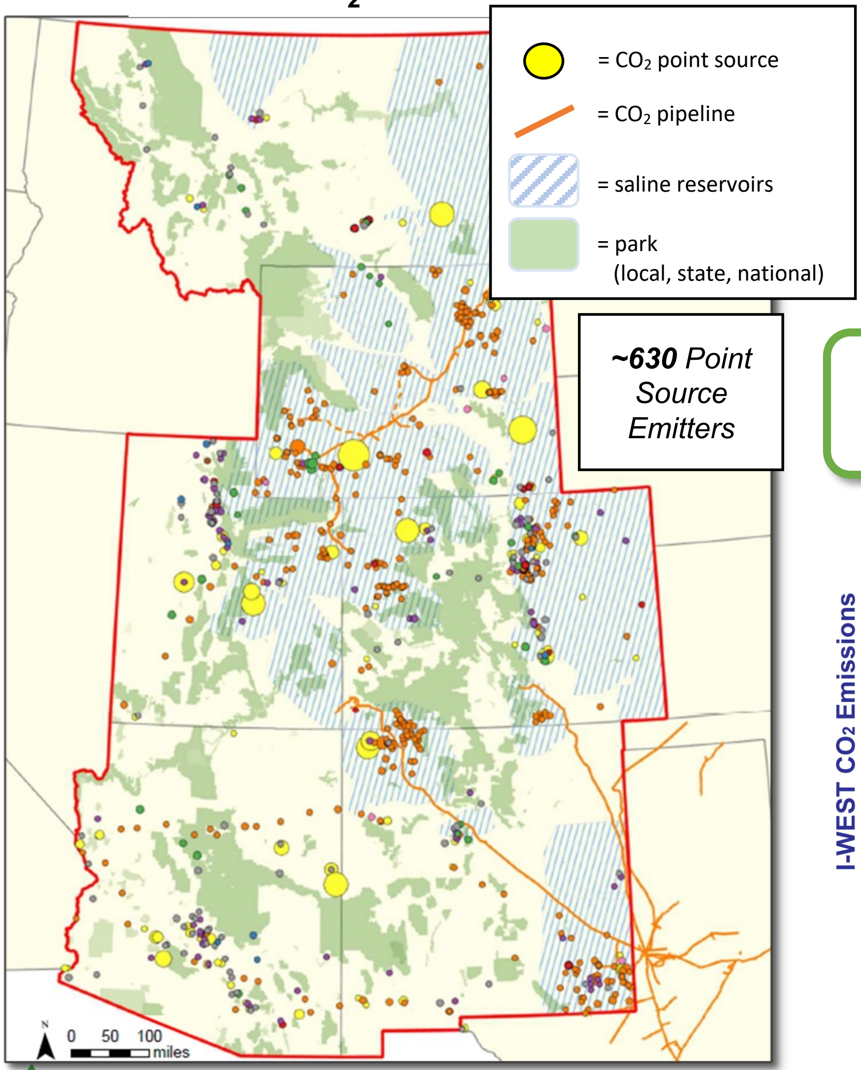
- Project aims to characterize storage targets for CO_2 captured from the **Basin Electric Power Cooperative's 483-megawatt coal-based Dry Fork Station** in Gillette, Wyoming.
- Determining if potential CO_2 storage zones and caprocks exist to safely accommodate and permanent store CO_2 on a scale of **upwards of 50+ million tonnes of CO_2.**



CO_2 storage and transportation opportunities identified within 25 miles of the Dry Forks Station

I-WEST CO_2 Emissions and Reduction Pathways

I-WEST CO_2 Point Sources



~630 Point Source Emitters

Source: EPA Flight Data (2022)

Point Sources CO_2e Emissions

243 Mt / yr

Largest Emissions Sectors

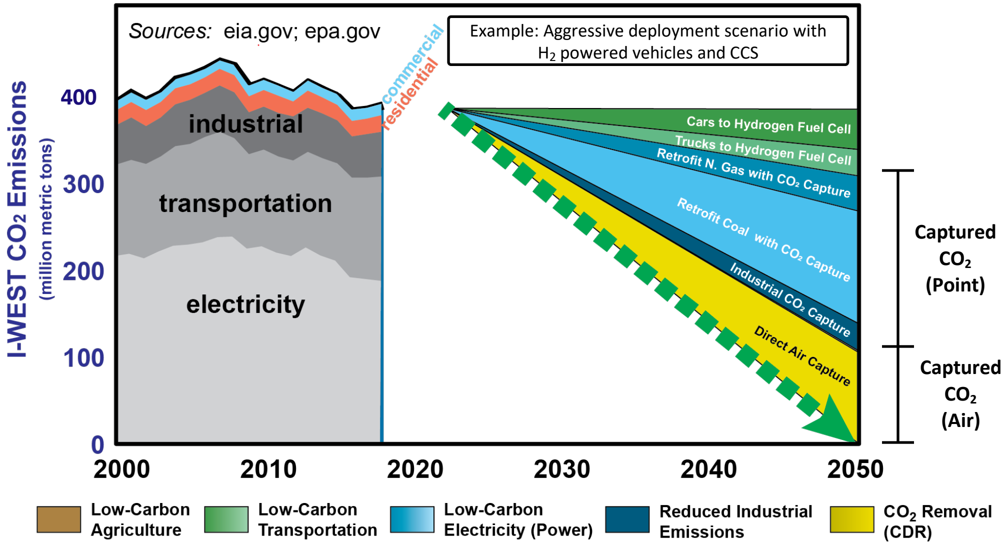
Power – 66%
Pet / NG – 20%

Emission Reduction Timeline

5-year
30 $MtCO_2$ / yr

10-year
100 $MtCO_2$ / yr

30-year
400 $MtCO_2$ / yr



Sources: eia.gov; epa.gov

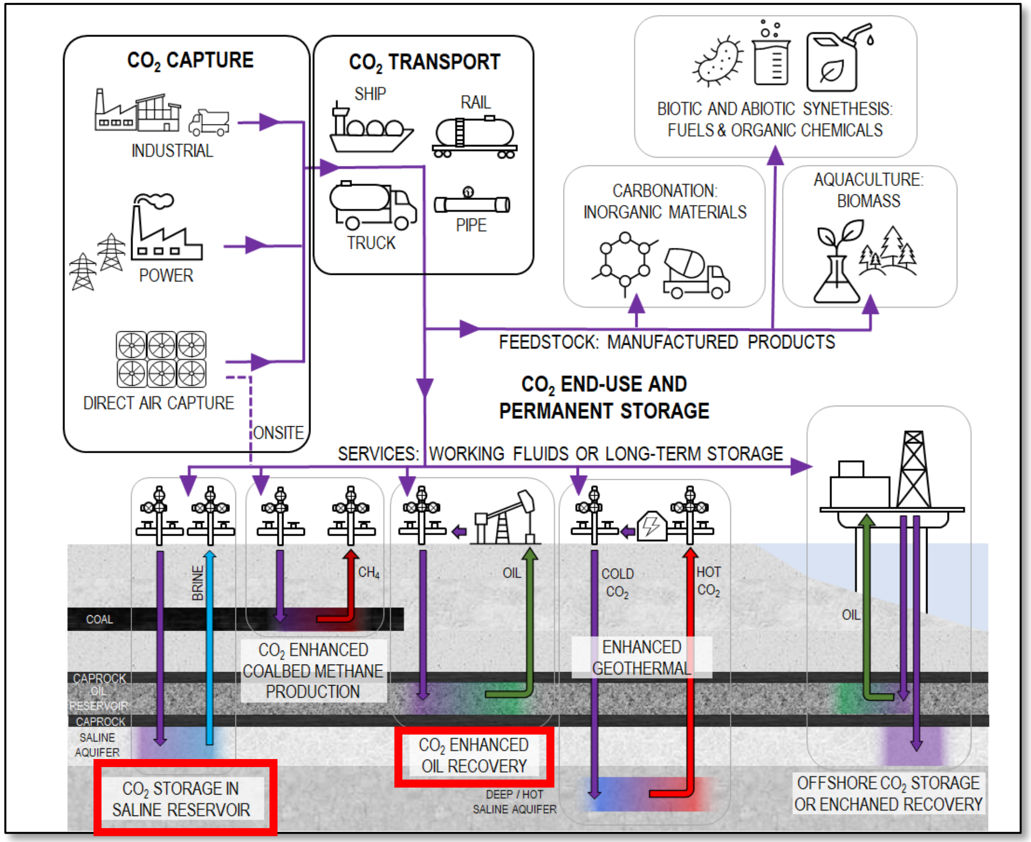
Example: Aggressive deployment scenario with H_2 powered vehicles and CCS

I-WEST

I-WEST CCUS Pathway Assessment Objectives

Evaluate the opportunity for CCUS to deploy at significant scale in the I-WEST region.

1. Identify regionally relevant opportunities and roadblocks given regionally relevant attributes.
2. Mitigate perceived technical/business risk with critical insight to promote widespread adoption.
3. Emphasize how projects are blending technology and policy support to create positive regional economic benefits.
4. Outline next steps to facilitate further deployment.
    - Consider synergies of existing power and industrial economies.
    - Identify research gaps and needs.
    - Support alignment of CCUS with new and emerging economies related to hydrogen, bioenergy, and direct air capture (DAC).



Multiple configurations exist across the CCUS value chain.

Process for Gaining “Place-Based” Insight

Workshops: discussions with regional stakeholders

- State/tribal-level outreach workshops.
- Technical roundtable.
- Socio-economic and policy roundtable.

I-WEST | STAKEHOLDER WORKSHOP SERIES

The Role of Carbon Storage and Geologic Utilization in Meeting Regional Carbon-neutrality Goals

Workshop Information:
Date: December 14, 2021
Time: 9:00 am – 1:00 pm MT

The Intermountain West Energy Sustainabili
delivering a regionally relevant technology r
states to a carbon-neutral energy economy.
New Mexico, Utah, and Wyoming. The proje
the geographical attributes, economic lands
online at www.iwest.org.

Why join this workshop?

Technologies to capture carbon dioxide, cou
(CCUS), are important components in a strat
can play a significant role economically as c
systems. This workshop will solicit perspecti
CO_2 storage and utilization in the Intermoun

The primary goal of the workshop is to iden
technologies that will evolve over the next 5,
to

- define and describe how captured CO_2 ca
  methods in support of regional carbon ma
- develop a consensus on the likely growth
  next 15 years, based on currently availabl
- identify technological and non-technologi
  this economic opportunity (e.g., as related
- facilitate networking across CO_2 storage
  collaboration, and discuss pathways to bu
- share experiences, lessons learned, and
  planning to conduct CO_2 storage/utilizatio

Input received at this workshop will feed dir
expert knowledge will be presented by field
projects.

Informative and Interactive

The format of this workshop will be a combi
utilization topics by current or emerging pro
2) facilitated discussions in which participan

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Intermountain West Energy Sustainability & Transitions

WORKSHOP SUMMARY

The Role of Carbon Storage and Geologic Utilization
in Meeting Regional Carbon-neutrality Goals

Virtual workshop held December 14, 2021

WORKSHOP FACILITATORS

Derek Vikara (derek.vikara@netl.doe.gov)
Timothy Grant (timothy.grant@netl.doe.gov)
Lee Spangler (spangler@montana.edu)
David Morgan (david.morgan@netl.doe.gov)
Kipp Coddington (kcodding@uwyo.edu)

I-WEST PRINCIPAL INVESTIGATOR

Rajesh Pawar
(rajesh@lanl.gov)

I-WEST PROJECT MANAGER

Rachel Atencio
(Rcatencio@lanl.gov)

SUBMITTED TO

U. S. Department of Energy
Office of Fossil Energy and Carbon Management

January 14, 2022

I-WEST 1

Summary available: https://iwest.org/events/

Group discussions with multi-state stakeholder team to formulate vision for assessing CCUS opportunity

- SWOT analysis.
- Gap assessment.

Participating Institutions

NATIONAL ENERGY TECHNOLOGY LABORATORY

THE UNIVERSITY OF UTAH®

Los Alamos NATIONAL LABORATORY EST. 1943

UNIVERSITY OF WYOMING

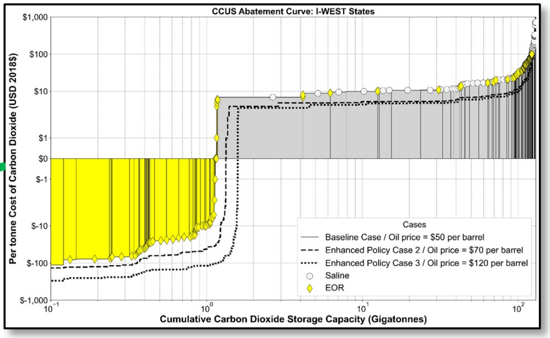
NEW MEXICO TECH SCIENCE • ENGINEERING • RESEARCH UNIVERSITY

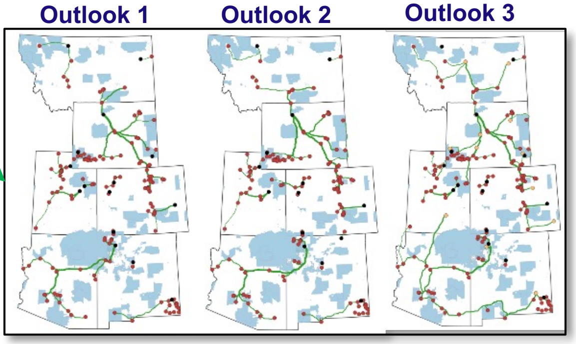
COLORADO SCHOOL OF MINES

Regional deployment outlook and economic assessment with mature CCUS analysis tools

- **NETL:** CO_2 storage, transport, and CO_2-EOR economic models.
- **LANL:** SimCCS model.

Resource Assessment





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CCUS in the I-WEST: SWOT

Strengths

- CCUS is a high TRL technology.
- Ample regional geologic storage potential.
- CO_2 pipeline networks exist and are expanding.
- Favorable policy progress and more being made.

Weaknesses

- Slow UIC Class VI permitting process, particularly for states/tribes without primacy.
- Expensive technology requiring large investment.
- Uncertainty in CCUS policy landscape.

Opportunities

- Evolving policy broadens opportunity (BIL, IRA - 45Q expansion, LCFS, Class VI primacy).
- Early-mover business cases exist (CO_2-EOR, acid gas injection).
- Produce/treat brine to augment water supply.

Threats

- Lack of public and social acceptance.
- Acceleration of fossil-plant shuttering.
- No expansion of 45Q or eligibility window.
- Federal or state-based leasing restrictions.
- Pressure issues if operations are not well managed.

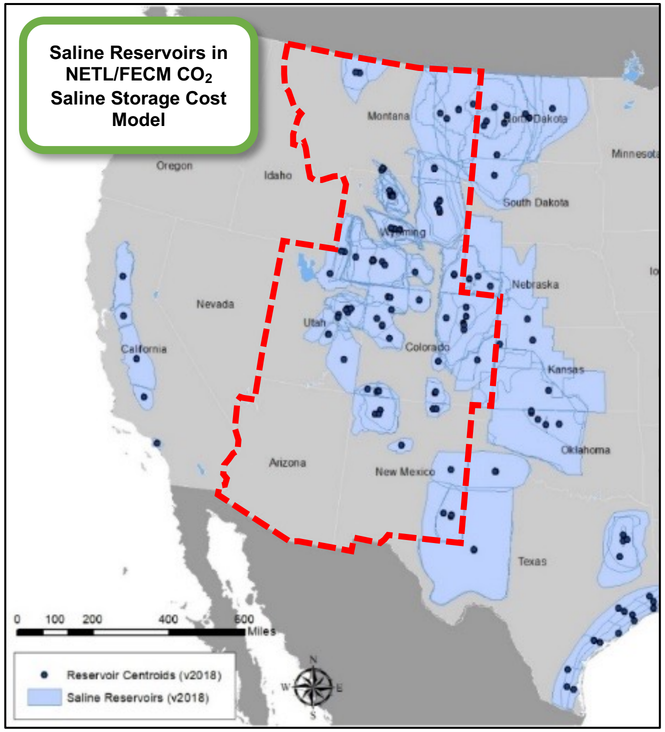
Assessing the Implications of CCUS Deployment in the I-WEST

- Does sufficient, **low-cost storage capacity** exist within the region to deploy CCUS at scale?
- What **percent of existing I-WEST point CO_2 emissions** could regional geology accommodate?
- Does **reserve storage capacity exist** and should CO_2 volume requiring storage increase over time?
- What **magnitude of projects** (and where are favorable geologic targets) need to be deployed based on the CO_2 volume to be managed?
- What is the **size of the pipeline network** required to connect capture point sources with viable geologic storage?
- What are the **workforce implications** given an emerging regional CO_2 economy in which CCUS plays a central role?

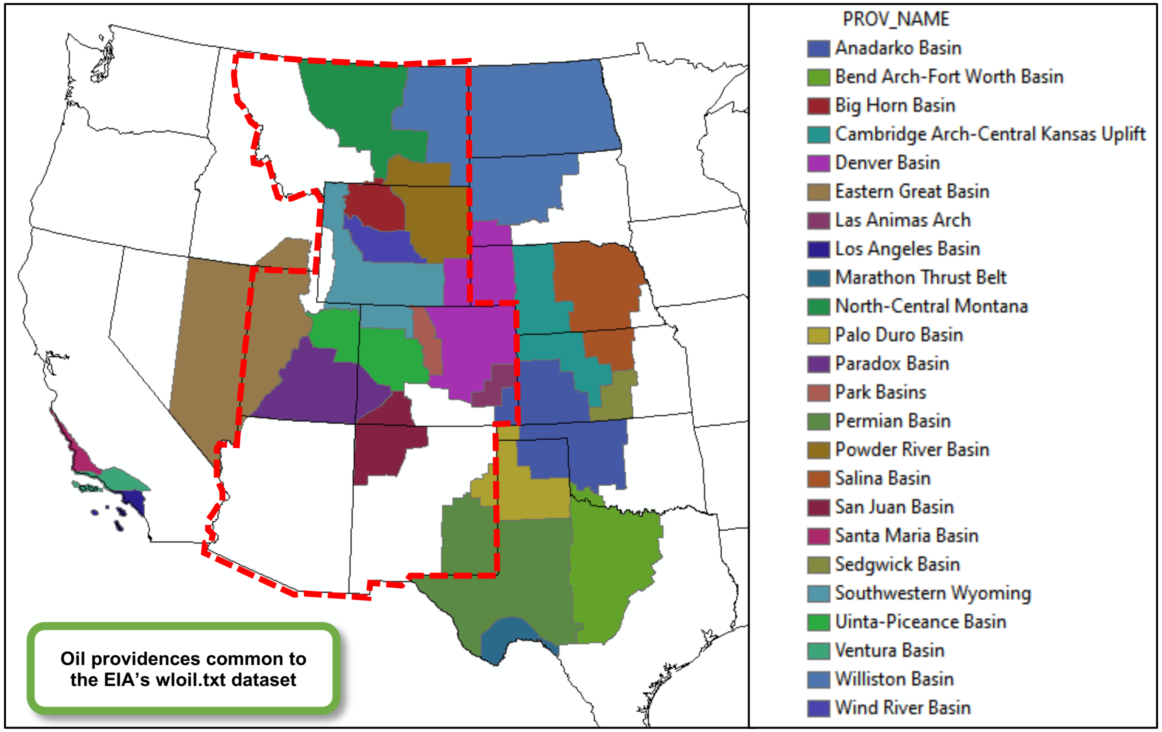
Tools Used To Analyze Regional CO_2 Storage Opportunities

Analytical framework applied leverages mature analysis tools with relevant geologic data.

Analytical Domain	CCUS Tool
Saline storage capacity and cost evaluation	FECM/NETL CO_2 Saline Storage Cost Model[1]
CO_2-EOR capacity and cost evaluation	FECM/NETL Onshore CO_2-EOR Evaluation System[2,3]



Saline Reservoirs in NETL/FECM CO_2 Saline Storage Cost Model



Oil providences common to the EIA's wloil.txt dataset

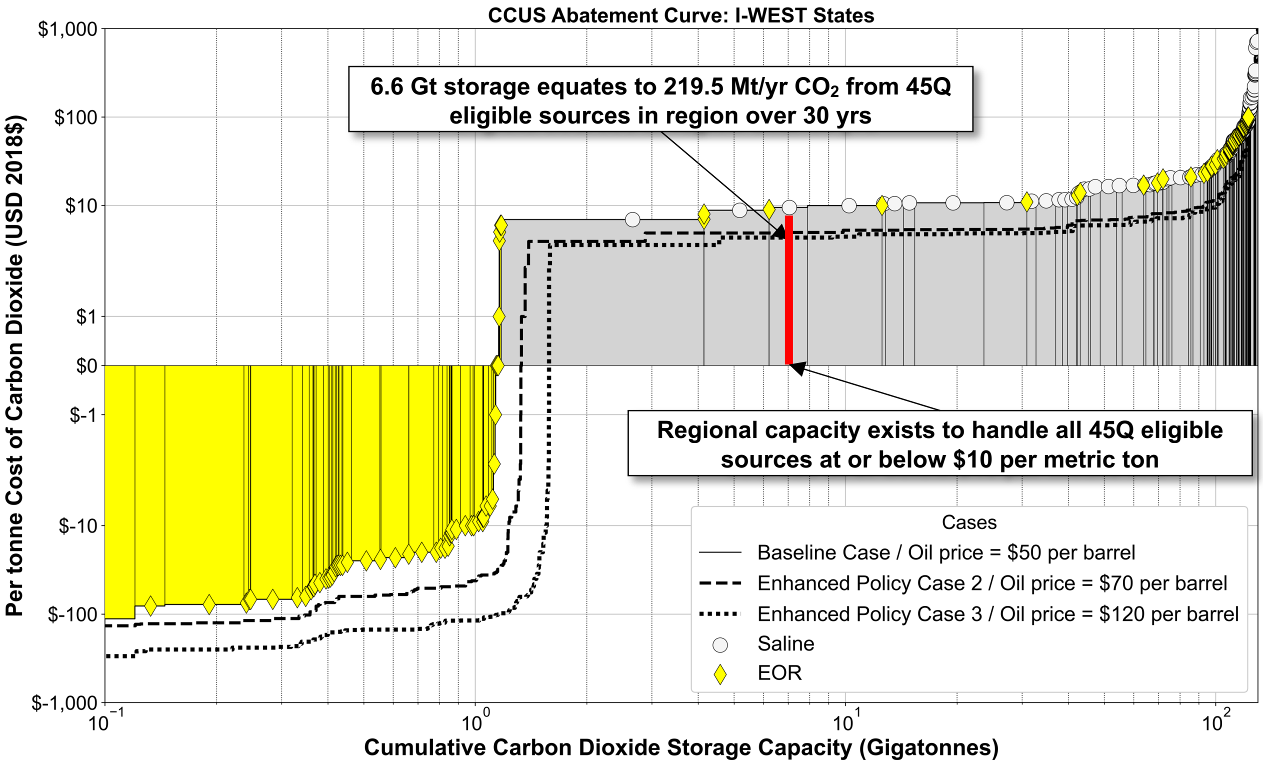
1 - https://netl.doe.gov/energy-analysis/search?search=CO2SalineCostModel
2 - https://netl.doe.gov/energy-analysis/search?search=CO2ProphetModel
3 - https://netl.doe.gov/energy-analysis/search?search=OnshoreCO2EORCostModel

Perspective on CO_2 Storage in the I-WEST

- Cost implications and capacity are evaluated under four distinct modeling scenarios.

- Each scenario reflects a **favorable** incremental change to storage-related technical, policy, or operational conditions from the baseline scenario.

- Notable factors adjusted (Morgan et al., 2022):
  - PISC duration.
  - Financial responsibility instrument.
  - Number of sites evaluated prior to selection.
  - Permitting timeframe.
  - Oil market price.



6.6 Gt storage equates to 219.5 Mt/yr CO_2 from 45Q eligible sources in region over 30 yrs

Regional capacity exists to handle all 45Q eligible sources at or below $10 per metric ton

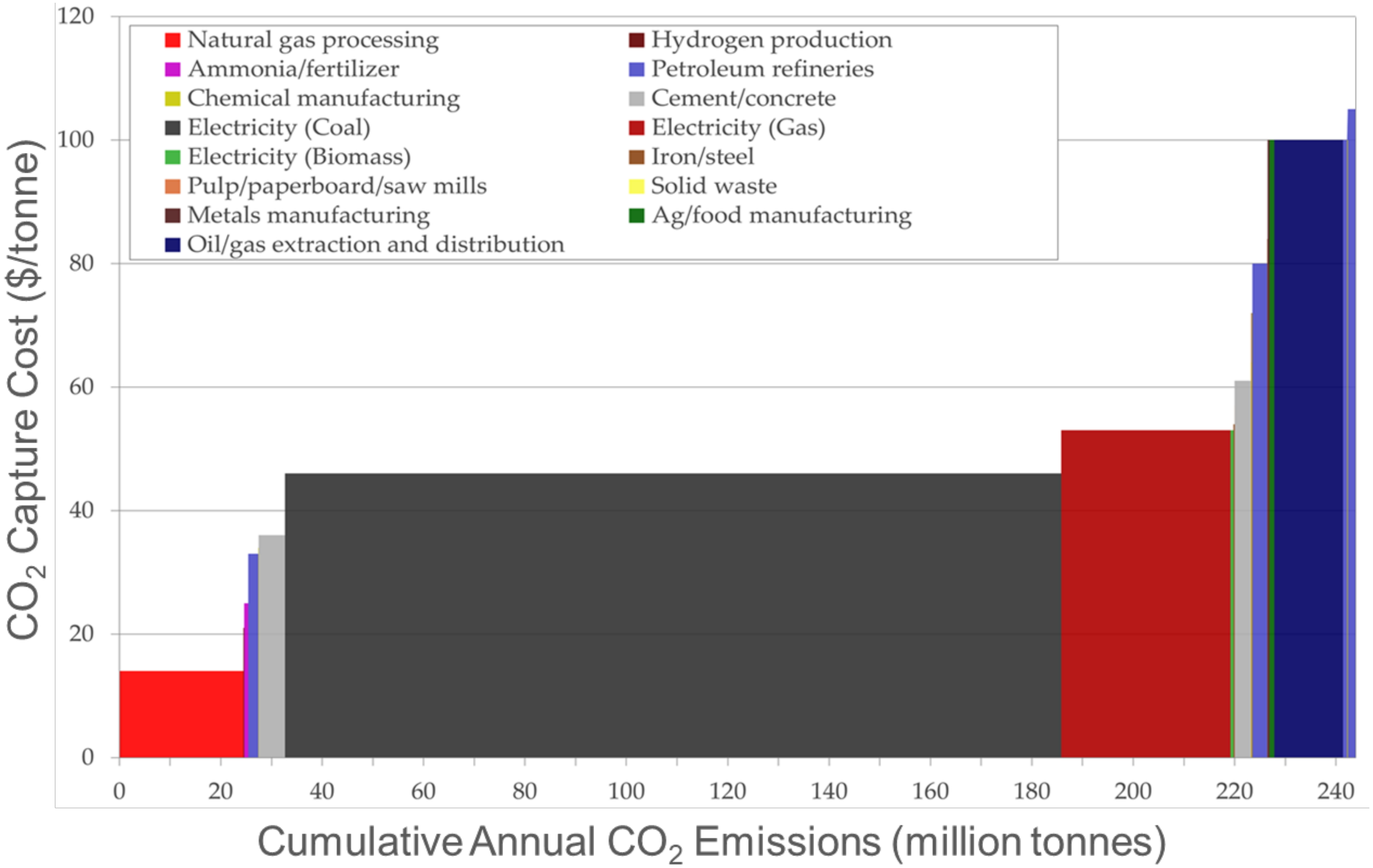
Results using the FECM/NETL Onshore CO_2-EOR Evaluation System and NETL/FECM CO_2 Saline Storage Cost Model w/ imposed capacity constraints as proposed by Teletzke et al., 2018.

Three "policy development" cases run to evaluate effects on storage costs.

Teletzke, G., Palmer, J., Drueppel, E., Sullivan, M., Hood, K., Dasari, G., and Shipman, G. 2018. Evaluation of Practicable Subsurface CO_2 Storage Capacity and Potential CO_2 Transportation Networks, Onshore North America. *14th International Conference on Greenhouse Gas Control Technologies.* Melbourne, Australia

Morgan, D., Guinan, A., Warner, T., Vikara, D. and Vactor, R.T. 2022. Intermountain West Energy Sustainability & Transitions Initiative: NETL/FECM Model and Analysis Approach Overview. National Energy Technology Laboratory. Pittsburgh, PA. (*pending release*)

CO_2 Supply Curve – Based on Point Source Characteristics

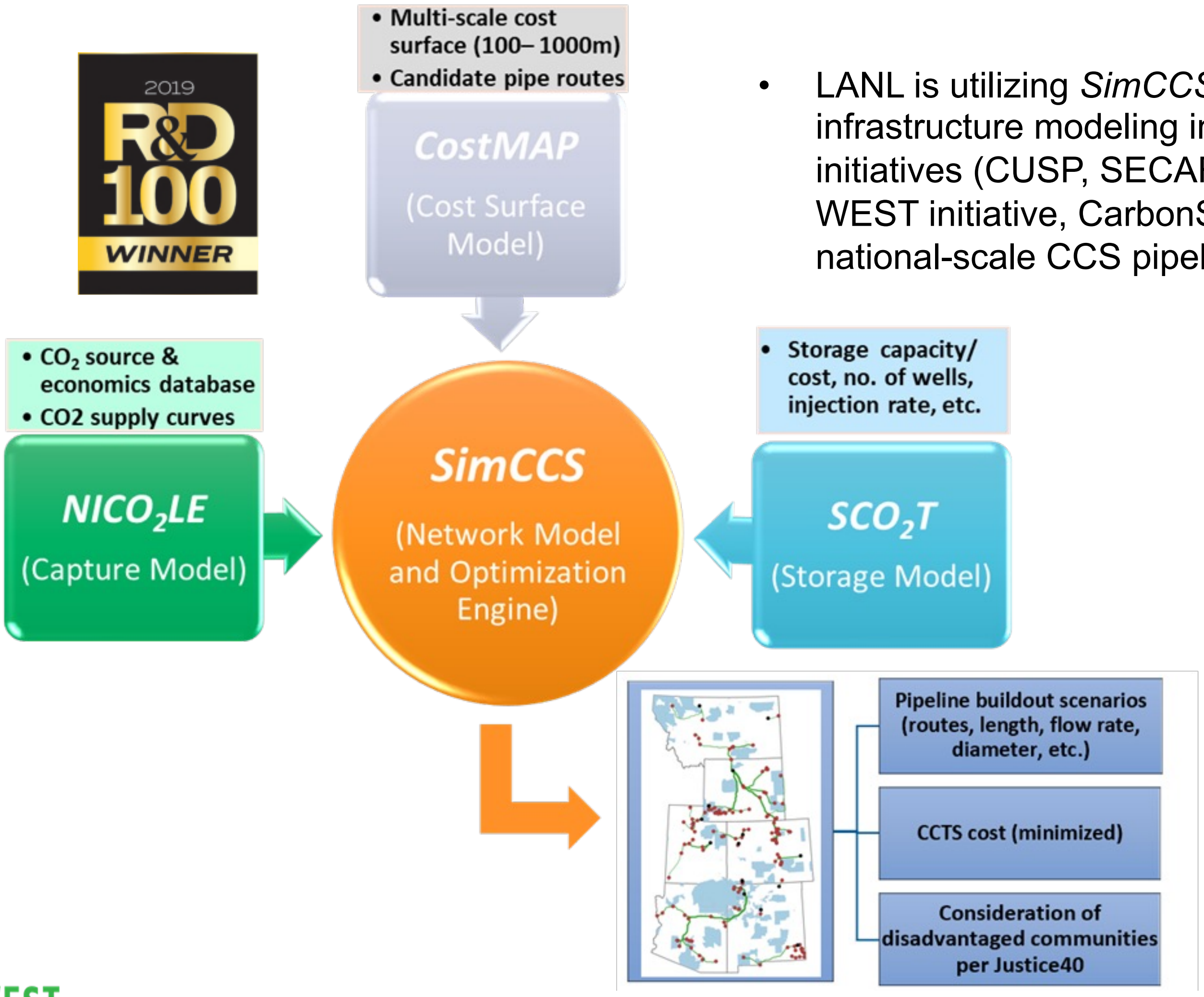


** Note: supply curve shows all sources within region, of which ~90% are 45Q compliant.*

SimCCS Determines the Costs and Optimized Pipeline Routing by Integrating Factors Across the CCS Value Chain

2019 R&D 100 WINNER

- LANL is utilizing *SimCCS* to support infrastructure modeling in three regional CCUS initiatives (CUSP, SECARB-USA, MRCI), I-WEST initiative, CarbonSAFE projects, and national-scale CCS pipeline modeling.



- Multi-scale cost surface (100– 1000m)
- Candidate pipe routes

CostMAP

(Cost Surface Model)

- CO_2 source & economics database
- CO2 supply curves

$NICO_2LE$

(Capture Model)

SimCCS

(Network Model and Optimization Engine)

- Storage capacity/ cost, no. of wells, injection rate, etc.

SCO_2T

(Storage Model)

Pipeline buildout scenarios (routes, length, flow rate, diameter, etc.)

CCTS cost (minimized)

Consideration of disadvantaged communities per Justice40

Publicly available @ https://simccs.lanl.gov/

Initial Scenarios of CCUS Deployment in I-WEST Assuming a Single Phase of Pipeline Buildout

- **Scenario 1 – CO_2 storage in saline formations without restricting passage of pipelines through disadvantaged communities.***
- **Scenario 2 – CO_2 storage in saline formations while restricting passage of pipelines through disadvantaged communities.**
- **Scenario 3 – CO_2 storage in saline and via CO_2-EOR while restricting passage of pipelines through disadvantaged communities.**

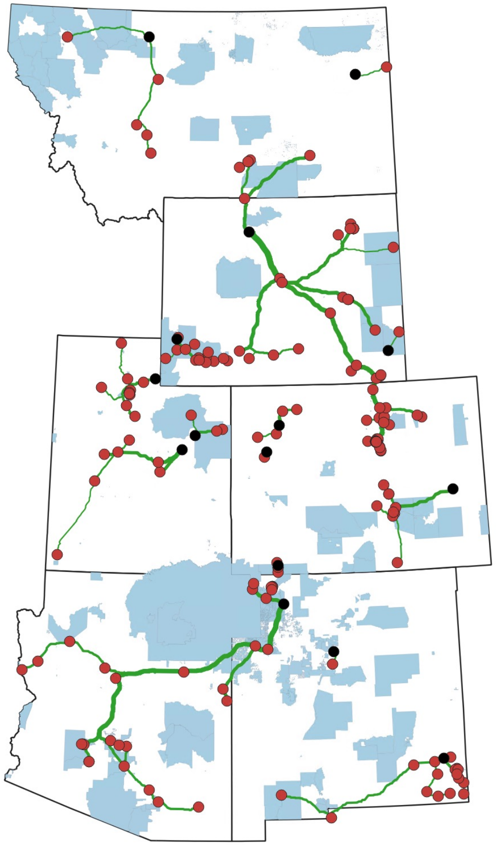
Assumptions:

- **Limited only to the I-WEST sinks.**
- **No dynamic evolution of sources.**

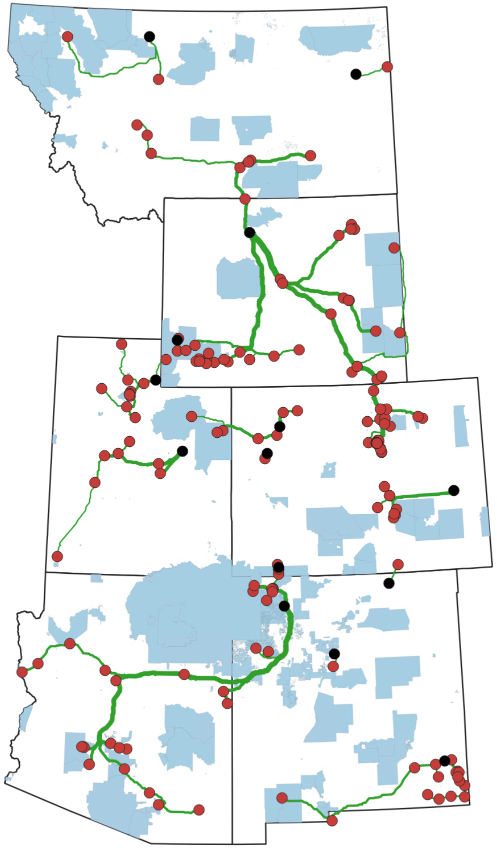
** The definition of "disadvantaged communities" used in this study is based on the US-DOE Justice40 definition given at: https://www.energy.gov/diversity/justice40-initiative*

Optimized Pipeline Network for Three Initial Scenarios

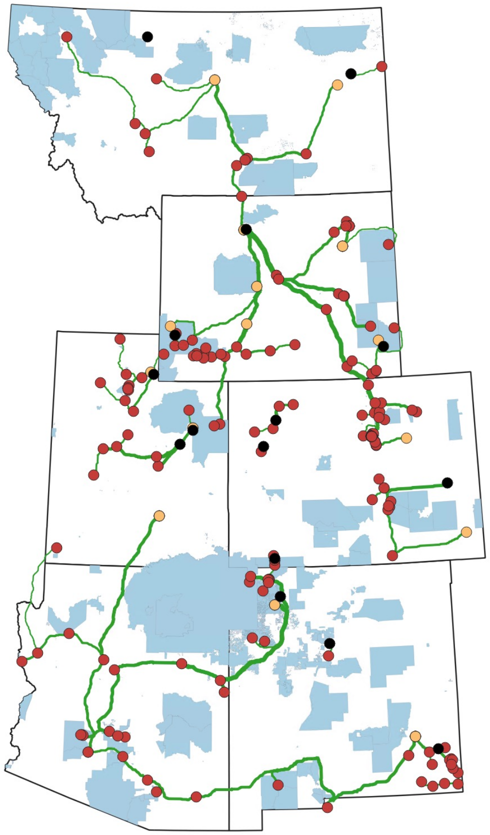
Saline storage only;
no environmental justice
considerations.



Saline storage only;
pipelines avoid
disadvantaged communities.



Saline storage and CO$_2$-EOR;
pipelines avoid disadvantaged
communities.



🟥 = Existing CO$_2$ point source

▬ = Potential CO$_2$ pipeline

🟨 = CO$_2$-EOR field centroid

● = Saline reservoir centroid

▨ = Disadvantaged community or tribal lands

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Pipeline Routing That Avoids Disadvantaged Communities Increases Pipeline Costs by $0.05 per Tonne of Stored CO_2

Economic Results	Scenario		
	Scenario 1: Saline storage without DC restriction	**Scenario 2:** Saline storage with DC restriction	**Scenario 3:** Saline + EOR storage with DC restriction
Total Captured CO_2 (million tonnes/year)	219.5	219.5	219.5
Optimized Pipeline Length (miles)	4,882	5,433	6,836
Weighted Average Cost for CO_2 Capture (\$/tonne CO_2)	46.87	46.87	46.87
Pipeline Construction Cost (\$/tCO_2)	0.11	0.16	0.20
Net Storage Cost (\$/tCO_2)	2.52	2.84	-29.76

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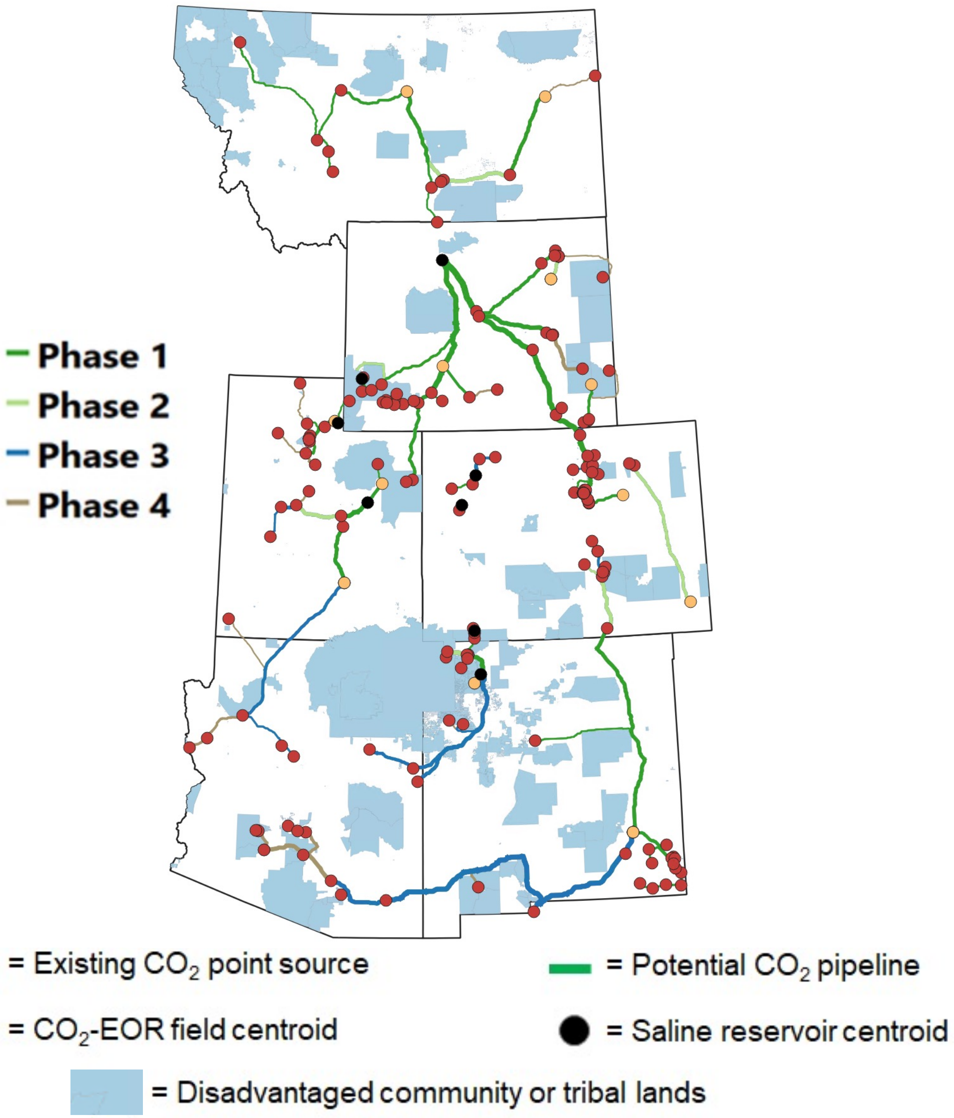
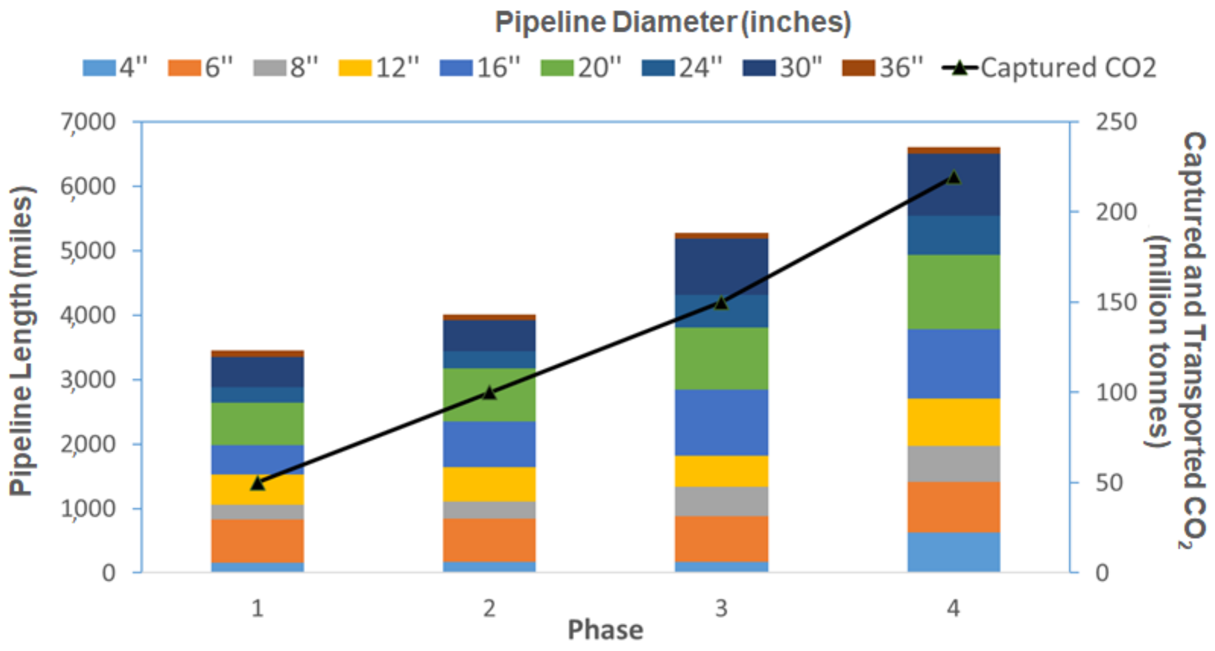
Assessed the Changes To the Pipeline Network if the Buildout Occurs in Multiple Stages

- Evaluated under four distinct phases, where each phase spans five years and reflects the incremental scale-up of CCUS deployment in the region over time.
- The volume of CO_2 assumed captured and stored in each phase includes 50, 100, 150, and 219.5 million tonnes/year, respectively.
- CO_2 sinks: saline reservoirs and CO_2-EOR fields.
- Pipeline routing considers disadvantaged communities.



Phase-based Pipeline Network Outlook in the I-WEST



Result Output	Buildout Phase			
	Phase 1	Phase 2	Phase 3	Phase 4
Capturable amount (million tonnes/year)	50	100	150	219.5
Pipeline length (miles)	3,447	4,010	5,278	6,601
Weighted average unit capture cost ($/tonne CO_2)	$28.37	$37.17	$40.11	$46.87

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Observations From Pipeline Transport Modeling

- Analysis results suggest new pipeline infrastructure needs on the order of 4,882 to 6,836 miles to connect I-WEST sources to regional storage options.

- With environmental justice considerations applied, pipeline networks grow in length (11% longer) to avoid surface crossings across disadvantaged communities and tribal land. Net costs increase by ~$0.05 per tonne of stored CO_2.

- The inclusion of CO_2-EOR as storage options increases the pipeline needs in the region.
  - The total potential pipeline network length would be significantly longer, on the order of 1,400 miles, when CO_2-EOR fields are included as storage options.

- Phase-based CCS infrastructure: the volume of new pipeline needed under each phase grows rapidly from 3,447 miles in Phase 1 to over 6,600 miles by Phase 4; regional weighted average unit capture cost increases over time (i.e., capture occurs initially at the lowest-cost sources).

Calls To Action:
Accelerating CCUS Deployment in the I-WEST

Technical and Cost

- Pre-investment in CO_2 transport and storage capacity as strategic infrastructure.
- **Improve certainty of storage capacity with containment to identify "shovel-ready sites" for rapid project deployment.**
- Reduce seismic survey costs to improve economics for characterization and monitoring.
- Scoping multiple prospective storage sites for projects.
- Elevation of all CCUS technology up the TRL scale via R&D, investment, and early-mover projects.

Policy

- **Financial / tax incentives and policies to drive private investment.**
- **State-level polices for pore space ownership and ownership transfer; applicable to produced brine.**
- **Rules for CO_2 ownership and long-term liability.**
- **State Primacy for UIC Class VI wells.**
- **Sufficient staffing and resources to evaluate permit applications and perform project oversight.**
- Supportive policies for CO_2 transport and storage on federal and state lands.
- Market development via state/federal procurement programs, portfolio requirements, and mandatory power purchase or offtake agreements.

Outreach / Societal

- **Well-planned, early engagement with stakeholders and community to educate as well as understand and address concerns.**
- **Outreach for all social levels; provide insight into benefits and risks of low-carbon solutions.**
- **Identify, develop, and promote "early-win" projects to show CCUS feasibility and economic and environmental benefits.**
- Overcome perceived human capital deficit required to plan, permit, and oversee projects.

Summary and Conclusions

I-WEST is well equipped to pioneer region-wide low-carbon/energy transition with CCUS playing a major role.

- Ample storage capacity to abate bulk of existing and expanding point source fleet.
- Uncertainty regarding Class VI rules implementation remains.
  - Reductions in PISC, monitoring rigor, and financial assurance may improve cost.
  - Clarity is needed in pore space ownership and liability transfer to reduce business risk.
- Existing pipeline network needs to be supplemented for large-scale deployment.

Summary and Conclusions

CCUS pathway(s) I-WEST analysis also includes the following:

- CCUS overview, business case configurations, and technology benefits and challenges.
- Workforce implications.
- CCUS assessment in regions proximal to I-WEST.
- State-level geologic resource deep dives (in development).

CCUS is only one aspect of the larger I-WEST effort that more broadly discusses the following pathway impacts:

- Environmental/social justice.
- Workforce and revenue.
- Stakeholder-specific priorities and perspectives.

PATHWAYS TO CO_2 UTILIZATION AND STORAGE FOR THE INTERMOUNTAIN WEST REGION

Figure 7. Current and emerging portfolio of technologies spanning the CCUS value chain

Policy and societal readiness are critical enabling mechanisms needed for CCUS to move forward : Given the UIC Class VI well's relatively nascent nature (established by EPA in 2010) the policy surrounding it remains mutable [97]. Through the past decade of project R&D, invaluable learnings have been accumulated to better inform CCUS policy and regulation. From this, it has become apparent that in order to reduce business risk and entice future investment, two things are imperative. First, a cleaner and more solid regulatory framework is necessary so prospective investors and operators are assured they can secure the right to inject in a timely fashion, comply with all regulatory requirements, and fully understand their potential liability. Second, these projects rely heavily on tax credits to become net-present-value positive and get off the ground, and additional aid is necessary [15]. To these ends, much progress has been made at a state and federal level in the region:

- **UIC Class VI Primacy** – One often-discussed impediment to CCUS development historically has been the lengthy, (i.e., 2–6 year) federal UIC Class VI permitting process. In an effort to streamline and expedite the process, some states are contemplating or have acquired Class VI primacy allowing them to control the permitting process at a state level. In the I-WEST region, Wyoming has already established primacy, Arizona is in the pre-application phase, and Utah has recently passed a CCUS-related bill laying the groundwork to move toward primacy application in the near future [98, 99]. These efforts seem like the most logical and effective method for improving permit approval speeds. Additionally, it affords the appropriate state-based entity with intimate knowledge of the local geologic setting,

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injectivity, and containment properties of sites [107] as well as the resulting CO_2 plume movement and pressure evolution in the subsurface. For example, reservoir depth impacts the drilling and operational costs of both injection and monitoring wells as deeper wells generally cost more than shallower wells. Reservoir thickness and permeability affect injectivity which, in turn, may influence the number of injection wells needed to inject the annual volume of CO_2 delivered to a storage site. Reservoir thickness and porosity, along with storage efficiency [141] and areal extent, determine the reservoir's overall storage capacity, which directly dictates the volume of CO_2 a reservoir can accommodate. Storage reservoirs with larger storage capacities can typically attain unit cost savings (i.e., \$/tonne basis) via economies of scale by storing larger volumes of CO_2 than smaller reservoirs. Reservoirs depicted in Figure 15 (and for the I-WEST region and proximal states in

Figure 23 in Appendix B: CO_2 Storage Resources Results – States Proximal to I-WEST) that typically contain higher reservoir quality attributes correlate to the lower cost options in general.

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(A) Saline without EJ (B) Saline with EJ (C) Saline and EOR w

● = Existing CO_2 point source
▬ = Potential CO_2 pipeline
● = CO_2-EOR field centroid
● = Saline reservoir centroid
▨ = Disadvantaged community or tribal lands

Figure 19. Pipeline network outlook connecting point sources and sinks under the three single phase scenarios

4.1.3.3 Phase-Based Pipeline Network Outlook

An additional CCUS network development outlook, rooted in a phased development approach, was generated for comparison to the single-phase scenarios. The phase-based outlook similarly assumes full abatement of all BBA 45Q-eligible sources in the region but does so over a 20-year development scale-up timeframe. The development timeframe was evaluated under four distinct phases, where each phase spans five years and reflects the incremental scale-up of CCUS deployment in the region over time. The volume of CO_2 assumed captured and stored in each phase is 50, 100, 150, and 219.5 million tonnes per year respectively. These volumes more closely coincide with the I-WEST Roadmap's phased decarbonization timeline than under the single-phase development outlooks.

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Project Contributors

Contributing team includes members from participating national labs and four regional universities

THE UNIVERSITY OF UTAH®

Brian McPherson
Robert Simmons
No’am Dvory
Carlos Vega-Ortiz
Lei Xu

NATIONAL ENERGY TECHNOLOGY LABORATORY

David Morgan
Luciane Cunha
Timothy Grant
Jeffrey Eppink
Scott Matthews
Travis Warner
Allison Guinan
Taylor Vactor
Derek Vikara
Michael Marquis

COLORADO SCHOOL OF MINES

Manika Prasad
Kirt Livo
Daisy Ning
Stephen Sonnenberg
Ali Tura

NEW MEXICO TECH
SCIENCE • ENGINEERING • RESEARCH UNIVERSITY

Robert Balch
Jean-Lucien Fonquergne
Martha Cather

UNIVERSITY OF WYOMING

Fred McLaughlin
Zunsheng Jiao
Charles Nye
Matthew Johnson
Nick Jones
Selena Gerace

Los Alamos NATIONAL LABORATORY
EST. 1943

Bailian Chen
Martin Ma
Ahmmed Bulbul
Rajesh Pawar

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Questions / Comments

I-WEST

Contacts: derek.vikara@netl.doe.gov; bailianchen@lanl.gov

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Thank you for participating!

A recording of this seminar will be available on the I-WEST website at www.iwest.org

Join us for the next seminar

Wednesday, June 21
"Certification for CO_2 Sequestration"
with Dr. Stephanie Arcusa, Arizona State University