Pathways to CO_2 Utilization and Storage for the Intermountain West Region

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I-WEST
https://iwest.org/

U.S. Department of Energy
National Energy Technology Laboratory
Carbon Management Project Review Meeting
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I-WEST Overview: the Road to Carbon Neutrality in the Intermountain West

I-WEST Objectives

Develop regional, stakeholder-informed technology "roadmap" for a sustainable and equitable transition to carbon neutral

- Regionally relevant technology pathways
- Options for deployment now & within next decade
- Explicit consideration of equity, impact, & workforce

Facilitate <u>regional coalitions to implement & deploy roadmap</u>

Enabling Mechanisms for CCUS

Partnerships — **Policy** — **Financing** — **Technology**

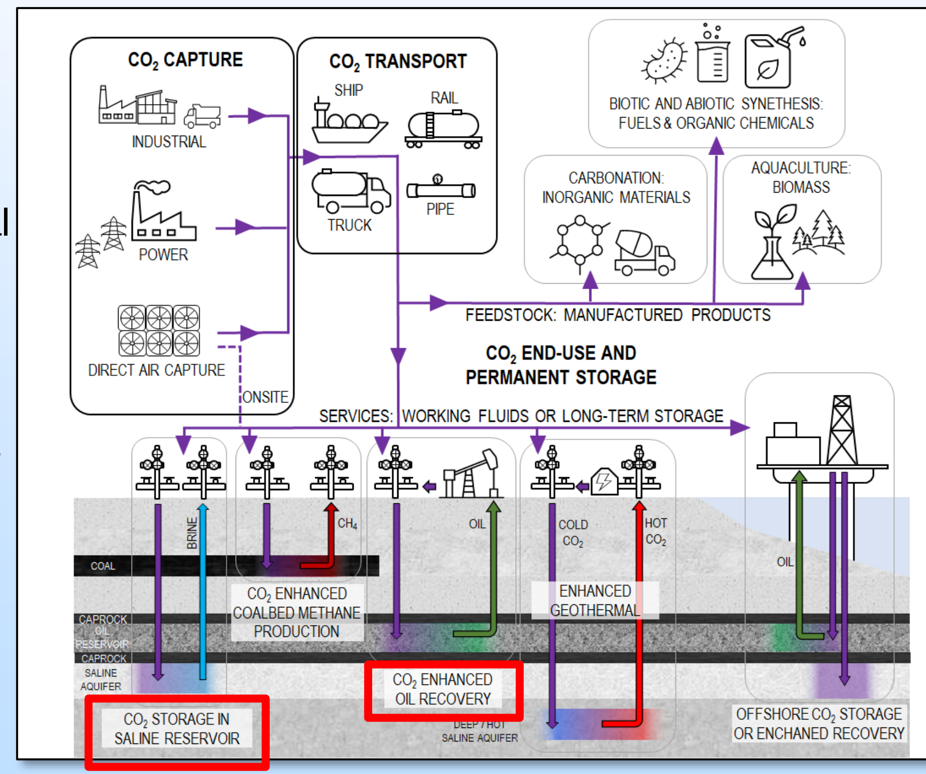
Value Delivery

- **Jobs**
- **CO_2 Reduction**
- **Positive GDP / Economic Impact**
- **Values Preservation**

CCUS Pathway Assessment Objectives

Evaluate opportunity for <u>CCUS</u> to deploy at significant scale in I-WEST region

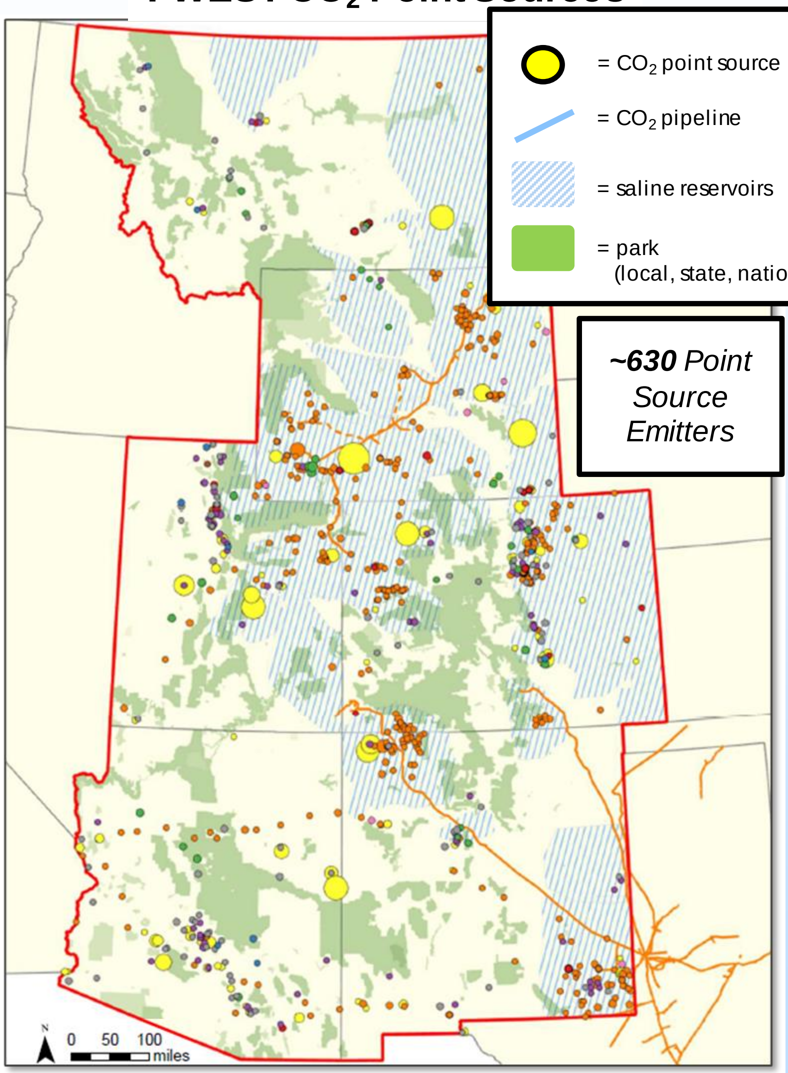
1. ID regionally relevant opportunities & roadblocks given regionally relevant attributes
2. Mitigate perceived technical/business risk with critical insight to promote widespread adoption
3. Emphasize how projects are blending tech & policy support to create positive regional economic benefits
4. Outline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



Multiple configurations exist across the CCUS value chain

CO_2 Emissions & Reduction Pathways

I-WEST CO_2 Point Sources



Source: EPA Flight Data

Point Sources CO_2e Emissions

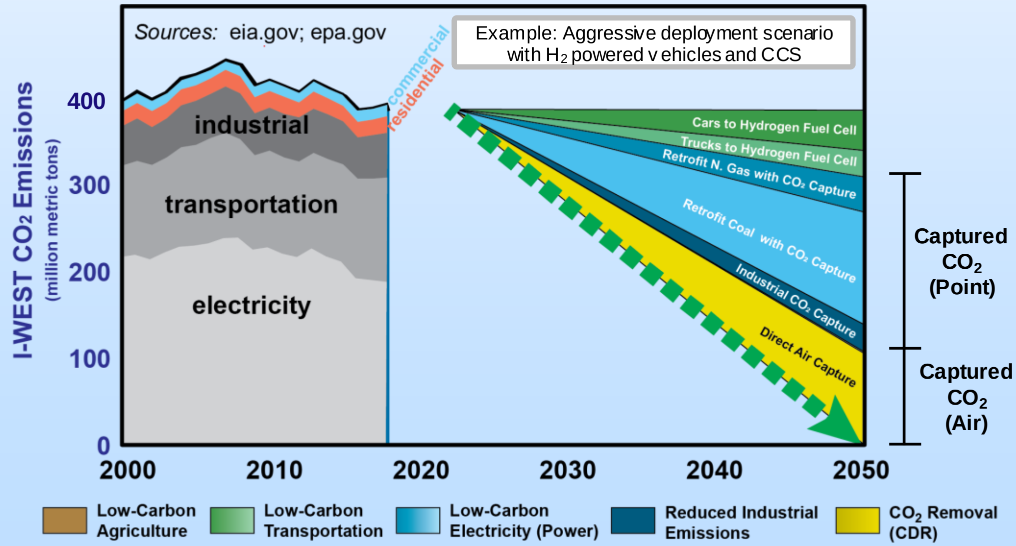
243 Mt / yr

Largest Emissions Sectors

Power – 66%
Pet / NG – 20%

Emission Reduction Timeline

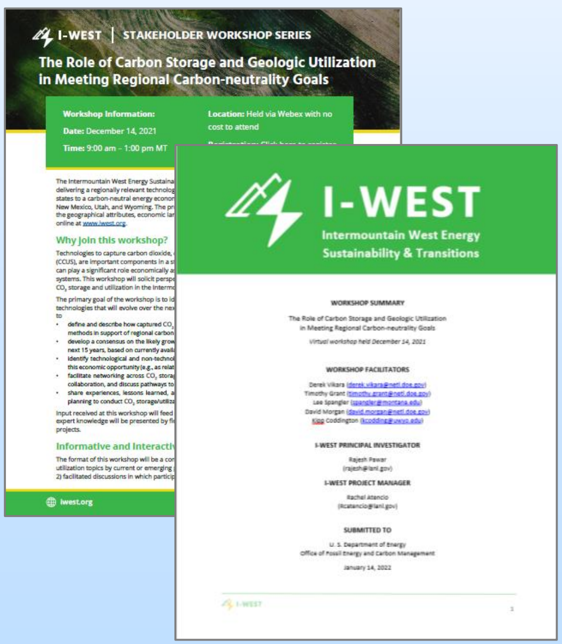
5-year *30 $MtCO_2$ / yr* → ***10-year*** *100 $MtCO_2$ / yr* → ***30-year*** *400 $MtCO_2$ / yr*



Process for Gaining "Place-Based" Insight

Workshops: Discussions with regional stakeholders

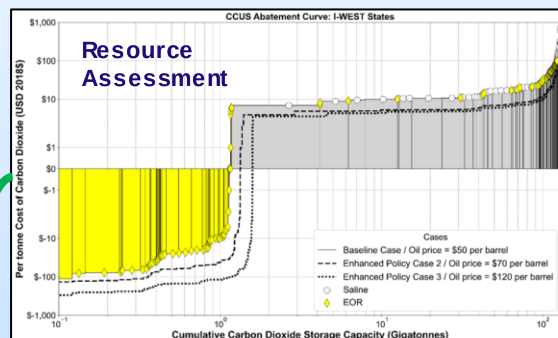
- State/tribal-level outreach workshops
- Technical roundtable
- Socio-economic & policy roundtable



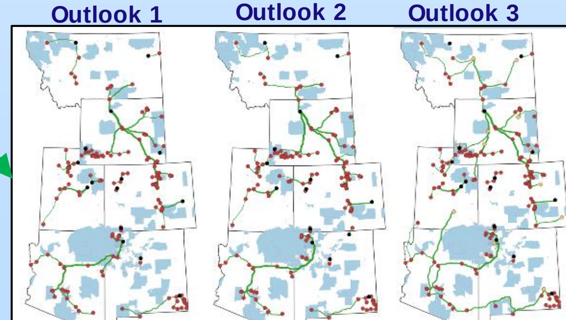
Summary available: https://iwest.org/events/

Regional deployment outlook & economic assessment with mature CCUS analysis tools

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



Outlook 1 | Outlook 2 | Outlook 3



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
University of Wyoming
New Mexico Tech
Colorado School of Mines

CCUS in the I-WEST: SWOT

Strengths

- CCUS is a high TRL technology
- Ample regional geologic storage potential
- CO_2 pipeline networks exist & are expanding
- Favorable policy progress & more in works

Weaknesses

- Slow UIC Class VI permitting process, particularly for states/tribes w/o primacy
- Expensive tech 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 & social acceptance
- Acceleration of fossil-plant shuttering
- No expansion of 45Q or eligibility window
- Federal or state-based leasing restrictions
- Pressure issues if ops not well managed

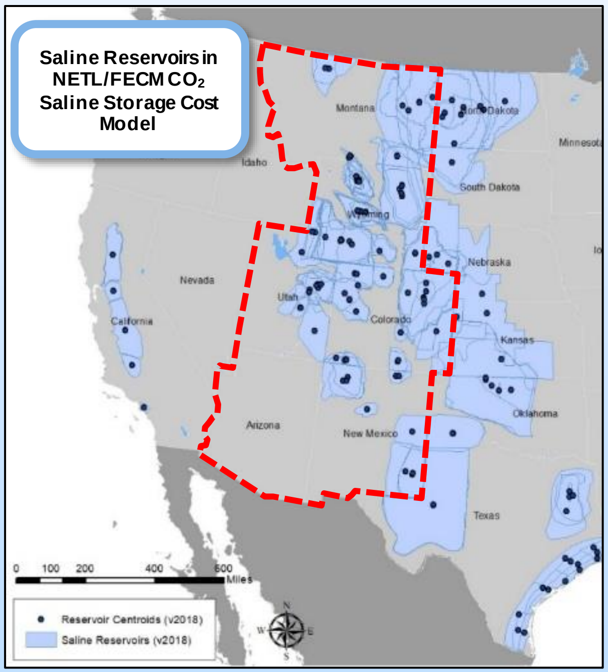
Assessing Implications of CCUS Deployment in the I-WEST

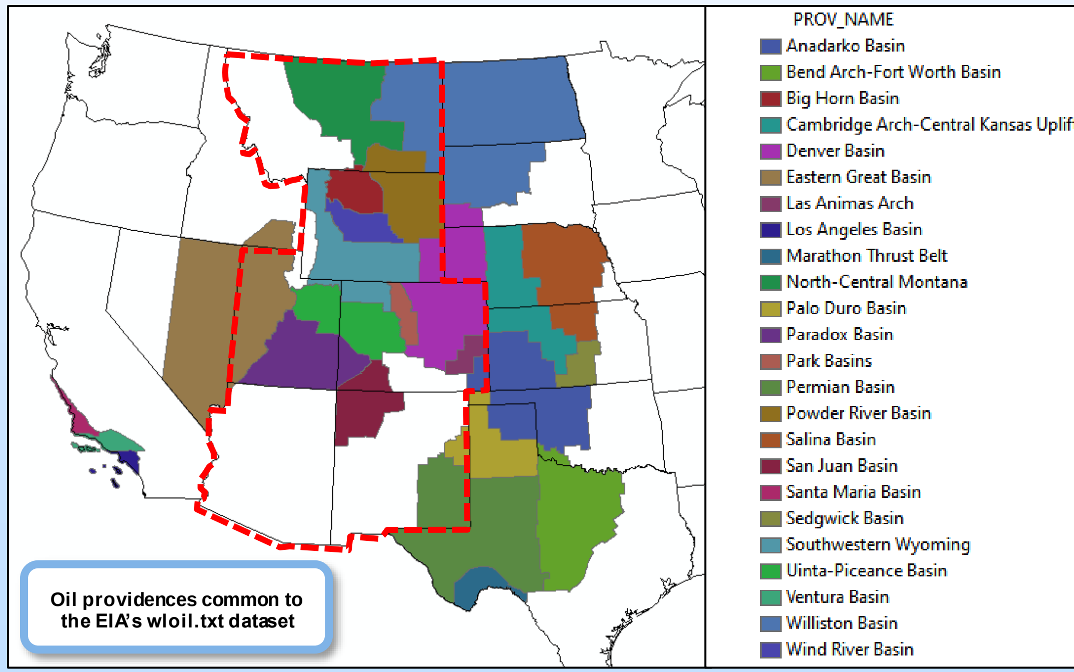
- Does sufficient, **<u>low-cost storage capacity</u>** exist within region to deploy CCUS at scale?
- What **<u>percent of existing I-WEST point CO_2 emissions</u>** could regional geology accommodate?
- Does **<u>reserve storage capacity exist</u>** should CO_2 volume requiring storage increase over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

CCUS Analytical Tools

Analytical framework applied leverages mature analysis tools with relevant geologic data

Analytical Domain	CCUS Tool
Saline storage capacity & cost evaluation	FECM/NETL CO_2 Saline Storage Cost Model[1]
CO_2-EOR capacity & cost evaluation	FECM/NETL Onshore CO_2-EOR Evaluation System[2,3]
CO_2 source to sink pipeline networking	SimCCS[4]

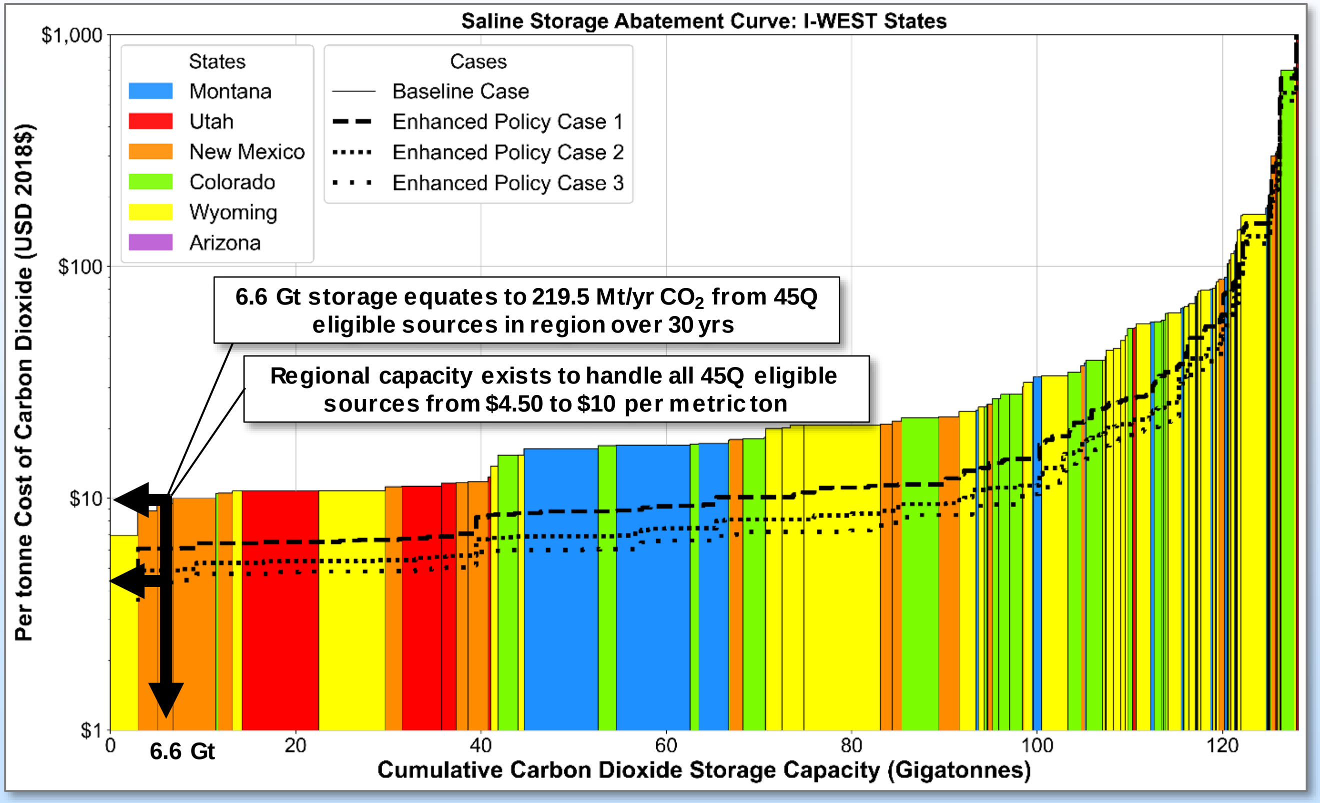




1 - https://netl.doe.gov/energy-analysis/search?search=CO2SalineCostModel
2 - https://netl.doe.gov/energy-analysis/search?search=CO2ProphetModel
3 - https://netl.doe.gov/energy-analysis/search?search=OnshoreCO2EORCostModel
4 - https://simccs.org/ and https://github.com/SimCCS/SimCCS

Perspective on CO_2 Storage in Saline-bearing Formations

- Cost implications & capacity evaluated under four distinct modeling scenarios
- Each scenario reflects a **favorable** incremental change to storage-related technical, policy, or operational condition from baseline scenario
- Notable factors adjusted (Morgan et al., 2022):
  - PISC duration
  - Financial responsibility instrument
  - Number of sites evaluated
  - Permitting timeframe



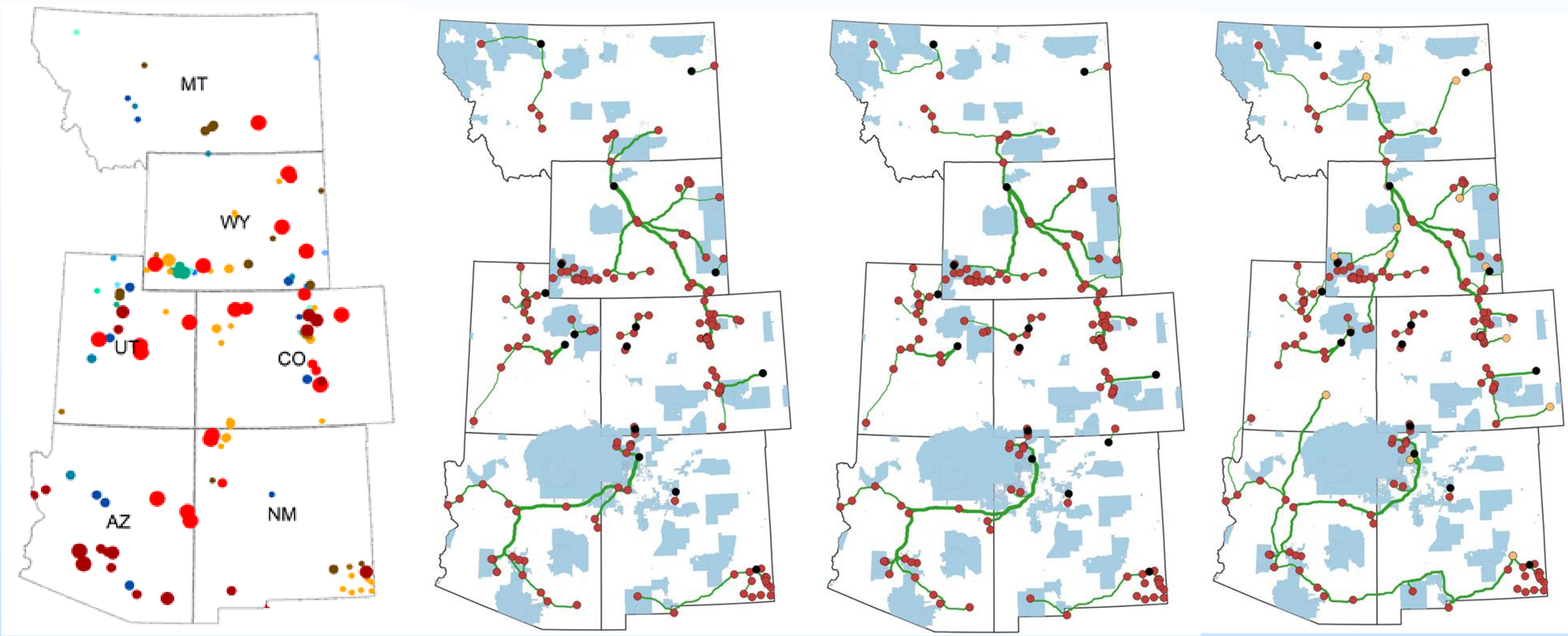
Results using NETL/FECM CO_2 Saline Storage Cost Model w/imposed capacity constraints as proposed by Teletzke et al., 2018. Three "policy development" cases run to evaluate effects on costs.

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 Pipeline Buildout – Single Phase

45Q-eligible point sources | (A) Saline without EJ | (B) Saline with EJ | (C) Saline and EOR with EJ



CO_2 sector
- Ag/food manufacturing
- Ammonia/fertilizer
- Cement/concrete
- Chemical manufacturing
- Electricity (Biomass)
- Electricity (Coal)
- Electricity (Gas)
- Electricity (Other)
- Facilities
- Hydrogen production
- Iron/steel
- Lime/gypsum
- Manufacturing (other)
- Metals manufacturing
- Mining
- Natural gas processing
- Oil/gas extraction and dist
- Other
- Petroleum refineries
- Pulp/paperboard/saw mills
- Solid waste

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

Economic Results	Scenario 1	Scenario 2	Scenario 3
Assumed CO_2 capture (Million tonnes/year)	219.5		
Resulting new pipeline installed (Miles)	**4,882**	**5,433**	**6,836**
Percent of national CO_2 pipeline network (2021)	91%	102%	128%

Calls to Action

Accelerating CCUS Deployment in I-WEST

Technical & Cost

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

Policy

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

Outreach / Societal

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

Summary & Conclusions

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

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

Summary & Conclusions

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

- CCUS overview, business case configurations, & technology benefits & challenges
- CO_2-EOR assessment
- Workforce implications
- CCUS assessment in proximal regions to I-WEST
- State-level geologic resource deep dives

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

- Environmental/social justice
- Workforce & revenue
- Stakeholder-specific priorities & perspectives

Project Contributors

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

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All images in this presentation were created by NETL, unless otherwise noted.

Thank you!

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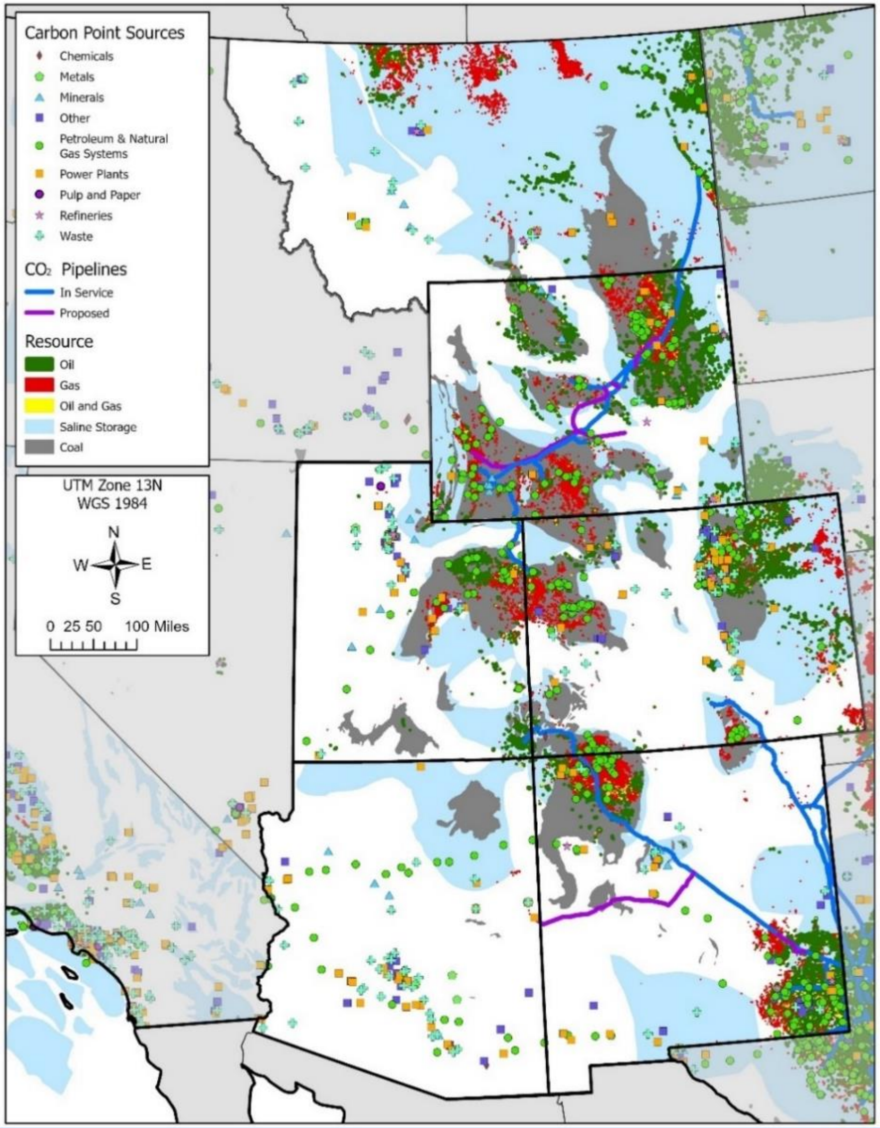
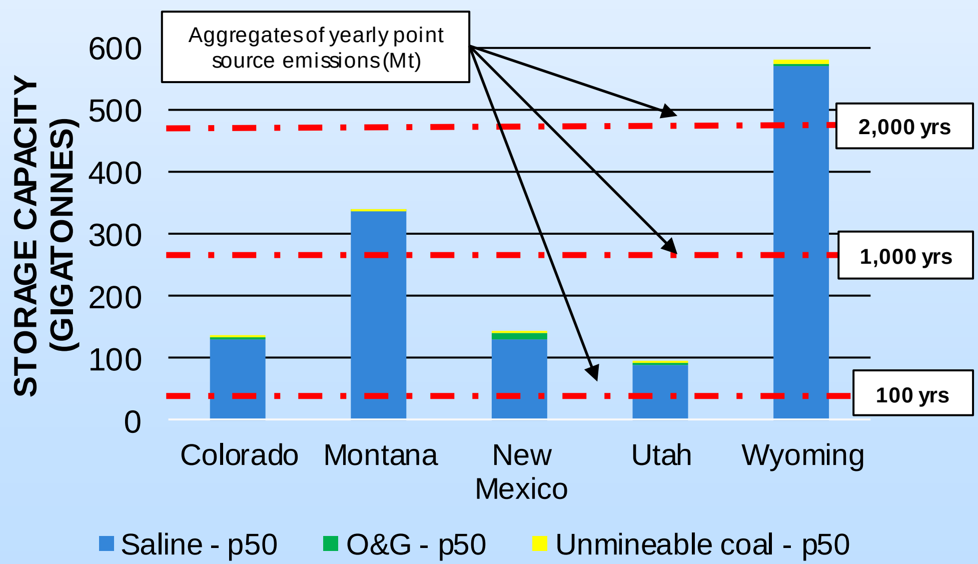
Appendix

- These slides will not be discussed during the presentation but are mandatory.

Favorable Geologic Resources Exist Across the Region



- Region has numerous geologic basins that hold a significant carbon storage resource endowment
- Sinks are co-located with or proximal to a large portion of the CO_2 point source fleet
- Capacity estimated between **354 to 3,365 gigatons**; can store regional point source emissions from **1,600 to over 15,000 years**



Capacity data from DOE's Carbon Storage Atlas – Fifth Edition
https://www.netl.doe.gov/coal/carbon-storage/strategic-program-support/natcarb-atlas

Snapshot on Regional Policy Headway

- State-level target to reach economy-wide GHG neutrality between 2045-2050
- Liability transfer for storage sites operators to the state 30 years after CO_2 injection ends
- Property tax incentives for facilities installing CCS equipment

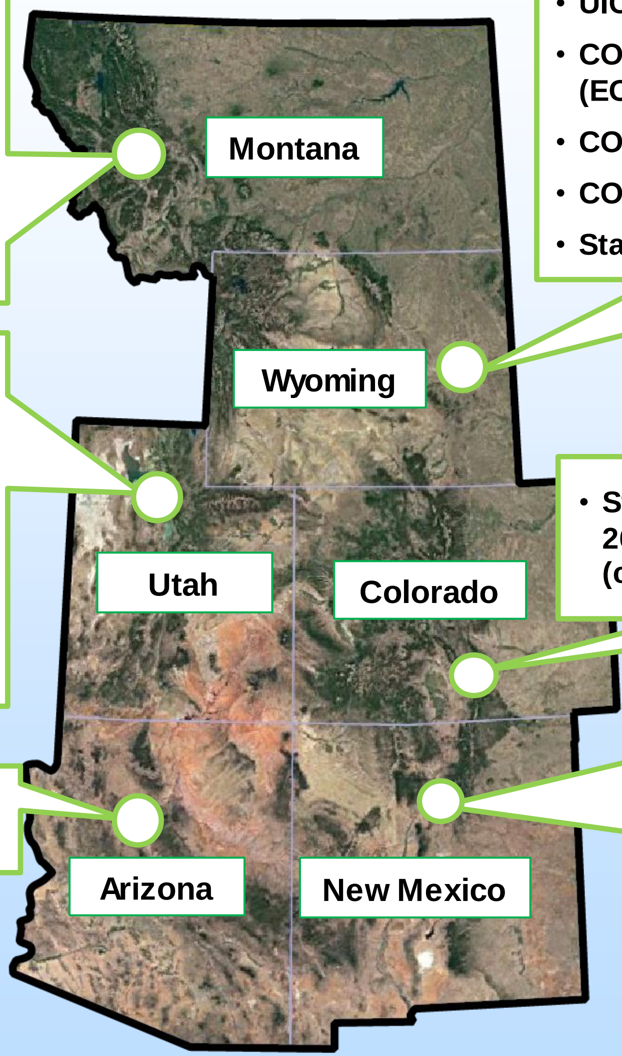
- UIC Class VI primacy
- CO_2 pipeline development corridor mapping (EOR)
- CO_2 storage long-term liability transfer
- CO_2 pipeline development financial assistance
- State tax exemption from CO_2 sales for EOR

- Established pore space ownership with respect to the surface estate
- Pore space owner safeguards from injection liability
- Long-term liability transfer to state 10 years after CO_2 injection ends
- Potential to seek jurisdiction for UIC Class VI injection well primacy

- Statutory state-level GHG reduction targets of 26% by 2025, 50% by 2030, and 90% by 2050 (compared to 2005 levels)

- Seeking primacy on all UIC well classes

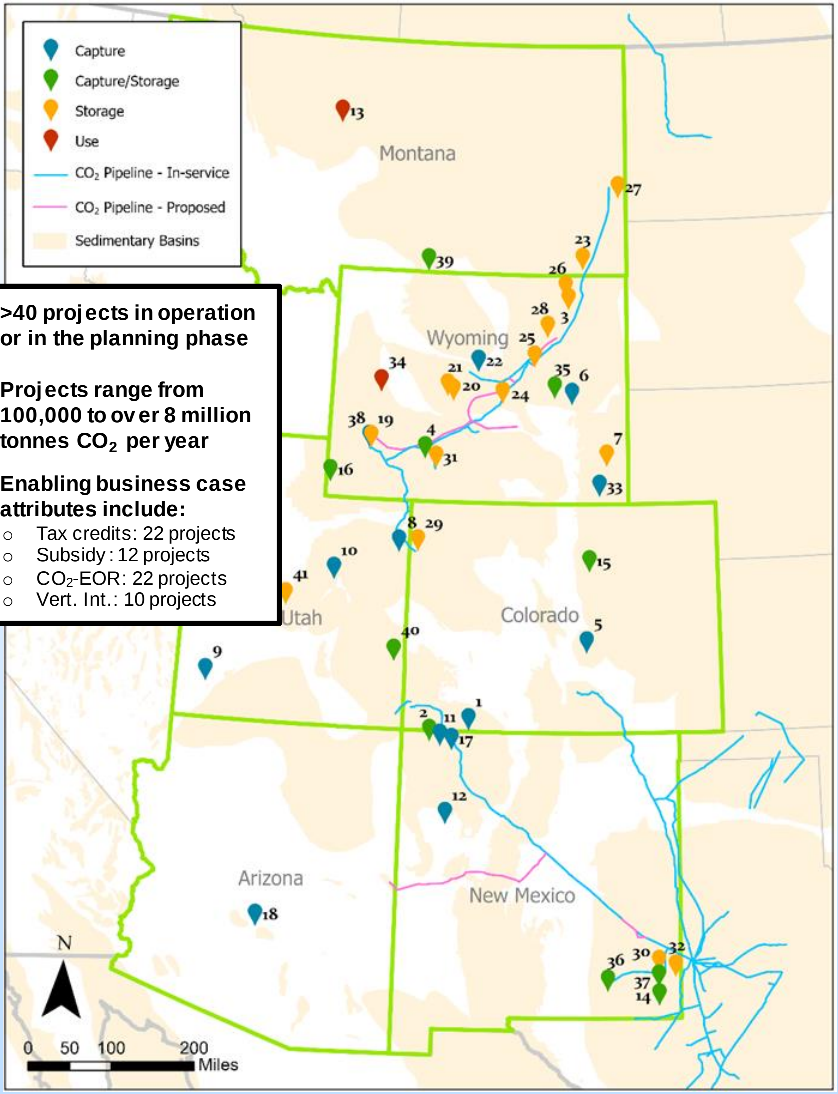
- State-level GHG reduction targets of 45% by 2030 (compared to 2005 levels)
- Mechanisms enabling public utilities to recover costs related to clean energy projects, including coal-fired power generation with CCS



Additional source material

- https://www.c2es.org/content/state-climate-policy/
- https://www.c2es.org/document/energy-financial-incentives-for-ccs/

CCUS is Ramping Up in the 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

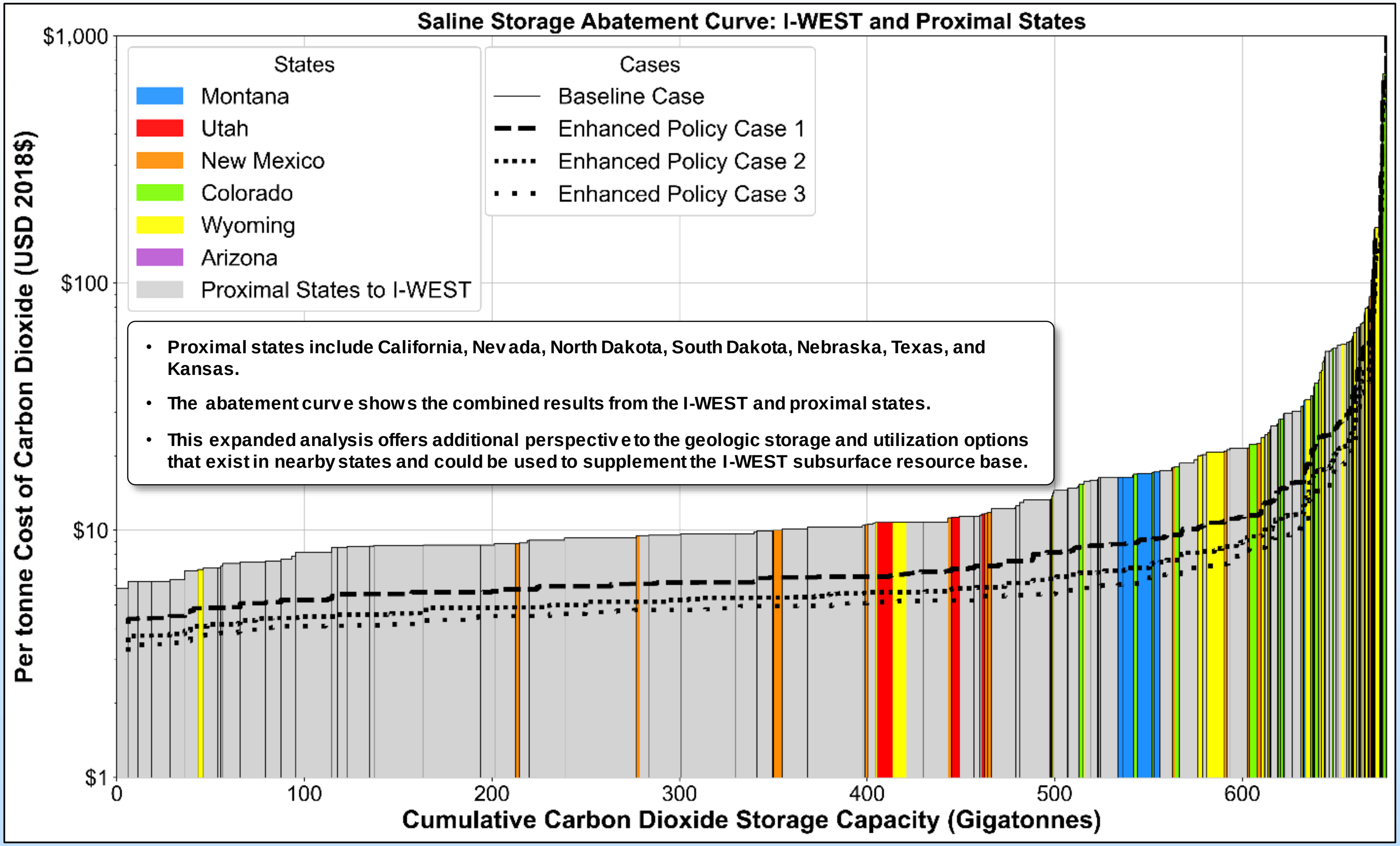
Project Name	Tax Credit	Grant Funding	Regulatory Requirement or Benefit	Pipeline Quality Requirement	Enhanced Oil Recovery	Vertically Integrated
1) Coyote Clean Power Project	■				■	
2) CarbonSAFE New Mexico: San Juan Basin	■	■			■	■
3) CarbonSAFE Wyoming: Dry Forks Station	■	■			■	■
4) Jim Bridger Plant 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 - Blue 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/

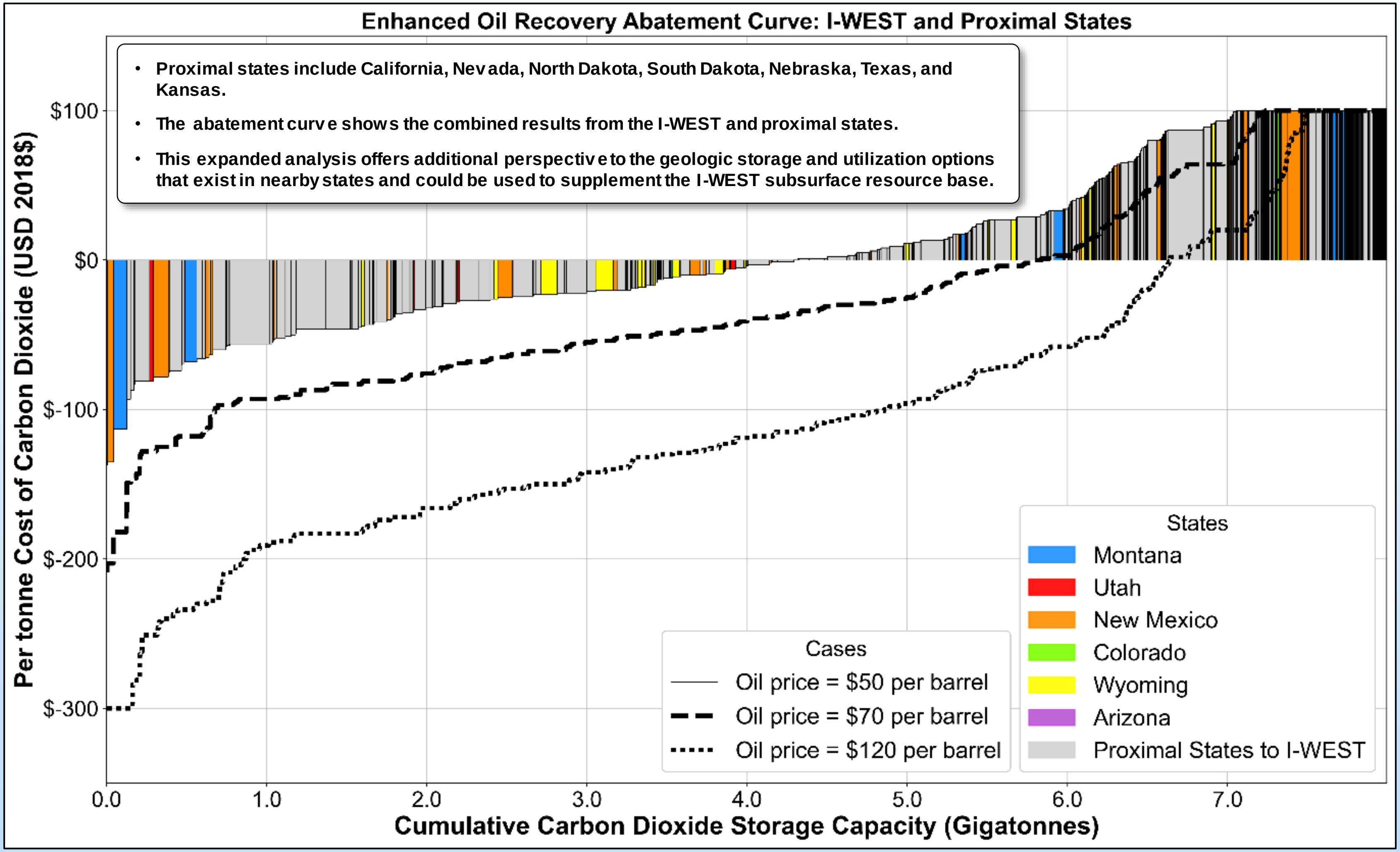
Top Five Lowest Cost Storage Reservoirs by State

State	CO2_S_COM Reservoir Name	Basin	1st-year breakeven CO_2 price (2018$/tonne)	Max Number Injection Projects	CO_2 Storage Capacity (Million tonnes)	Depth to top of formation (ft)	Thickness (ft)	Porosity	Horizontal permeability (mD)	Area (mi^2)
NM	Seven Rivers2	Permian	9	16	2,064	3,064	516	19.0%	22	9,342
	Morrison2	San Juan	9	13	1,677	5,511	883	13.0%	15	8,518
	Wolfcamp2	Tucumcari	10	36	4,644	3,663	1,000	12.5%	100	8,495
	Leonard2	Permian	11	12	1,548	5,808	1,000	9.0%	10	9,342
	Canyon2	Tucumcari	11	14	1,806	5,517	724	8.5%	42	8,495
WY	Frontier3	Big Horn	7	23	2,967	3,280	740	22.1%	73	4,073
	Lance1	Wind River	11	8	1,032	7,394	1,000	17.5%	16	3,927
	Tensleep4	Wyoming Thrust Belt	11	56	7,224	6,375	440	22.0%	150	6,903
	Fort Union2	Wind River	14	6	774	5,966	1,000	8.4%	8	6,324
	Entrada6	Denver	15	5	645	7,163	382	15.7%	31	5,031
CO	Morrison1	San Juan	10	2	258	5,390	846	13.0%	15	1,960
	Morrison8	Piceance	15	17	2,193	6,382	435	14.0%	30	17,368
	Arbuckle2	Las Animas Arch	17	15	1,935	5,890	260	14.0%	60	11,610
	Entrada8	San Juan	17	7	903	3,391	161	20.0%	370	1,707
	Hermosa1b	Paradox	18	1	129	8,275	1,000	7.5%	9	1,467
MT	Minnelusa2	Powder River	16	22	2,838	8,000	295	19.0%	200	3,611
	Madison Gp-Mission Canyon Fm4	Williston	16	40	5,160	6,500	545	12.0%	8	42,151
	InyanKara1	Williston	17	62	7,998	5,000	250	18.0%	100	27,105
	Red River2	Williston	17	25	3,225	9,500	360	14.0%	35	21,306
	Duperow-Lower1	Kevin Dome	24	2	258	3,800	300	12.5%	20	4,804
UT	Entrada2	Uinta	11	64	8,256	7,240	670	16.5%	100	10,798
	Tensleep5	Wyoming Thrust Belt	11	33	4,257	6,780	420	22.0%	145	4,435
	Morrison7	Uinta	12	12	1,548	6,858	804	13.0%	21	8,004
	Navajo01	San Rafael Swell	12	2	258	6,500	420	23.5%	15	1,830
	Dakota5	Uinta	54	2	258	8,640	130	12.0%	20	10,678

Saline Storage Assessment Applicable to I-WEST Region and Proximal States



CO_2-EOR Assessment Applicable to I-WEST Region and Proximal States



CO_2 Transportation Network Outlook: Integrating Sources and Sinks

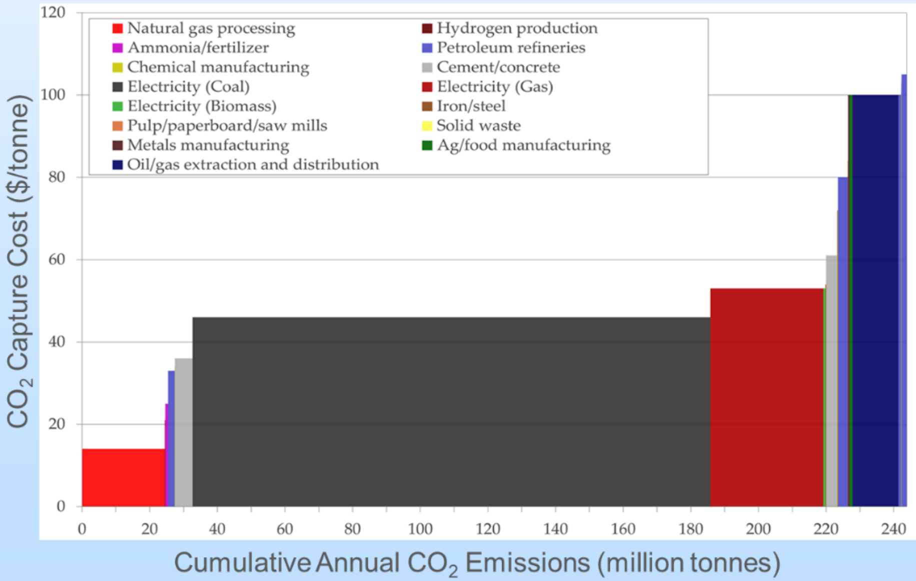
SimCCS Overview

- LANL's SimCCS utilized to simulate pipeline buildouts
- Optimizes networks based on total system unit costs (capture, transport, and storage)
- Connecting pipelines are sized to handle the total volume of CO_2 captured from all point sources part of a CCUS network

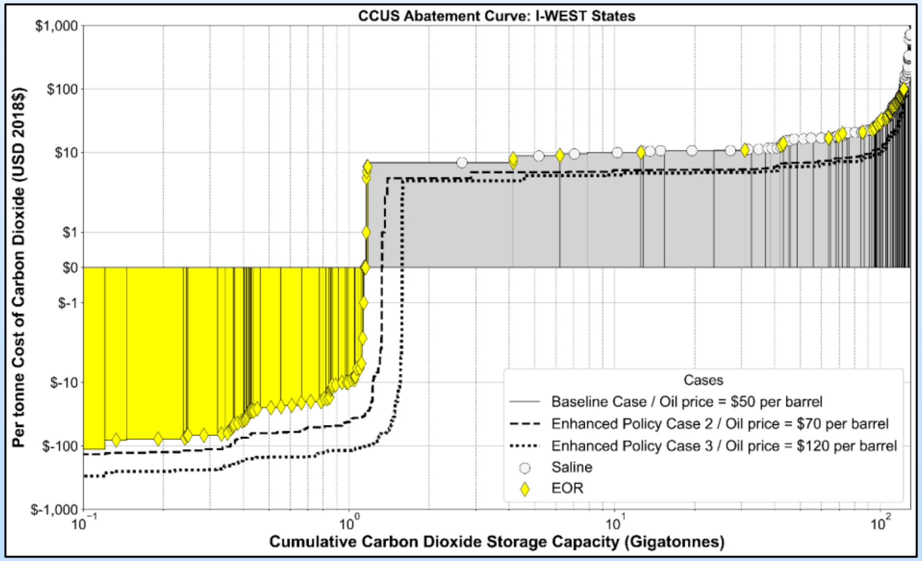
Approach Objective

- SimCCS implemented to target full decarbonization from all 45Q eligible point sources in the current I-WEST fleet using CCUS
- Annual CO_2 emission volume = 219.5 million tonnes per year

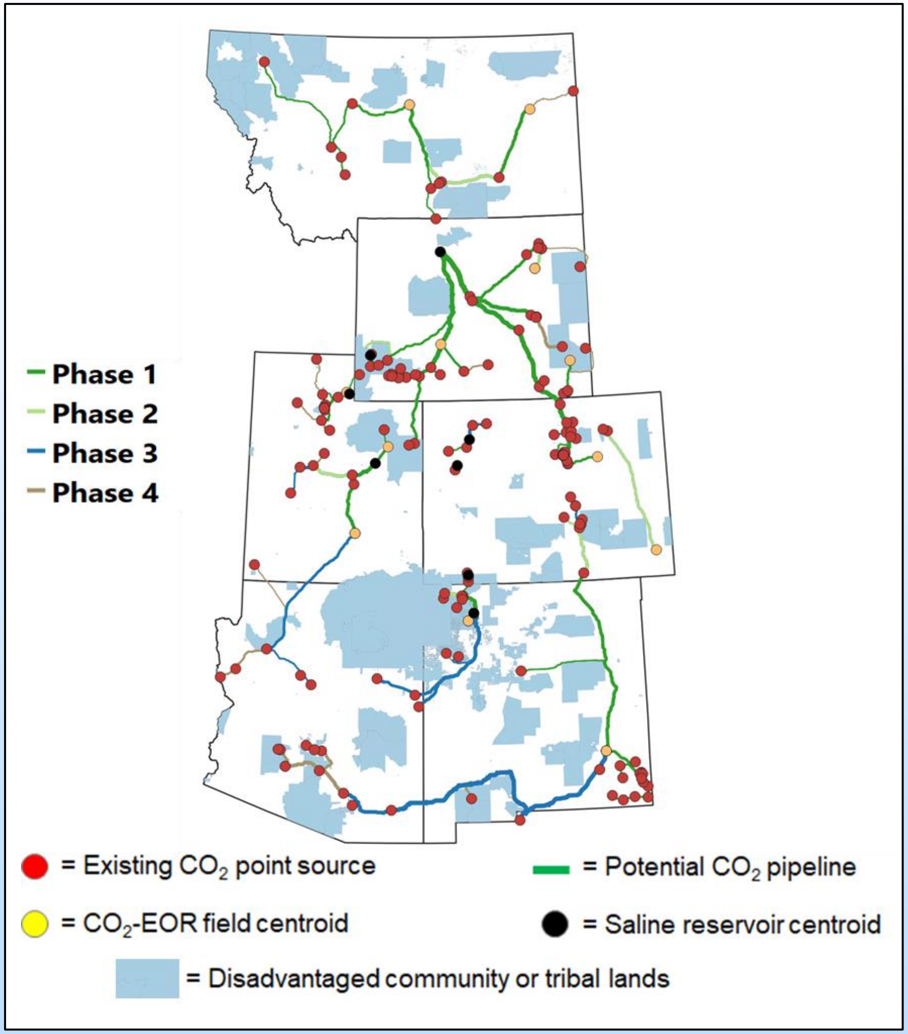
Assumed unit costs for CO_2 capture by source type (*NICO$_2$LE*)



Unit costs of storage and CO_2-EOR by field / reservoir



"Phased" Deployment Buildout



- **Full CCUS 45Q point source decarbonization over a 20-year development scale-up timeframe assumed**
- **CO_2 volumes managed closely coincide with I-WEST Roadmap's phased decarbonization timeline**
- **Early (Phase 1 and 2): CO_2 largely sent to a mix of "same state" EOR fields and saline storage**
- **Late (Phases 3 and 4): connection of sources far from reservoirs with EOR options (AZ and NM sources)**

Result Output	Buildout Phase			
	Phase 1	Phase 2	Phase 3	Phase 4
Captured amount of CO_2 (Million tonnes/year)	50	100	150	219.5
New pipeline installed (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