



# Quantifying the Value Proposition of CO<sub>2</sub> Storage and Domestic Oil Production in the U.S. Using CO<sub>2</sub> EOR

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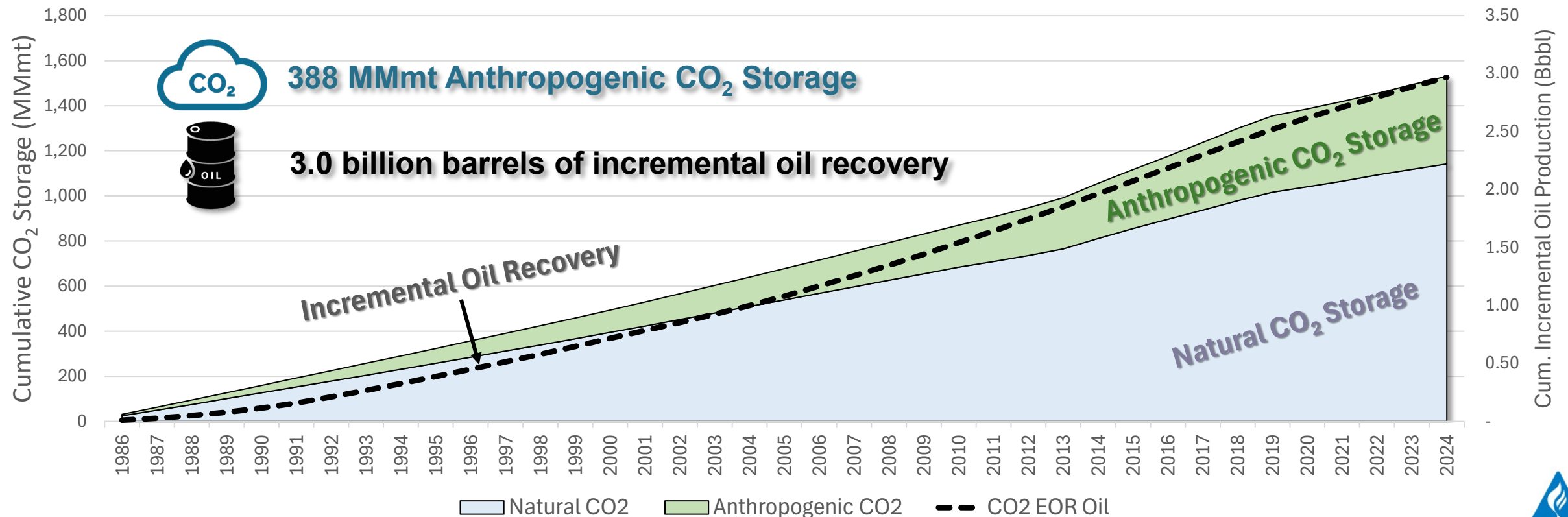


# Introduction and Study Objectives

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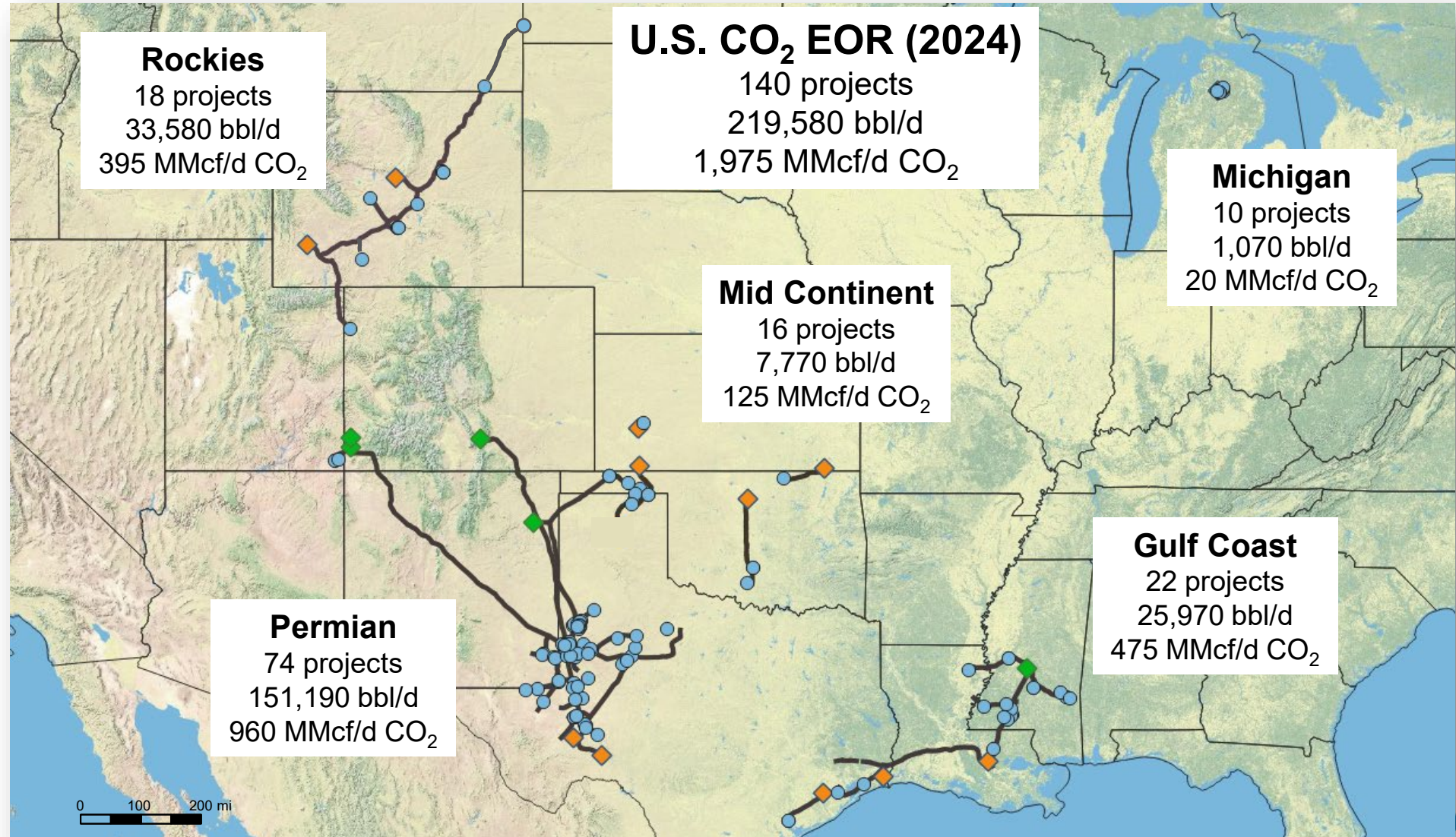
# Cumulative Oil Production and CO<sub>2</sub> Storage with CO<sub>2</sub> EOR

- Since 1986, CO<sub>2</sub> EOR projects in the U.S. have stored nearly 390 MMmt of anthropogenic CO<sub>2</sub> (1.5 Bmt total) and produced 3.0 Bbbl of incremental oil.
- This is an average of over 10 MMmt of anthropogenic CO<sub>2</sub> utilization and storage (39 MMmt total) per year for 38 years.**



# The Status of CO<sub>2</sub> EOR in the U.S.

- CO<sub>2</sub> EOR produced about 220,000 bbl/d in 2024 using 1,975 MMcf/d (37.9 MMmt/y) of CO<sub>2</sub>.
- However, annual production has been declining since a high of ~315,000 bbl/d in 2017.



# The CO<sub>2</sub> EOR Value Proposition

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*The question this study seeks to answer is:*

**What is the value base of CO<sub>2</sub> EOR in the U.S. in terms of:**

- Potential incremental revenue generation, and**
- Direct/indirect associated job creation?**

Quantifying this value potential is important for states to understand the impact of CO<sub>2</sub> EOR project investment and promotion.



# Identification of Anthropogenic CO<sub>2</sub> Sources for CO<sub>2</sub> EOR

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# Anthropogenic CO<sub>2</sub> Source Categories

- 1. Industrial:** Ammonia, chemical, refineries, hydrogen, cement, and steel facilities with expressed interest in CO<sub>2</sub> capture for CCS/CCUS.
- 2. Power:** Large-scale natural gas and coal power plants.
- 3. Data Centers:** Existing and planned hyperscale data centers in the SECARB Region that could capture CO<sub>2</sub> directly from behind-the-meter natural gas power generation.
- 4. Gas Processing:** Existing natural gas processing facilities that could separate CO<sub>2</sub> from high-concentration CO<sub>2</sub> natural gas.
- 5. Direct Air Capture:** Existing and planned DAC facilities that could supply CO<sub>2</sub> for CO<sub>2</sub> EOR.

*Includes many CarbonSAFE project CO<sub>2</sub> sources.*

*This study identifies:*

- Opportunities for CO<sub>2</sub> storage with CCUS,*
- Opportunities to convert from CCS to CCUS post 12-year 45Q credit period.*

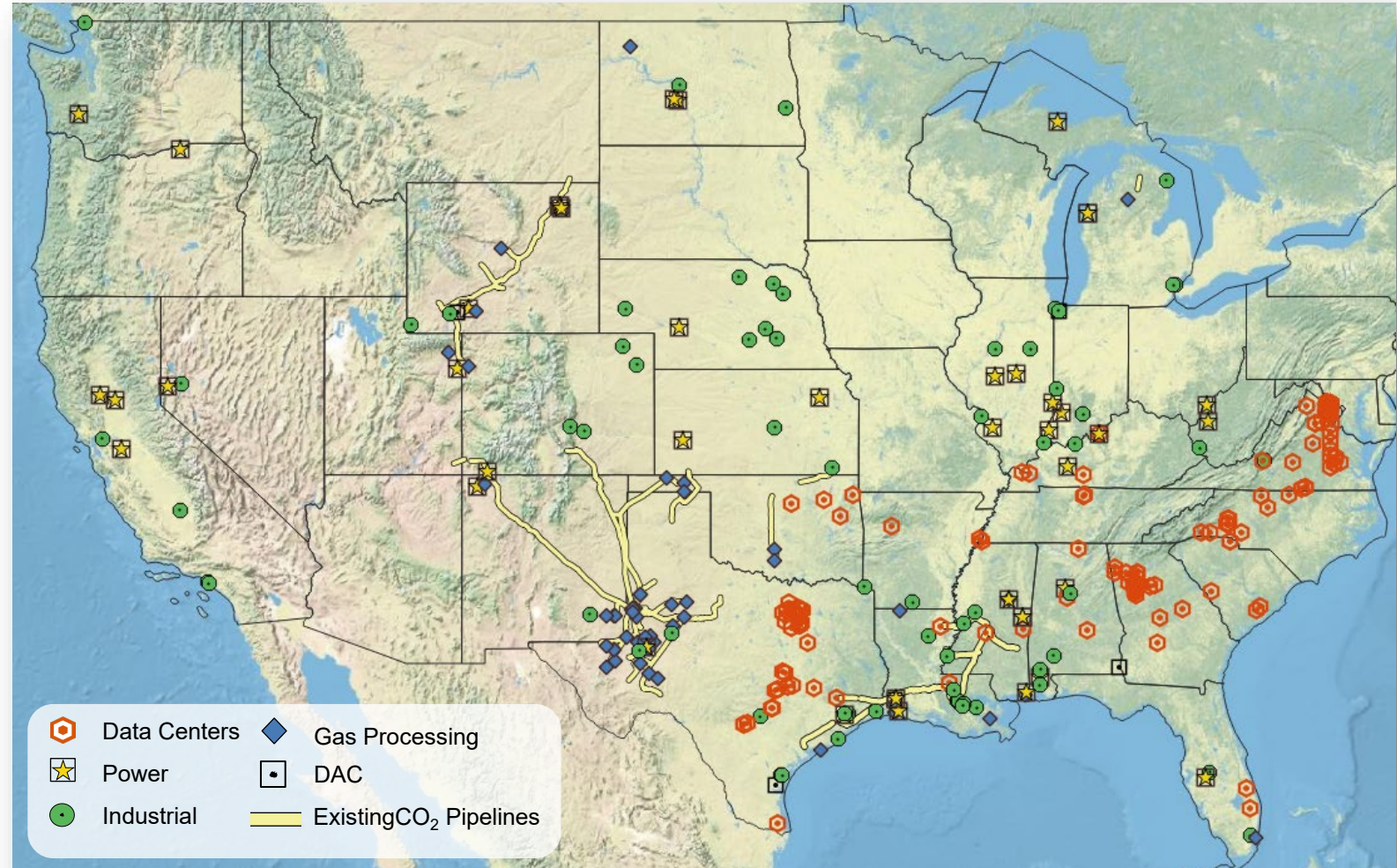
# Potential New CO<sub>2</sub> Sources for CO<sub>2</sub> EOR

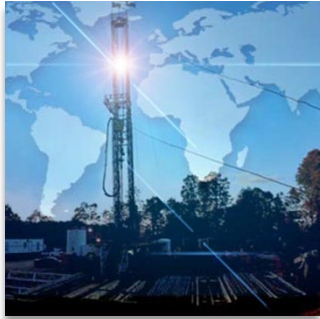
- We identified 324 potential new\* sources could supply 28.2 Bcf/d (541 MMmt/y) of CO<sub>2</sub> for CO<sub>2</sub> EOR.

\* Does not include any existing sources supplying 1,975 MMcf/d (37.9 MMmt) of CO<sub>2</sub> for CO<sub>2</sub> EOR

Source Type	Sources	CO <sub>2</sub> Supply	
		Bcf/d	MMmt/y
Data Centers	159	10.0	191.2
Power	42	6.7	128.4
Industrial	68	6.5	125.3
Gas Processing	50	4.6	89.3
Direct Air Capture	5	0.4	7.0
<b>Total</b>	<b>324</b>	<b>28.2</b>	<b>541.0</b>

## Potential CO<sub>2</sub> Sources for CO<sub>2</sub> EOR





# Technically- and Economically-Viable CO<sub>2</sub> EOR Resources

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# ARI Big Oil Fields Database (BOD)

- The ARI Big Oil Fields Database (BOD) contains nearly 2,000 large onshore oil reservoirs (10 MMbbl of OOIP or greater) in the L48 U.S.
- The BOD contains key reservoir property data – see example table at right – used to model CO<sub>2</sub> EOR resources.
- Screening the BOD identified 1,340 candidate oil reservoirs that screen positive for miscible CO<sub>2</sub> EOR.
- These 1,340 reservoirs have a total ROIP of 187 Bbbl that is the target for CO<sub>2</sub> EOR.

ARI BOD Reservoirs	Reservoir Count	OOIP (Bbbl)	P/S Production (Bbbl)	ROIP (Bbbl)
All	1,926	352.4	114.0	238.4
Miscible	1,340	280.3	93.7	186.6

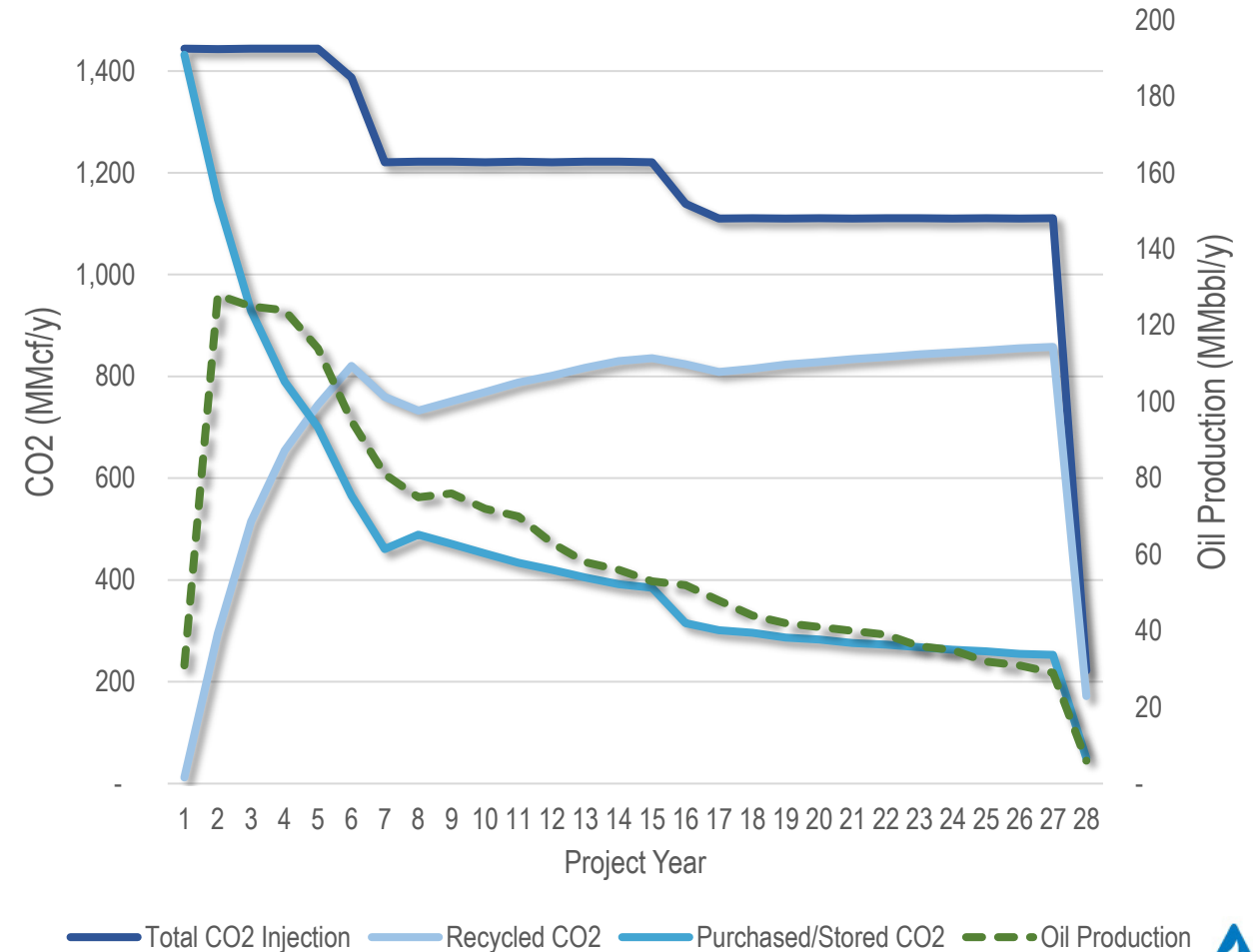
## Example BOD Data

Original Oil In Place	1,730 MMbbls
Area	93,561 acres
Net Pay	25 feet
Initial Oil Saturation	70%
Residual Oil Saturation	30%
Porosity	15%
Formation Volume Factor	1.1
Depth	3,328 feet
Permeability (matrix)	60 md
Temperature	110° F
Initial Pressure	1,200 psi
Oil Gravity	42° API
Viscosity	2.5 cp
MMP (estimated)	1,240 psi
Dykstra-Parsons	0.80

# ARI CO<sub>2</sub> Prophet Model

- CO<sub>2</sub> Prophet is a finite-difference stream tube model that generates streamlines fluid flow between a CO<sub>2</sub>/water injector and a producer.
- The model uses reservoir properties and fluid injection volumes to calculate pattern-level output data for CO<sub>2</sub>/water injection and oil, CO<sub>2</sub>, and water production.
- Pattern-level data is then scaled to the full reservoir area.

## Example Pattern-Level CO<sub>2</sub> Prophet Output Data



# Technically-Viable CO<sub>2</sub> EOR Resources

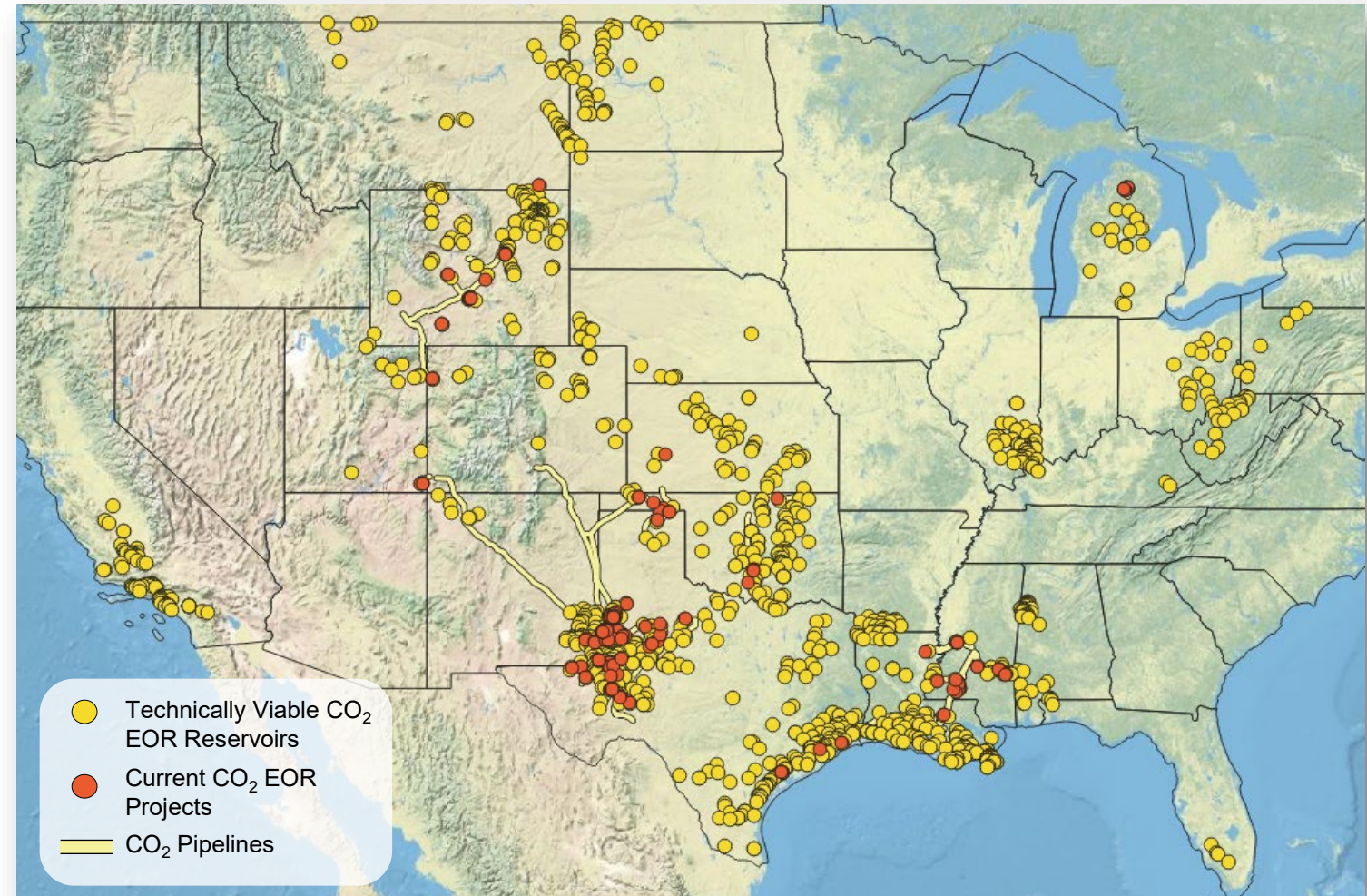
- The CO<sub>2</sub> Prophet Model calculated a technically viable resource of 39 Bbbl of incremental oil and 24.7 Bmt of CO<sub>2</sub> utilization.
- This is an overall incremental recovery of 14% of OOIP, consistent with expected CO<sub>2</sub> EOR performance.
- This resource does not include any past or current CO<sub>2</sub> EOR resources.

State	Res Count	OOIP (Bbbl)	CO <sub>2</sub> EOR Oil (Bbbl)	% of OOIP	CO <sub>2</sub> Storage (Tcf)	CO <sub>2</sub> Storage (Bmt)
TX	192	60.3	7.1	12%	88.9	4.7
LA	167	18.4	2.5	13%	36.8	1.9
TXPB	151	58.9	9.0	15%	102.3	5.4
WY	113	12.5	1.6	13%	18.1	1.0
OK	104	33.5	5.7	17%	53.0	2.8
CA	88	32.5	3.4	10%	77.5	4.1
IL	73	5.7	0.7	13%	7.1	0.4
NM	66	13.2	1.9	14%	19.9	1.0
KS	49	9.5	1.5	16%	11.7	0.6
ND	42	3.6	0.7	20%	6.0	0.3
MT	38	4.6	0.7	16%	6.8	0.4
WV	31	2.1	0.3	13%	2.5	0.1
MS	27	2.6	0.3	12%	3.6	0.2
CO	25	3.8	0.6	15%	6.0	0.3
AL	24	2.0	0.4	20%	3.7	0.2
KY	21	0.4	0.1	13%	0.6	0.0
MI	20	1.3	0.2	15%	1.9	0.1
Other (9)	109	15.5	2.3	15%	23.6	1.2
<b>Total</b>	<b>1,340</b>	<b>280.3</b>	<b>39.0</b>	<b>14%</b>	<b>469.8</b>	<b>24.7</b>

# Technically-Viable CO<sub>2</sub> EOR Resources

## Oil Reservoirs Technically Viable for CO<sub>2</sub> EOR

- The 1,340 miscible candidate CO<sub>2</sub> EOR reservoirs (yellow dots) with 39 Bbbl of technically-viable oil recovery and 24.7 Bmt of CO<sub>2</sub> storage potential.
- The orange dots are the locations of the 140 current CO<sub>2</sub> EOR projects.
- This map illustrates the widespread potential for CO<sub>2</sub> EOR in the U.S., beyond locations where CO<sub>2</sub> EOR is currently happening.



# ARI CO<sub>2</sub> EOR Cost Model and Price Cases

## CO<sub>2</sub> EOR Cost Model Price Cases

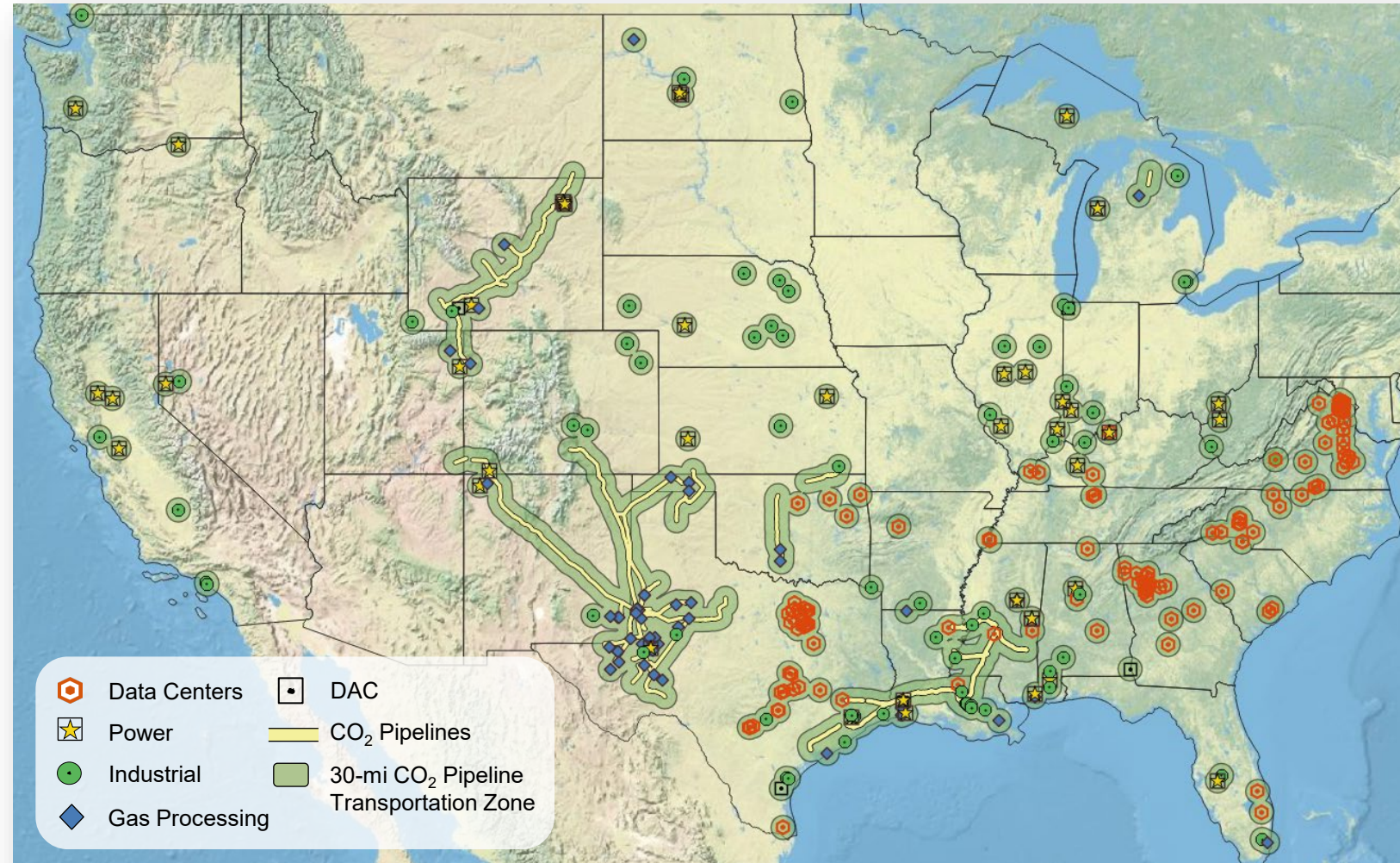
- We calculated project economics using a rigorous CO<sub>2</sub> EOR Cost Model that accounts for all applicable CAPEX, OPEX, and CO<sub>2</sub> costs required for CO<sub>2</sub> EOR.
- Economic viability was determined as 10%+ IRR.
- We used six price cases for this analysis:
  - Base, Low, and High oil price, and
  - CO<sub>2</sub> cost based on market rate or 45Q incentive

Price Case	Oil Price (\$/bbl)	45Q Incentive?	CO <sub>2</sub> Cost (\$/mcf)	CO <sub>2</sub> Cost (\$/mt)
1	\$50	No	\$ 1.00	\$ 19.00
2	\$70	No	\$ 1.40	\$ 26.60
3	\$90	No	\$ 1.80	\$ 34.20
4	\$50	Yes	\$ 0.26	\$ 5.00
5	\$70	Yes	\$ 0.26	\$ 5.00
6	\$90	Yes	\$ 0.26	\$ 5.00

# CO<sub>2</sub> EOR Project Feasibility

- Proximity to CO<sub>2</sub> supplies is a significant factor for CO<sub>2</sub> EOR project feasibility.
- We applied a 30-mile CO<sub>2</sub> pipeline transportation zone around all 324 potential CO<sub>2</sub> sources and existing CO<sub>2</sub> pipeline infrastructure.
- A 30-mile CO<sub>2</sub> pipeline transportation zone reflects real-world CO<sub>2</sub> EOR pipeline development parameters.

## 30-Mile CO<sub>2</sub> Transportation Zone for Potential CO<sub>2</sub> Sources



\* Does not include any of the sources currently supplying 1,975 MMcf/d (37.9 MMmt/y) of CO<sub>2</sub> for CO<sub>2</sub> EOR

# Economically Viable CO<sub>2</sub> EOR Resources

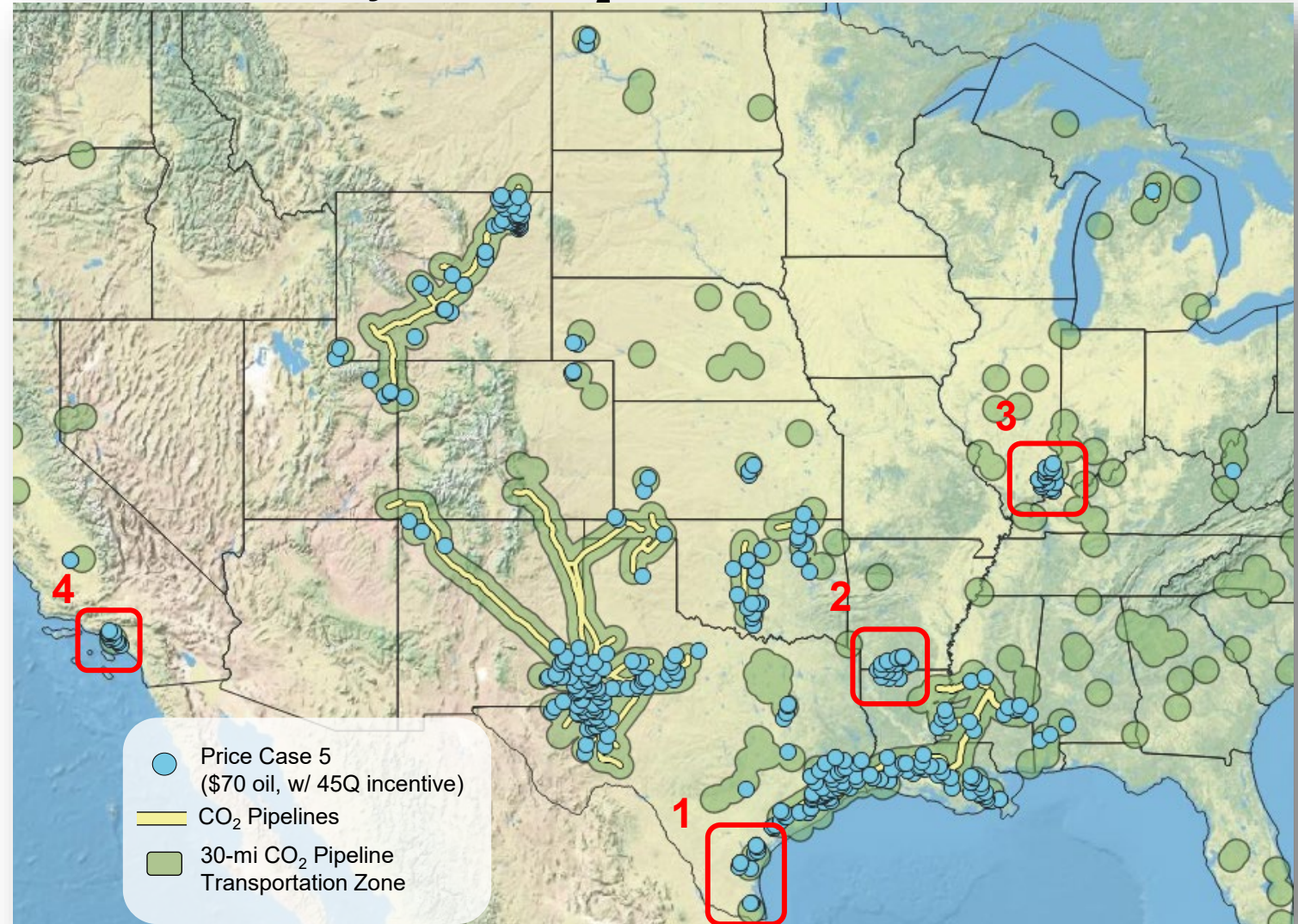
- We identified between 179 and 483 economically viable CO<sub>2</sub> EOR reservoirs within the 30-mile CO<sub>2</sub> pipeline transportation zone.
- Under the 6 Price Cases economic oil recovery ranges from 5.7 to 11.6 Bbbls and CO<sub>2</sub> storage ranges from 3.2 to 7.2 Bmt.
- **Notably, 45Q incentives sustains oil production under low oil prices.**

Price Case	Oil Price (\$/bbl)	45Q Incentive?	CO <sub>2</sub> Cost (\$/mt)	Economic Reservoirs	CO <sub>2</sub> EOR Oil (Bbbl)	CO <sub>2</sub> Storage (Tcf)	CO <sub>2</sub> Storage (Bmt)
CO <sub>2</sub> EOR To-Date	Variable	No	Variable	140	3.0	28.5	1.5
1	\$50	No	\$ 19.00	179	5.7	60.4	3.2
2	\$70	No	\$ 26.60	266	7.3	79.3	4.2
3	\$90	No	\$ 34.20	335	8.7	93.8	4.9
4	\$50	Yes	\$ 5.00	329	8.7	102.9	5.4
5	\$70	Yes	\$ 5.00	433	10.0	118.7	6.2
6	\$90	Yes	\$ 5.00	483	11.6	136.8	7.2

# Economically Viable CO<sub>2</sub> EOR Resources

- The map shows the locations of oil reservoirs economically viable for CO<sub>2</sub> EOR under Price Cases 5 (\$70/bbl oil and \$5/mt CO<sub>2</sub> cost).
- The map shows economic potential for CO<sub>2</sub> EOR outside of current CO<sub>2</sub> EOR basins:
  - 1. TX Gulf Coast,
  - 2. N LA, S AR,
  - 3. IL Basin,
  - 4. CA

Economically Viable CO<sub>2</sub> EOR Reservoirs – Price Case 5





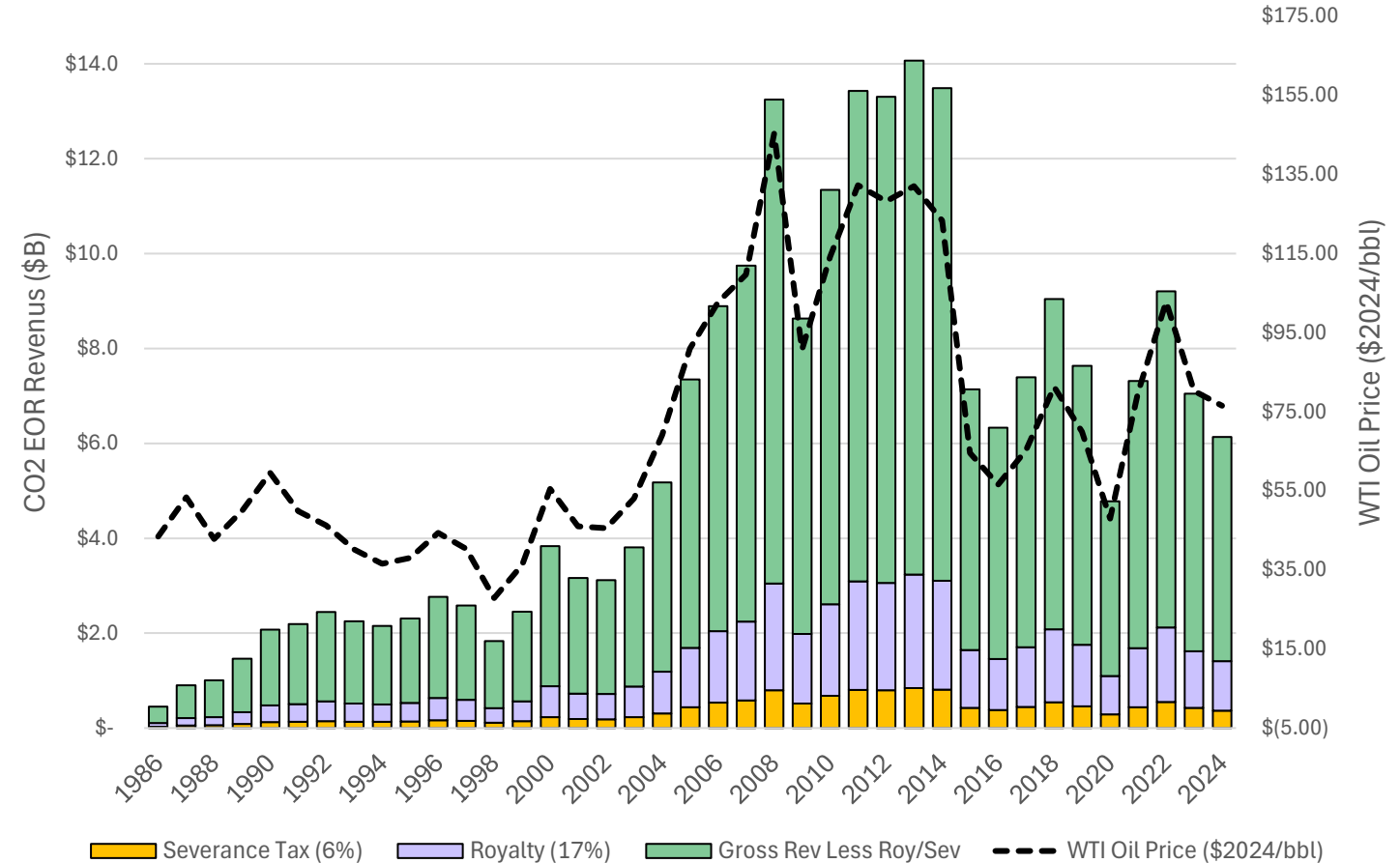
# The Value Proposition of CO<sub>2</sub> EOR in the U.S.

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# CO<sub>2</sub> EOR Supports Sustained Revenue Generation

- Since 1986 we estimate U.S. CO<sub>2</sub> EOR projects have generated:
  - Over \$178 billion in gross revenue from oil sales,
  - \$39 billion in revenue to mineral rights holders through royalty payments,
  - Over \$14 billion in state severance tax payments
  
- This is revenue that otherwise would have required additional investment for greenfield exploration and development.

Estimated U.S. CO<sub>2</sub> EOR Gross Sales, Royalties, and Severance Taxes



# The CO<sub>2</sub> EOR Value Proposition – Incremental Revenue

- Incremental revenue includes oil sales, royalties (17% of revenue), severance taxes (6% of revenue), and 45Q credit value (\$85/mt) for each Price Case.
- Total incremental revenue ranges from \$288 B to \$1,226 B, with 45Q credits ranging from \$143 B to \$183 B in value to the capturer.
- Each Price Case has significantly greater incremental revenue than the estimated ~\$231 B generated by CO<sub>2</sub> EOR in the U.S. to-date.

Price Case	Oil Price (\$/bbl)	45Q Incentives?	Economic Reservoirs	Oil Revenue (\$B)	Royalty (17%) (\$B)	Severance (6%) (\$B)	45Q Credit* (\$B)	Total Incremental Revenue (\$B)
CO <sub>2</sub> EOR To-Date	Variable	No	140	\$ 178.0	\$ 39.0	\$ 14.0	\$ -	\$ 231.0
1	\$50	No	178	\$ 221.4	\$ 48.9	\$ 17.2	\$ -	\$ 287.5
2	\$70	No	265	\$ 396.0	\$ 87.4	\$ 30.9	\$ -	\$ 514.2
3	\$90	No	334	\$ 600.9	\$ 132.7	\$ 46.8	\$ -	\$ 780.4
4	\$50	Yes	328	\$ 335.3	\$ 74.0	\$ 26.1	\$ 142.5	\$ 578.0
5	\$70	Yes	432	\$ 540.2	\$ 119.3	\$ 42.1	\$ 163.6	\$ 865.1
6	\$90	Yes	482	\$ 802.9	\$ 177.3	\$ 62.6	\$ 183.2	\$ 1,226.0

\* Credit paid at \$85/mt for the first 12 years of CO<sub>2</sub> storage

# The CO<sub>2</sub> EOR Value Proposition – Job Creation

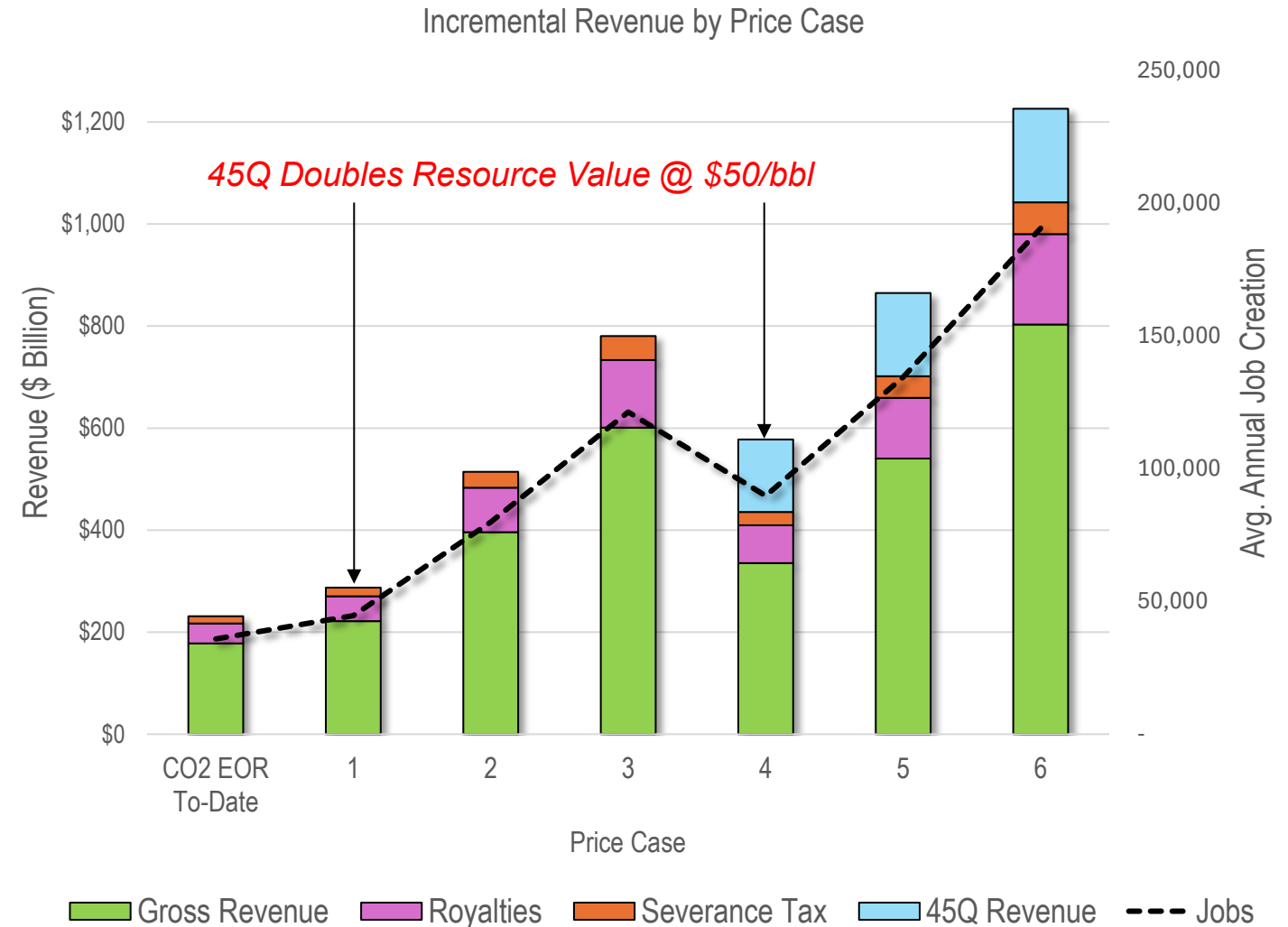
- Average annual CO<sub>2</sub> EOR job creation is calculated using a total job multiplier of 7.0 per \$1 million in revenue generation\*, comprised of multipliers for:
  - Direct jobs (upstream operators): 2.0 per \$1 million revenue
  - Indirect jobs (oilfield services and supply chain): 2.5 per \$1 million revenue
  - Induced jobs (community and household spending): 2.5 jobs per \$1 million revenue

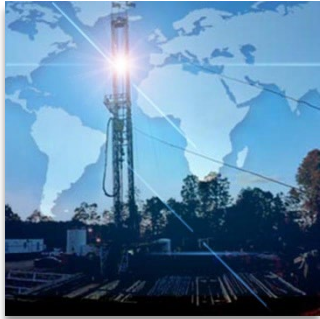
Price Case	Oil Price (\$/bbl)	45Q Incentives?	Economic Reservoirs	Total Incremental Revenue (\$B)	Avg. Annual Job Creation (7 jobs per \$1M Rev)
CO <sub>2</sub> EOR To-Date	Variable	No	140	\$ 231.0	35,900
1	\$50	No	178	\$ 287.5	44,700
2	\$70	No	265	\$ 514.2	80,000
3	\$90	No	334	\$ 780.4	121,400
4	\$50	Yes	328	\$ 578.0	89,900
5	\$70	Yes	432	\$ 865.1	134,600
6	\$90	Yes	482	\$ 1,226.0	190,700

\*This is a conservative multiplier specifically for CO<sub>2</sub> EOR operations derived from IMPLAN data and other sources; it does not include jobs associated with CO<sub>2</sub> capture or CO<sub>2</sub> transportation pipelines. RIMS II multipliers for direct, indirect, and induced jobs ranges from 10 to 20 per \$1 million in revenue

# The CO<sub>2</sub> EOR Value Proposition by Price Case

Price Case		Total Incremental Revenue (\$B)	Avg. Annual Job Creation (7 jobs per \$1M Rev)
CO <sub>2</sub> EOR To-Date		\$ 231.0	40,400
1	\$50/bbl, No 45Q	\$ 287.5	44,700
2	\$70/bbl, No 45Q	\$ 514.2	80,000
3	\$90/bbl, No 45Q	\$ 780.4	121,400
4	\$50/bbl, With 45Q	\$ 578.0	89,900
5	\$70/bbl, With 45Q	\$ 865.1	134,600
6	\$90/bbl, With 45Q	\$ 1,226.0	190,700





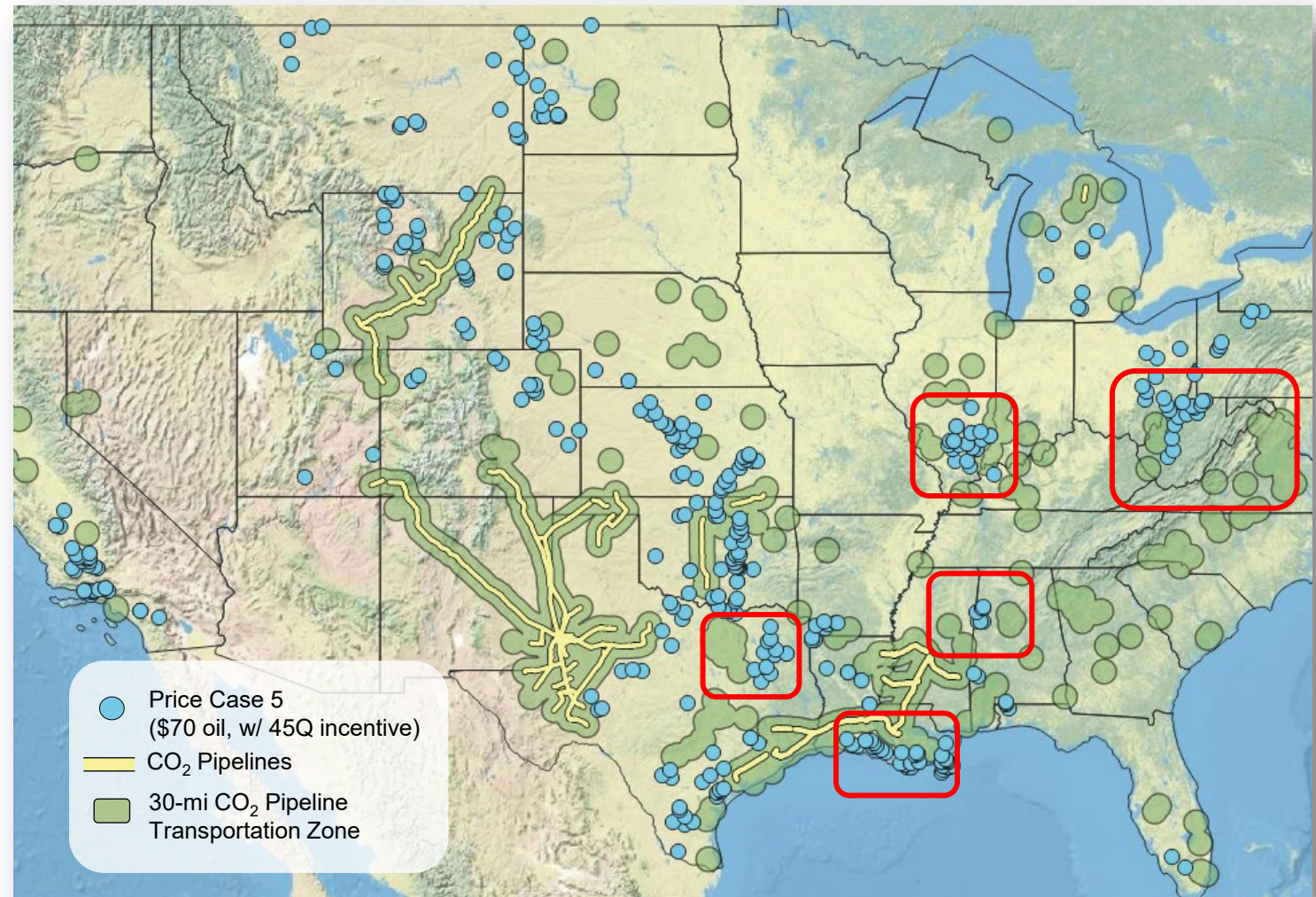
# Conclusions and Topics for Further Study

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# Optimizing CO<sub>2</sub> Pipeline Transportation for CO<sub>2</sub> EOR

- There are 905 economically viable reservoirs outside of the 30-mile CO<sub>2</sub> transportation zone.
- Incremental value = \$2,350 B
  - Gross Revenue = \$1,325 B
  - Royalties = \$300 B
  - Severance Tax = \$100 B
  - 45Q Revenue = \$625 B
- Annual job creation = 365,200
- **The map shows economic CO<sub>2</sub> EOR resource areas that could benefit from low cost-per-ton CO<sub>2</sub> transportation from high-volume CO<sub>2</sub> supply clusters.**

Economically Viable CO<sub>2</sub> EOR Reservoirs Beyond 30-Mile CO<sub>2</sub> Transportation Zone



# Study Conclusions

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- **Significant Value Proposition to States** -- CO<sub>2</sub> EOR could provide hundreds of billions in incremental revenue generation and tens of thousands of annual job creation over a range of Price Cases, both with and without supportive credits from 45Q.
- **45Q Supports Domestic Oil Production** -- The economic analysis demonstrates the importance of 45Q credits for supporting early-stage CO<sub>2</sub> EOR projects that can continue to operate economically following the 12-year credit period.
- **CO<sub>2</sub> EOR Contributes to U.S. Energy Security** -- Most importantly, the study identifies CO<sub>2</sub> EOR as a viable option for sustaining our current levels of oil production contributing to domestic energy security.

# Topics for Further Study

- **Updated CO<sub>2</sub> EOR Resource Characterization Studies** – There is a need for updated and revised characterization of U.S. CO<sub>2</sub> EOR resource potential that incorporates a significant amount of new CO<sub>2</sub> EOR modeling knowledge and up-to-date CAPEX and OPEX costs.
- **Develop New Unconventional CO<sub>2</sub> EOR Resources** – This study is limited to conventional CO<sub>2</sub> EOR reservoir analysis, however significant potential exists in tight oil basins, residual oil zones, and other resources that could benefit significantly from CO<sub>2</sub> utilization.
- **CO<sub>2</sub> Transportation Optimization Studies** – Further study should be done to examine the potential for transporting larger volumes of CO<sub>2</sub> over longer distances to areas with high CO<sub>2</sub> demand for CO<sub>2</sub> EOR without existing infrastructure.



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