

CO₂ EOR: Increasing Oil Production While Providing a Lower Carbon Future

Wyoming CO₂ EOR 2022 Update Report

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Enhanced Oil Recovery Institute

Wyoming CO₂ Injection/EOR/Sequestration Projects

- Wyoming has been sequestering CO₂ since 1986
- Injecting into 9 reservoirs in 7 fields at commercialscale
- Four other small-scale pilot tests



Wyoming Fields with CO₂ Injection

CO₂ EOR's Contribution to Wyoming Production

- Since 2010, CO₂ EOR projects have produced roughly 7 million BOPD (about 10% of the state's oil)
- Total oil from CO₂ EOR sums to over 135 million barrels

CO₂-EOR's Contribution







Wyoming CO₂ Sources, Pipelines, and Sinks

- Wyoming has large CO₂rich gas reservoirs
 - LaBarge platform feeds the Shute Creek processing plant and contains 100 Tcf
 - Madden (Lost Cabin) contains about 1 Tcf
- Shute Creek is the primary supplier of CO₂ into the pipeline system





Wyoming's CO₂ Sinks

- Successful CO₂ EOR projects in three of the state's major oil-producing basins
- Suitable formations in each basin of the state
- Big Horn Basin has no access to CO₂

	Green River Basin		Wind River Basin		Powder River Basin	
Removed Cenozoio	Seque	nces				
		Lance Fm		Lance Fm		Lance Fm
		Fox Hills Ss		Meeteetse Fm		Fox Hills Ss
		Lewis Sh		Lewis Sh		Lewis Sh
	Mesaverde	Almond Fm	Mesaverde	Teapot Ss	sa- de	Teapot Ss
		Ericson Fm		Parkman Ss	Me ver	Parkman Ss
		Rock Springs Fm		Wallace Creek		Sussex Ss
		Blair Fm		Fales Member	Ę	Shannon Ss
Upper Cretaceous			Cody Sh Frontier Fm Mowry Sh	ody S	Steele Sh	
		Baxter Sh		Cody Sh	Ŭ	Niobrara Sh
						Sage Breaks Sh
				Frontier Fm	Frontier	Wall Cr Ss
		Frontier Fm				Frontier/Turner Ss
						Belle Fourche Sh
		Mowry Sh		Mowry Sh		Mowry Sh
						Shell Creek Sh
		Muddy Ss		Muddy Ss		Muddy Ss
		Thermopolis Sh		Thermopolis Sh		Thermopolis Sh
LOWER CIELACEOUS		Cloverly Fm	Cloverly	Rusty Beds	an ra	Fall River/Dakota Fm
				Lakota Ss	ln) Ka	Lakota Fm
Removed Jurassic a	and Tria	ssic Sequences				
Permian		Phosphoria Fm		Phosporia/Park City/Goose Egg Fm	Goose Egg	Ervay
						Forelle Ls
						Glendo Sh
						Minnekahta Ls
						Opeche Sh
Pennsylvanian		Tensleep Ss		Tensleep Ss/Casper Fm		Tensleep Ss/Minnelusa Fm
		Amsden Fm		Amsden Fm		Amsden Fm
Mississippian		Darwin Ss		Darwin Ss		Madiaanta
		Madison Ls		Madison Ls		
Devonian		Darby Fm		Darby Fm		Darby Fm

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Wyoming's CO₂ Sinks – Basin Potential

- Big Horn Basin
 - Highest potential
- Powder River Basin
 - Many smaller fields
 - High potential
- Table includes current CO₂ EOR projects

Basin	Number of Fields Amenable to CO ₂ EOR*	CO ₂ EOR Potential** (million barrels)
Big Horn	14	900
Green River	14	222
Powder River	47	780
Wind River	7	129
Total	82	2,031

* Fields selected based on 2009 EORI study

** Production potential updated in 2022 by EORI staff



CO₂ EOR Example from Patrick Draw

- Anadarko began CO₂ pilot in 2001
- Homogeneous sand with very little fingering
- Production and injection rates, bbl/D or Mcf/D • CO_2 injection began in 2003, production ramped up to pseudohigh in 2007, but ultimately peaked in 2017 (from 40 to 7,000 BOPD)
- Current inc. recovery is 18% of OOIP
- Sold to FDL in 2015, sold again to Contango O&G in 2022



Patrick Draw (Almond) Field

CO₂ EOR Example from Beaver Creek

- Devon purchased in 2000 and began evaluation process
 - Screening and laboratory testing
 - Reservoir characterization
 - Detailed sector modeling and fullfield modeling
- CO₂ injection began in 2008, peak production in 2012
- Production increased from 200 to 5,000 BOPD
- Current recovery is 11.5% OOIP
- Sold field to Denbury in 2021



CO₂ Sources: Current, Proposed, and Potential

- Shute Creek gas processing plant (current)
- Lost Cabin gas processing plant (small amount)
- Riley Ridge gas plant (proposed)
- Numerous, large coal-fired power plants and other industrial sources (potential)
- ExxonMobil's Shute Creek plant
 - Primary source for the CO₂ pipeline system
 - Input is 830 MMcf/D of sour gas (65% CO₂) from the LaBarge platform 40 miles to NW
 - CO₂ output
 - 60% is compressed to be sold to customers
 - 5% of the CO_2 is re-injected with H_2S
 - 15% is combined with hydrogen and used as fuel gas for cogeneration turbines.
 - Remaining 15% to 20%—about 100 MMcf/D is vented

Shute Creek Gas Plant CO₂ Sales



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Wyoming is **Not** Constrained by CO₂ Source

- A commercial $CO_2 EOR = roughly 50 MMcf/D$
- Shute Creek vents about 100 MMcf/D
 - LaBarge platform contains about 100 Tcf of CO₂
- Lost Cabin gas plant (0.9 Tcf) operating, but not supplying CO₂
- Riley Ridge, part of LaBarge platform, not fully operating and is not supplying CO₂
- Wyoming's 10 coal-fired power plants, if retrofitted with capture technology, could supply between 780 Mcf/D and 2.35 Bcf/D



Wyoming is Not Constrained by Pipeline Capacity

_	CO ₂ Pipeline	Diameter	Estimated Pipeline Capacity	5-year Average Flow Rate	%
Owner	Name	(in.)	(MMct/D)	(MMct/D)	Capacity
Amplify Energy Corp.	Bairoil Pipeline Spur	16	43	15	34.9
Contango	Salt Creek Pipeline	16	290	211	72.8
Contango	Salt Creek Field Spur	12	200	132	66.0
Contango	Patrick Draw Field Spur	8	80	33	41.3
Denbury Resources	Greencore Pipeline	20	720	58	8.1
Denbury Resources	Beaver Creek Pipeline	8	80	20	25.0
Denbury Resources	Big Sand Draw Field Spur	8	80	15	18.8
Denbury Resources	North Grieve Field Spur	8	30	21	70.0
ExxonMobil Corp.	Shute Creek to Rock Springs	24	1220	309	25.3
ExxonMobil Corp.	Rock Springs to Bairoil	20	500	246	49.2
Scout Energy	Raven Ridge Pipeline	16	220	30	13.6





Carbon Negative Crude Oil (??)

- More CO₂ is sequestered than the combined scope 1, 2, and 3 emissions
- Scope 1 emissions are direct greenhouse (GHG) emitted by an organization
- Scope 2 emissions are indirect GHG emissions associated with the organization's energy use
- Scope 3 emissions include all others resulting from organization's activities



Source: https://www.epa.gov/climateleadership/scope-1-and-scope-2-inventory-guidance



Helping to Meet Governor's Net Zero Carbon Goal

- Headlines
 - "Oxy Will Sell 'Net zero oil' to Korean Refiner" Bloomberg 22 March 2022
 - "25% of Denbury's production is Scope 3 carbon negative through the use of industrial-sourced CO₂" – J.P. Morgan 2022 Energy Conference



Carbon-Negative Crude Oil (Yes!!)

- More CO₂ is sequestered than the combined scope 1, 2, and 3 emissions
- A Wyoming-based example of carbon negative crude oil: Beaver Creek
 - CO₂ sequestered estimated to be
 9.9 Mt or 22 billion lb_m
 - EUR is 15.9 million barrels of incremental oil from CO₂ EOR
 - Equivalent to roughly 1400 lb_m of CO₂/bbl
 - Scope 1, 2, & 3 emissions estimated to be 1200 $\rm Ib_m~CO_2e/bbl^*$
 - * J.P. Morgan 2022 Energy Conference, June 2022



That's carbon negative crude oil !



Summary

- Shown that Wyoming is:
 - Not constrained by CO₂ source
 - Have 500 years supply just from Shute Creek
 - Many other potential sources
 - Not constrained by pipeline capacity
 - Except to access Big Horn Basin potential
 - Not constrained by oil fields with potential for CO₂ EOR
 - Every basin in the state has many opportunities
- Production from CO₂ EOR floods can be carbon negative oil
- EORI is a strong supporter of CO₂ EOR as a primary technology for CO₂ storage



Discussion Points

- Oxy and Denbury are promoting low-carbon oil from CO₂ EOR
 - Also called "blue oil," "green oil," "carbon-negative oil," or "net-zero oil"
 - Can CO₂ EOR oil be promoted for a premium?
- Can a CO₂ pipeline be built to extend infrastructure into the Big Horn Basin?
 - What role does the Wyoming Pipeline Corridor Initiative play?
- Significant financial and engineering investment is required
 - How can these be overcome?
- What can be done to promote CO₂ EOR?
 - Does the state and/or federal government have a role?
 - Incentives? Tax relief?
 - What can CO₂ source owners, pipeline owners, and field operators do?



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DENVER BASIN

WIND RIVER BAS

Questions, comments, or concerns?

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A Leading Producer of Low-Carbon Oil



~25% of Denbury's production is Scope 3 carbon negative through the use of industrial-sourced CO2



Denbury O

1) Based on a 3-year average of the years ending December 31, 2018, 2019 and 2020. Source: Clean Air Task Force, IEA and Denbury internal information.