



The Survey of U.S. CO₂ Enhanced Oil Recovery (EOY 2020)

Prepared for:
2021 Midland CO₂ Conference Week

Theme Session #2: “CO₂ EOR, CCUS Case Histories II”

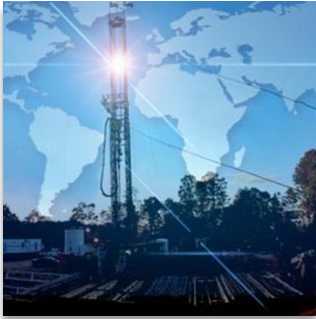
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December 9, 2021
Midland, TX



The Survey of U.S. CO₂ Enhanced Oil Recovery (EOY 2020)

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Introduction to the U.S. CO₂ EOR Survey

Introduction to the U.S. CO₂ EOR Survey

TECHNOLOGY

CO₂-EOR set for growth as new CO₂ supplies emerge

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Development of large natural sources of CO₂ in Colorado (McElmo Dome/Doe Canyon) and New Mexico (Bravo Dome) plus construction of high-volume CO₂ pipelines enabled CO₂ enhanced oil recovery (CO₂-EOR) to achieve its first burst of growth in the Permian basin starting in the 1980s.

Subsequent development of natural CO₂ supplies at Jackson Dome, Mississippi, and the capture of vented CO₂ at the massive LaBarge natural gas processing plant in western Wyoming provided the foundations for the second round of CO₂-EOR growth at the turn of the century in

the Gulf Coast and the Rocky Mountains.

Based on these first two phases of growth, the industry now injects 3.5 bcf/d (68 million tonnes/year [tpy]) of natural and industrial CO₂ to produce 300,000 b/d of oil via EOR.

Fig. 1 provides the state-by-state locations for the 136 currently active CO₂-EOR projects. Much of the activity is in West Texas with 77 projects, followed by Mississippi (19 projects), and Wyoming (14 projects).

Fig. 1 also shows the location of existing CO₂ supply sources. While much of the CO₂ is from natural CO₂ fields, industrial sources in growing numbers also provide CO₂ to the EOR industry. A robust infrastructure of CO₂ pipelines, totaling more than 3,000 miles, links CO₂ supply areas with oil fields.

While oil production from CO₂-EOR has steadily increased, its growth has slowed in the past few years (Fig. 2). This is due primarily to limits on ac-

CO₂-EOR OPERATIONS, CO₂ SOURCES: 2014

Oil production, 2014	
CO ₂ -EOR projects	136
Oil production, 1,000 b/d	300

CO ₂ supplies, 2014	
Number of sources	17
• Natural	5
• Industrial	12
CO ₂ supply, MMcf/d	3.5
• Natural	2.8
• Industrial	0.7

136 Number of CO ₂ -EOR projects	
• Natural CO ₂ source	77
• Industrial CO ₂ source	19
• CO ₂ pipeline	14
• CO ₂ proposed pipeline	2

Source: Advanced Resources International Inc. based on OGJ EOR Heavy Oil Survey 2014 and other sources.

Reprinted with revisions to format, from the April 7, 2014 edition of OIL & GAS JOURNAL
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- The Oil & Gas Journal (OGJ) EOR Survey was a biennial status report of international enhanced oil recovery projects.
- The last EOR Survey was released in 2014 before publication was suspended.
- Advanced Resources revived the U.S. CO₂ EOR Survey beginning in 2020 (EOY 2019).
- The U.S. CO₂ EOR Survey is an ongoing, joint effort between Advanced Resources Int., EORI, and Melzer Consulting.

Introduction to the U.S. CO₂ EOR Survey

Overview

- The U.S. CO₂ EOR Survey is a valuable public resource for petroleum and carbon management industry stakeholders.
- It is important to highlight the sustained success of CO₂ EOR in the U.S. and its viability and potential for secure CO₂ storage.
- The survey includes field-specific information on each CO₂ flood location, project data, reservoir characteristics, and production data.

Survey Data

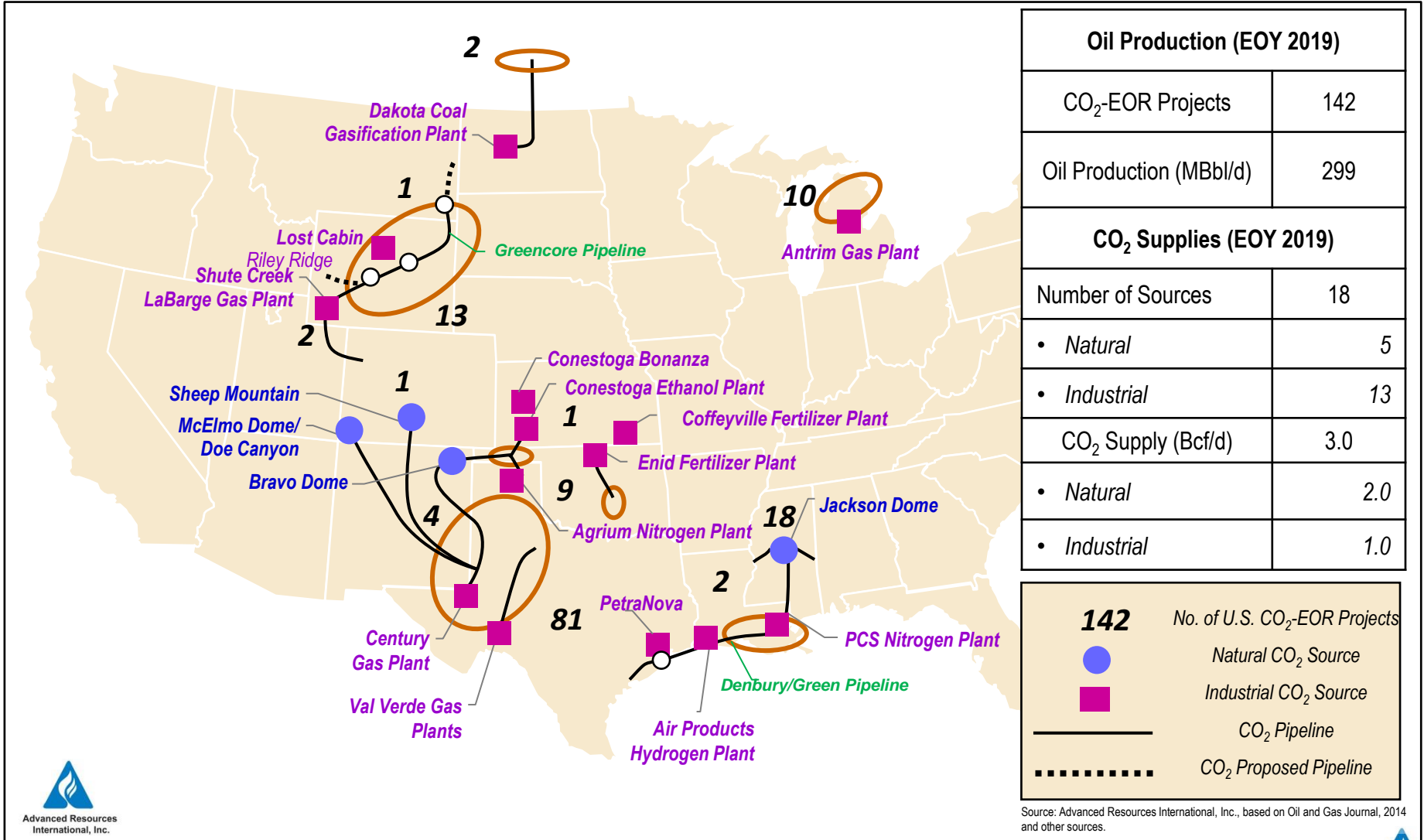
Location	Operator
	Field Name
	State
Project Data	Project Start Date
	Field Area (ac)
	Production/Injection Wells
	Pay Zone
	Previous Production Type
Reservoir Characteristics	Porosity (%)
	Soi (%)
	Sor (%)
	Avg. Permeability (md)
	Depth (ft)
	Gravity (API)
	Oil Viscosity (cp)
	Reservoir Temperature (F)
Production Data	Total Production (bbl/d)
	Enhanced Production (bbl/d)

Introduction to the U.S. CO₂ EOR Survey

Ongoing Updates

- The survey team will compile and publish an annual survey update.
 - Even years will include operator-verified production totals and project data
 - Odd years will include an internal update of the production data
- Ultimately the success of the survey depends on the cooperation and participation of the CO₂ EOR operators.
- Historically operators have been supportive of the EOR Survey by providing accurate and up-to-date project data.
- About 65% of the EOY 2019 Survey was verified by the operators; we expect to increase this percentage for 2021.

Previous Survey Results (EOY 2019)



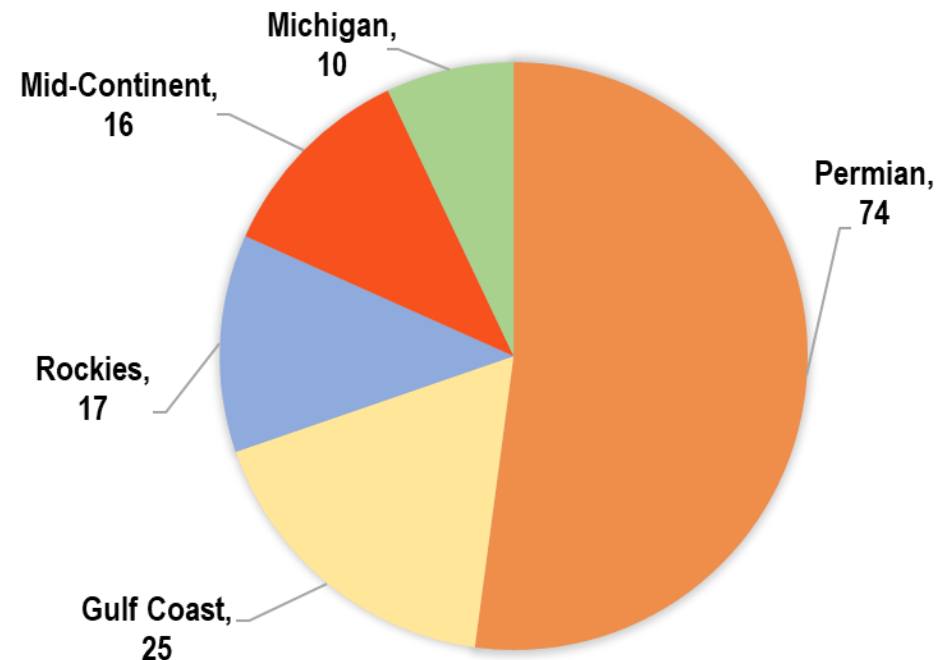


Updating the Survey to EOY 2020

Updated List of U.S. CO₂ EOR Projects

- A total of 142 projects are included in the EOY 2020 U.S. CO₂ EOR Survey.
- Between 2014 and 2019 a total of 11 projects were added and 5 projects were removed for a net increase of 6 projects.
- No additional projects were added for EOY 2020, although several projects changed hands between operators.

2020 Survey Projects by Region



Updated List of CO₂ EOR Project Operators

Region	Projects	Operators
Permian (TX, NM)	74	Apache, Chevron, ConocoPhillips, Fasken, Four Corners Petroleum, George R. Brown, Great Western Drilling, KinderMorgan, Oxy, OrlaPetco, Perdure Petroleum, Sabinal, Tabula Rasa, XTO
Gulf Coast (MS, LA, TX)	25	Denbury, Hillcorp, Tellus, TMR Exploration
Rockies (WY, UT, MT, CO)	17	Amplify Energy, Chevron, Denbury, Elk Petroleum, Fleur De Lis
Mid Continent (OK, KS)	16	Daylight Petroleum, Maverick Energy, Perdure Petroleum, PetroSantander, Remnant
Mid West (MI)	10	Core Energy
Total	142	26

- There are a total of 26 CO₂ EOR operators in the U.S.
- One operator, Devon, was removed for the EOY 2020 update.
- Chevron, Denbury, and Perdure Petroleum operate CO₂ floods in multiple regions.

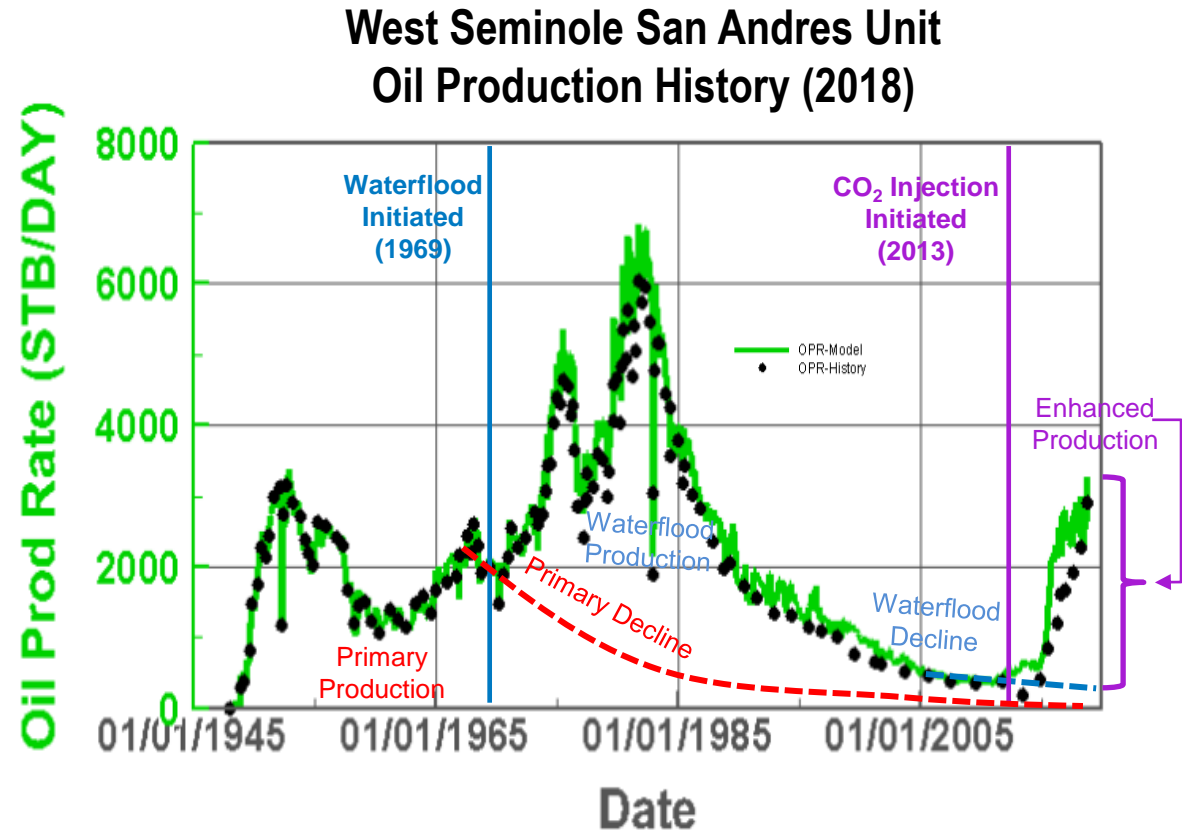
Methodology for Updating EOR Production Data

Enhanced Recovery Calculations

- Calculating the total and enhanced production for each project requires the greatest effort to update the Survey.
- We gather oil production data for each project from Enverus (Drilling Info) and state oil and gas commission databases (TXRRC, WYOGCC, etc).
- Enhanced recovery totals are calculated based on primary/secondary decline curve analysis.
- Calculated enhanced recovery totals (barrels per day) are then checked against previous survey data and current production data from the operators, where available.

Example: West Seminole San Andres Unit

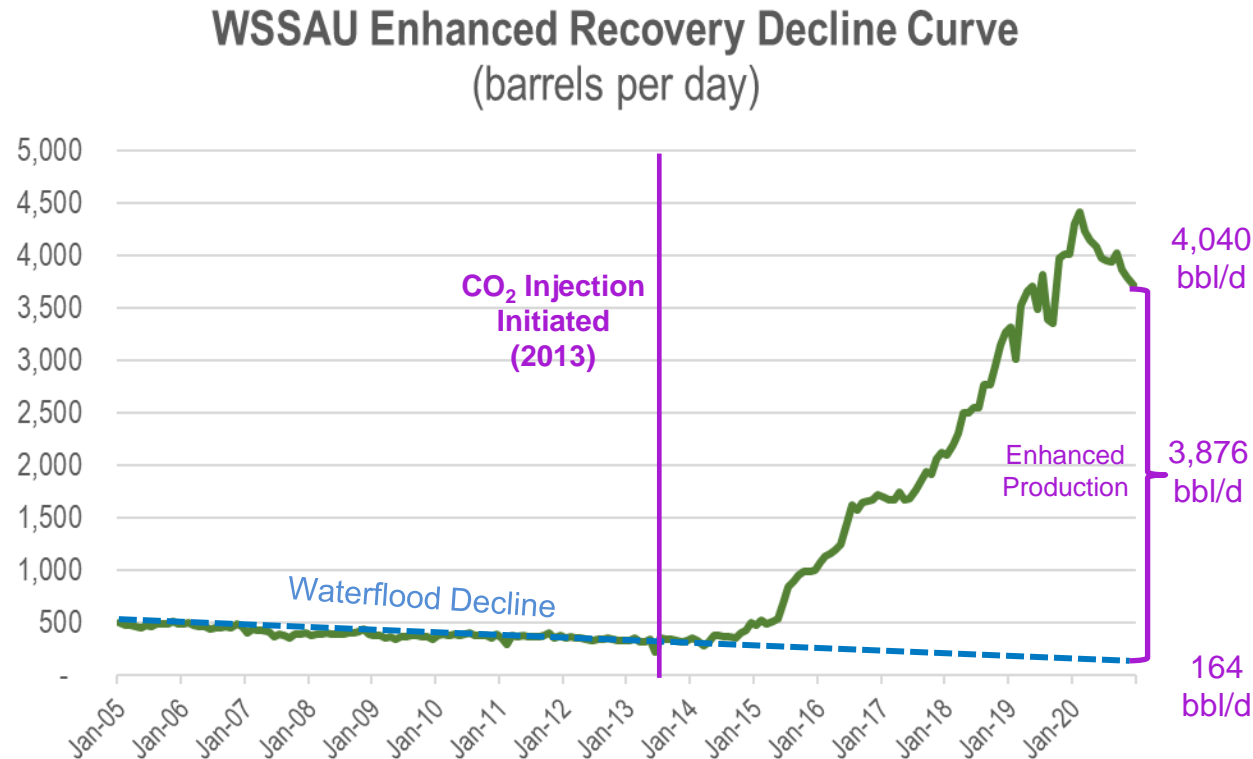
- The WSSAU began producing oil in 1948.
- Waterflood operations were initiated in 1969.
- CO₂ injection began in 2013.
- The chart shows estimated primary and secondary decline curves.



Source: WSSAU MRV Plan, 2021

Example: West Seminole San Andres Unit

- The chart shows a close-up view of the secondary decline curve and enhanced production from 2005 to 2020.
- Total production in 2020 averaged 4,040 bbl/d.
- Remaining secondary production was calculated to be 164 bbl/d
- Enhanced Production for WSSAU was estimated to be 3,876 bbl/d in 2020.



Methodology for Updating EOR Production Data

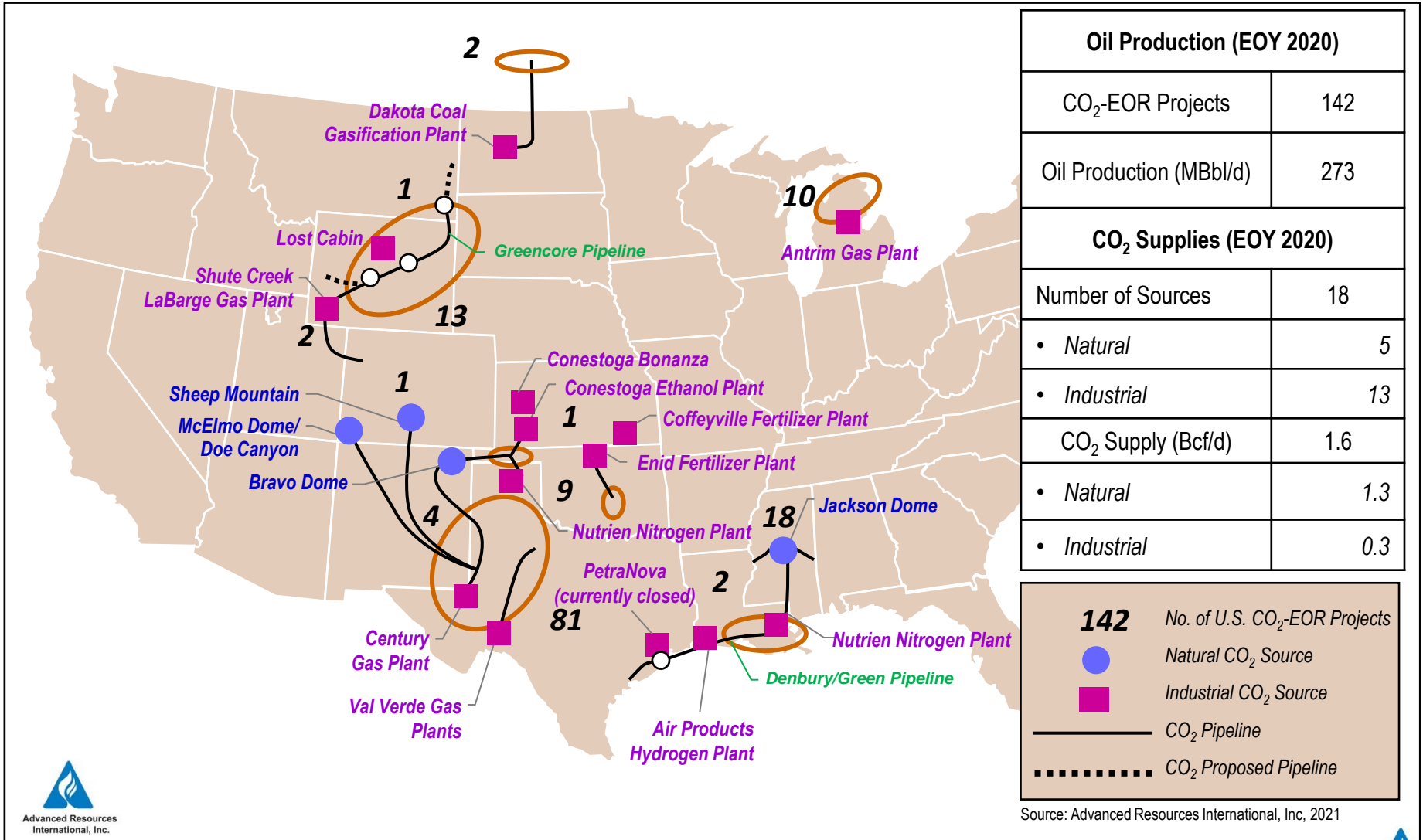
Adjusting Estimates Based on EOY 2019 Survey

- For continuity we compared the EOY 2020 survey results to the EOY 2019 survey data.
- Calculated enhanced production data for EOY 2020 was adjusted, as needed, based on the verified data from the EOY 2019 Survey.
- This included adding or removing specific leas/unit production totals within the CO₂ EOR field.



The 2020 U.S. CO₂ EOR Survey Results

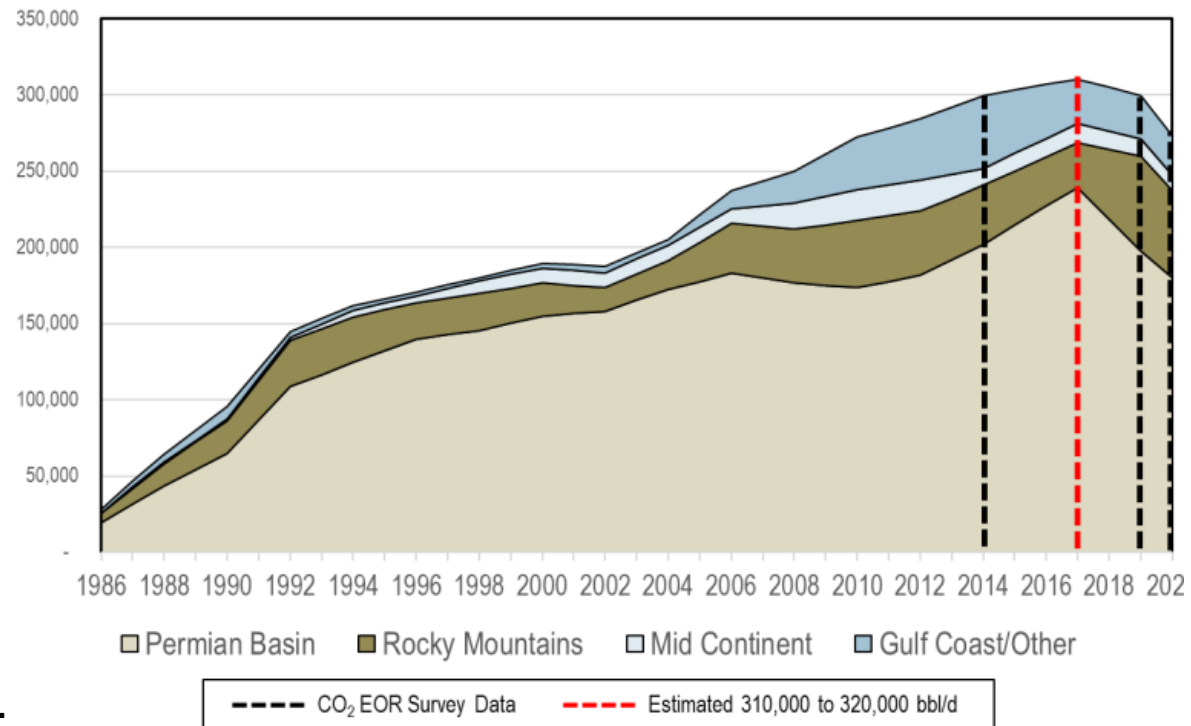
The Status of U.S. CO₂ EOR (EOY 2020)



The Status of U.S. CO₂ EOR (EOY 2020)

U.S. CO₂ EOR Production History

- The last OGJ EOR Survey reported 300,000 bbl/d in 2014.
- CO₂ EOR production in 2017 is estimated between 310,000 and 320,000 bbl/d.
- The 2019 Survey reported 299,000 bbl/d.
- The 2020 Survey declined to 273,000 bbl/d.



The Status of U.S. CO₂ EOR (EOY 2020)

Region	EOY 2020 U.S. CO ₂ EOR Survey		
	No. Projects	Enhanced Recovery (MB/D)	CO ₂ Supply (MMcf/D)
Permian Basin (W TX, NM)	74	183.5	1,025
Gulf Coast (MS, LA, E TX)	25	39.3	360
Rockies (CO, WY, MT, UT)	17	37.4	110
Mid Continent (OK, KS, N TX)	16	12.0	120
Michigan	10	0.5	20
Total	142	272.7	1,635

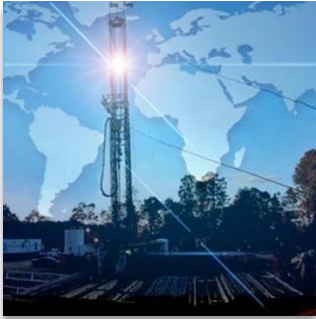
- The 2020 U.S. CO₂ EOR Survey reported:
 - 273,000 barrels per day of enhanced oil recovery
 - 142 unique projects operated by 26 different producers
 - Total CO₂ supply of 1.6 Bcf/d
 - 1.3 Bcf/d natural CO₂; 0.3 Bcf/d industrial CO₂

The Status of U.S. CO₂ EOR (EOY 2020)

CO₂ Supplies for CO₂ EOR

- The Survey included total CO₂ supply for CO₂ EOR in the U.S. of 1,635 MMcf/d.
- Natural sources, including McElmo Dome, Bravo Dome, and Jackson Dome reduced production based on a decline in demand for CO₂.
- CO₂ supplies from gas processing were reduced significantly due to lower gas processing rates.
- CO₂ supplies from industrial sources, including ammonia, ethanol, and hydrogen remained mostly unchanged.

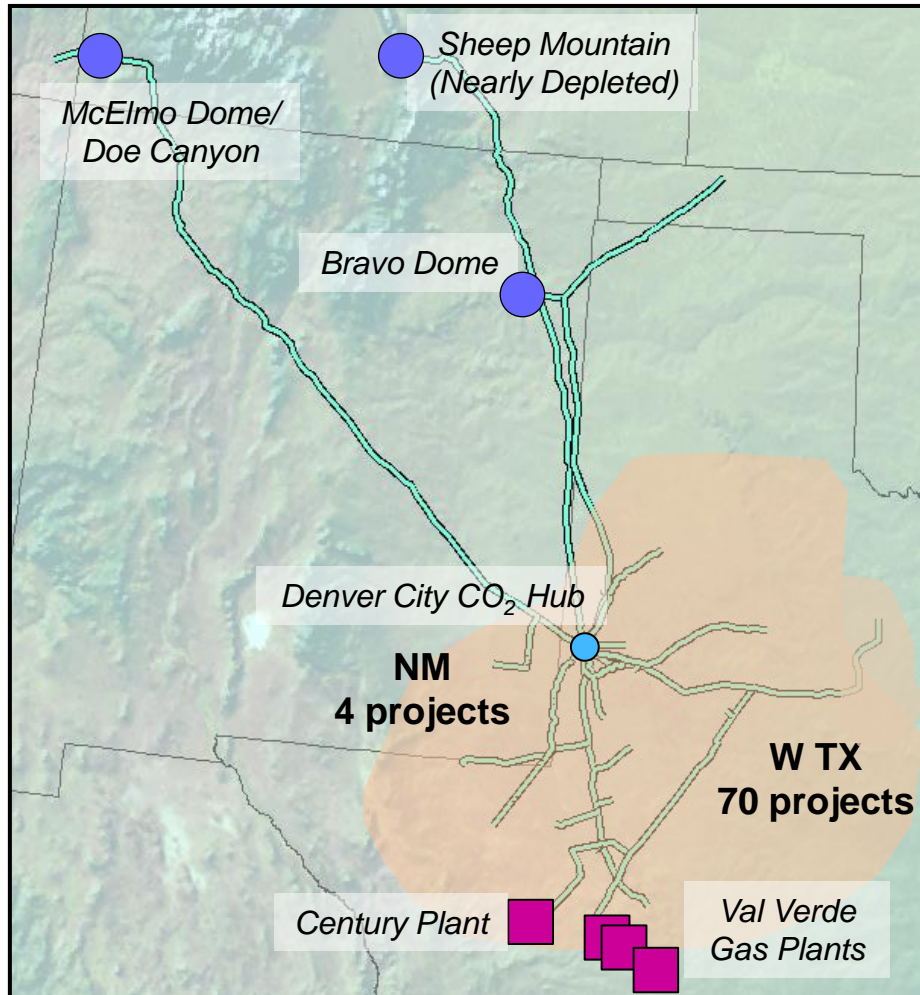
Permian Basin	Natural	950
	Industrial	75
	Total	1,025
Gulf Coast	Natural	300
	Industrial	60
	Total	360
Rockies	Natural	25
	Industrial	85
	Total	110
Mid-Continent	Natural	25
	Industrial	95
	Total	120
Michigan	Natural	-
	Industrial	20
	Total	20
Total U.S.	Natural	1,300
	Industrial	335
	Total	1,635



The Status of U.S. CO₂ EOR in the U.S. by Region

The Status of Permian Basin CO₂ EOR

Permian Basin CO₂ EOR

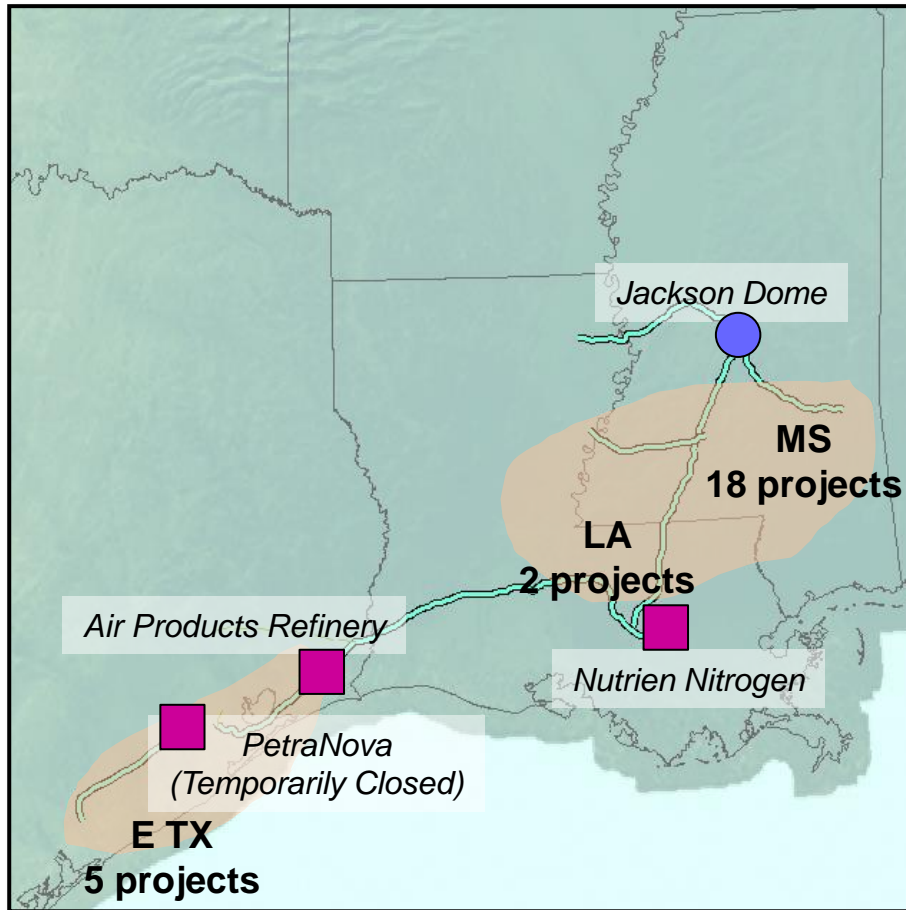


CO ₂ EOR Projects		2019 Survey	2020 Survey
Operators		14	14
Enhanced Recovery (MB/D)		202	184
Projects	W TX	70	70
	NM	4	4
	Total	74	74
CO ₂ Sources	Natural	4	4
	Industrial	2	2
	Total	6	6
CO ₂ Supply (MMcf/D)	Natural	1,500	950
	Industrial	330	75
	Total	1,830	1,025

- Enhanced recovery declined from 202,000 b/d in 2019 to 184,000 b/d in 2020.
- 14 operators own the 74 active CO₂ EOR projects in the Permian Basin.
- The largest CO₂ EOR operator in the Permian Basin is Oxy Petroleum, who operates a total of 34 CO₂ floods that produce over 100,000 b/d.
- Total CO₂ supply for EOR declined from 1,830 MMcf/d in 2019 to 1,010 MMcf/d in 2020.

The Status of Gulf Coast CO₂ EOR

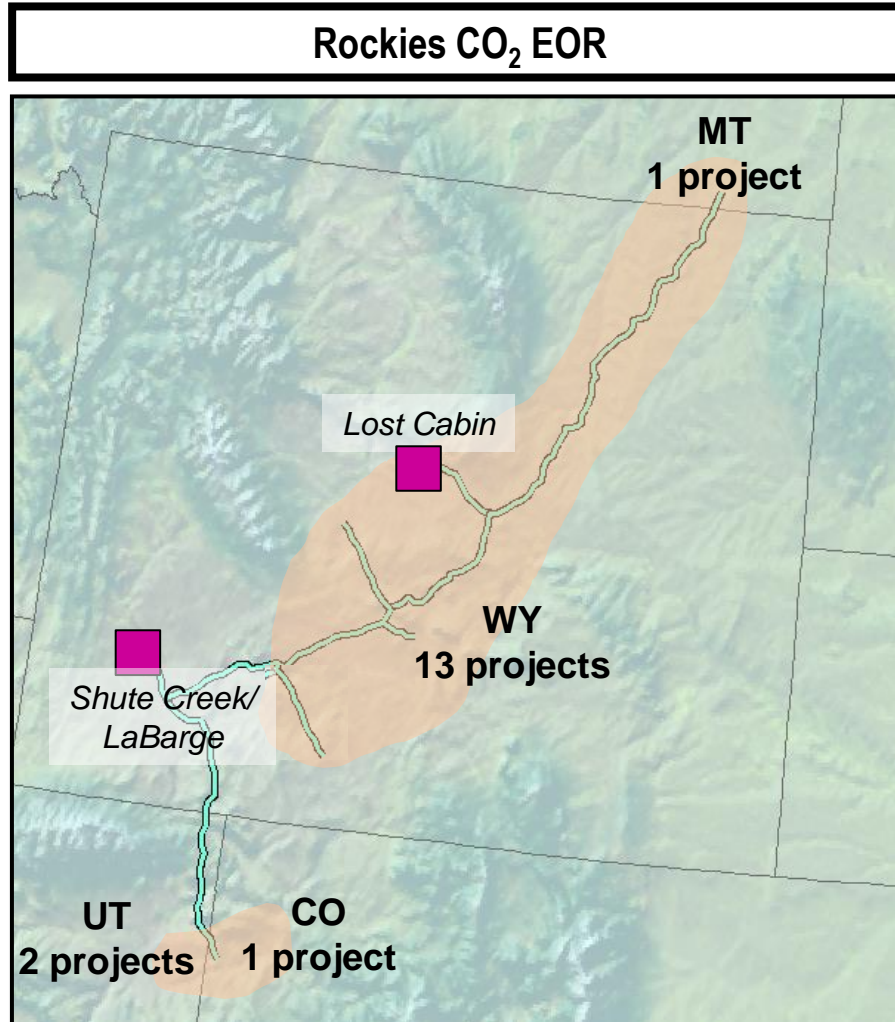
Gulf Coast CO₂ EOR



CO ₂ EOR Projects		2019 Survey	2020 Survey
Operators		4	4
Enhanced Recovery (MB/D)		43	39
Projects	MS	18	18
	E TX	5	5
	LA	2	2
	Total	25	25
CO ₂ Sources	Natural	1	1
	Industrial	3	3
	Total	4	3
CO ₂ Supply (MMcf/D)	Natural	450	300
	Industrial	150	60
	Total	600	360

- Enhanced recovery in the Gulf Coast declined from 43,000 b/d in 2019 to 39,000 b/d in 2020.
- Four operators own the 25 active CO₂ EOR projects in the Gulf Coast.
- The largest CO₂ EOR operator in the Gulf Coast is Denbury, who operates 18 CO₂ floods that produce approximately 33,500 b/d.
- Total CO₂ supply for EOR declined from 600 MMcf/d in 2019 to 360 MMcf/d in 2020.

The Status of Rockies CO₂ EOR

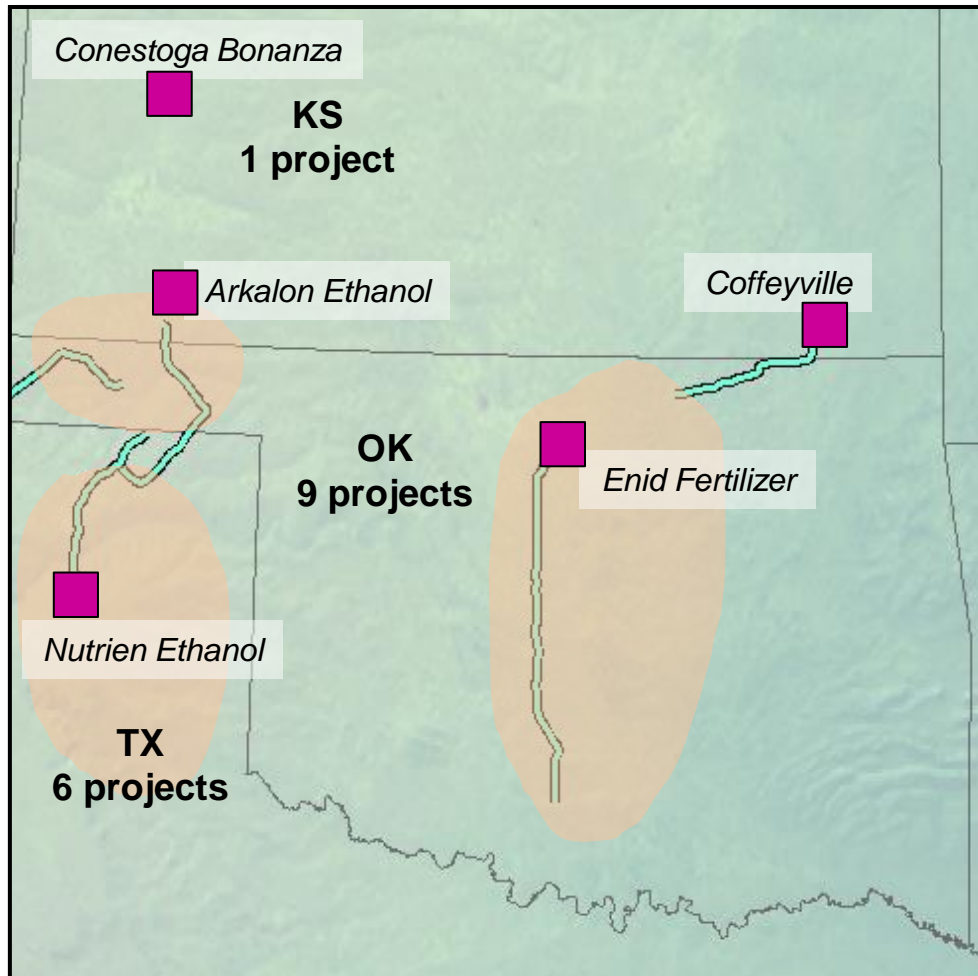


CO ₂ EOR Projects		2019 Survey	2020 Survey
Operators		6	5
Enhanced Recovery (MB/D)		39	37
Projects	WY	13	13
	UT	2	2
	CO	1	1
	MT	1	1
	Total	17	17
CO ₂ Sources	Natural	1	1
	Industrial	2	2
	Total	3	3
CO ₂ Supply (MMcf/D)	Natural	50	25
	Industrial	395	85
	Total	445	110

- Enhanced recovery in the Rockies declined from 39,000 b/d in 2019 to 37,000 b/d in 2020.
- Five operators own the 17 active CO₂ EOR projects in the Rockies.
- The largest CO₂ EOR operator is Fleur De Lis, who operates 6 CO₂ floods that produce about 15,700 b/d.
- Total CO₂ supply for EOR declined from 445 MMcf/d in 2019 to 110 MMcf/d in 2020.

The Status of Mid-Continent CO₂ EOR

Mid Continent CO₂ EOR

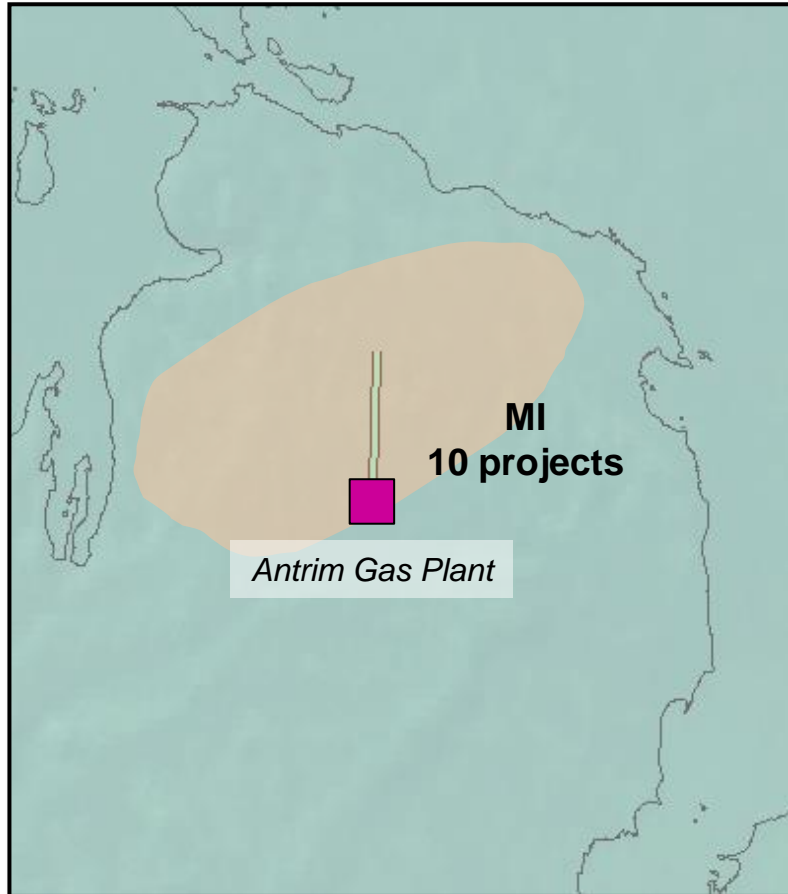


CO ₂ EOR Projects		2019 Survey	2020 Survey
Operators		4	5
Enhanced Recovery (MB/D)		13	12
Projects	OK	9	9
	W TX	6	6
	KS	1	1
	Total	16	16
CO ₂ Sources	Natural	1	1
	Industrial	5	5
	Total	6	6
CO ₂ Supply (MMcf/D)	Natural	35	25
	Industrial	100	95
	Total	135	120

- Enhanced recovery in the Mid-Continent declined from 13,000 b/d in 2019 to 12,000 b/d in 2020.
- Five operators own the 16 active CO₂ EOR projects in the Mid-Continent.
- The largest CO₂ EOR operator is Maverick Energy, who operates 4 CO₂ floods that produce approximately 6,000 b/d.
- Total CO₂ supply for EOR declined from 135 MMcf/d in 2019 to 120 MMcf/d in 2020.

Michigan CO₂ EOR Status

Michigan CO₂ EOR

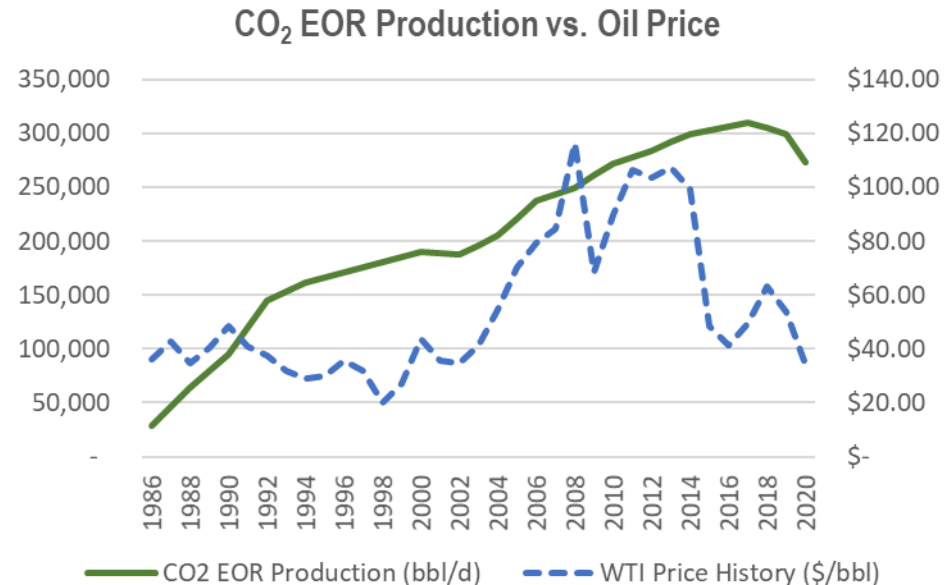


CO ₂ EOR Projects		2019 Survey	2020 Survey
Operators		1	1
Enhanced Recovery (MB/D)		1.4	0.5
Projects	MI	10	9
	Total	10	9
CO ₂ Sources	Natural	0	0
	Industrial	1	1
	Total	1	1
CO ₂ Supply (MMcf/D)	Natural	0	0
	Industrial	20	20
	Total	20	20

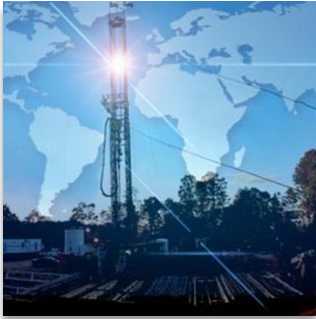
- Enhanced oil recovery production in Michigan declined from 1,400 b/d in 2019 to 500 b/d in 2020.
- One operator, Core Energy, owns all 10 active CO₂ EOR projects in Michigan.
- Total CO₂ supply for EOR remained constant at approximately from 20 MMcf/d
- CO₂ for EOR in Michigan is supplied from the Antrim Gas Processing Plant.

Resiliency of the CO₂ EOR Industry

- 2020 was a challenging year, not just for the CO₂ EOR industry but for all energy producers.
- Some critics of CO₂ EOR claim that project success is tied to either high oil prices or cheap/free CO₂.
- The production vs. oil price chart (WTI, adjusted for inflation) shows a history of increasing CO₂ EOR production against declining/flat oil prices.
- In 2020, CO₂ EOR production was down 9% YOY, similar to U.S. crude.
- However, this production survived an almost 50% reduction in CO₂ supplies, instead relying on CO₂ recycling.
- Hopefully the downturn seen in 2020 will rebound with increasing oil prices and increased CO₂ supply.



U.S. CO ₂ EOR	2019	2020	% Decline
Incremental Oil Production (MMbbl/d)	0.299	0.273	8.7%
CO ₂ Supply/Storage (Bcf/d)	3.0	1.6	46.7%
CO ₂ Utilization (Mcf/bbl)	10.0	5.9	



A Look Ahead to the 2021 U.S. CO₂ EOR Survey



A Look Ahead to the U.S. CO₂ EOR Survey (EOY 2021)

- The EOY 2021 U.S. CO₂ EOR Survey will again seek to verify project and production data with the operators.
- Expecting a significant increase in CO₂ EOR oil production – will we get back to 300,000 barrels per day?
- Also expecting a rebound in CO₂ supplies, primarily from industrial and gas processing sources.
- Near-term developments expected in the Rockies and Gulf Coast – both new CO₂ EOR projects and increase in CO₂ supplies for CO₂ EOR.



Acknowledgments

Acknowledgments

- Sincere appreciation to Steve Melzer and Lon Whitman, who have coordinated with operators and provided project insights.
- Many thanks to our summer intern, Cayman Kelly, who provided significant support on the decline curve analysis.
- Thanks to the operators who provided verification of project data for the EOY 2019 Survey:
 - Amplify Energy
 - Alan Shatto, TransPetco
 - Kate Ryan, Denbury
 - Gary Teletzke, XTO
 - Ray Ambrose, Elk Petroleum
 - David Hampton, OXY
 - Fleur De Lis
 - Bob Mannes, Core Energy



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