

# CCS to CCUS: Continuing Carbon Storage with CO<sub>2</sub> Enhanced Oil Recovery Post 45Q

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International, Inc.**

# Can CCS Projects in the U.S. Extend Their Carbon Storage Life Beyond 45Q Tax Benefits?

- The IRS 45Q tax benefit has launched the development of dozens of carbon capture and storage projects in the U.S.
- Most of these projects are planning to store captured CO<sub>2</sub> in saline aquifers.
- However, the current tax benefits that make these project economically viable are only available for 12 years after the project start date and will sunset by 2045.
- Additionally, CO<sub>2</sub> enhanced oil recovery (CO<sub>2</sub> EOR) is a proven technology in the U.S. but is limited by the volume of high-quality CO<sub>2</sub> available for utilization and storage.
- **Study Objective: Can CO<sub>2</sub> EOR offer an economically viable pathway to continue CO<sub>2</sub> capture and storage in the U.S. following the end of 45Q tax benefits?**

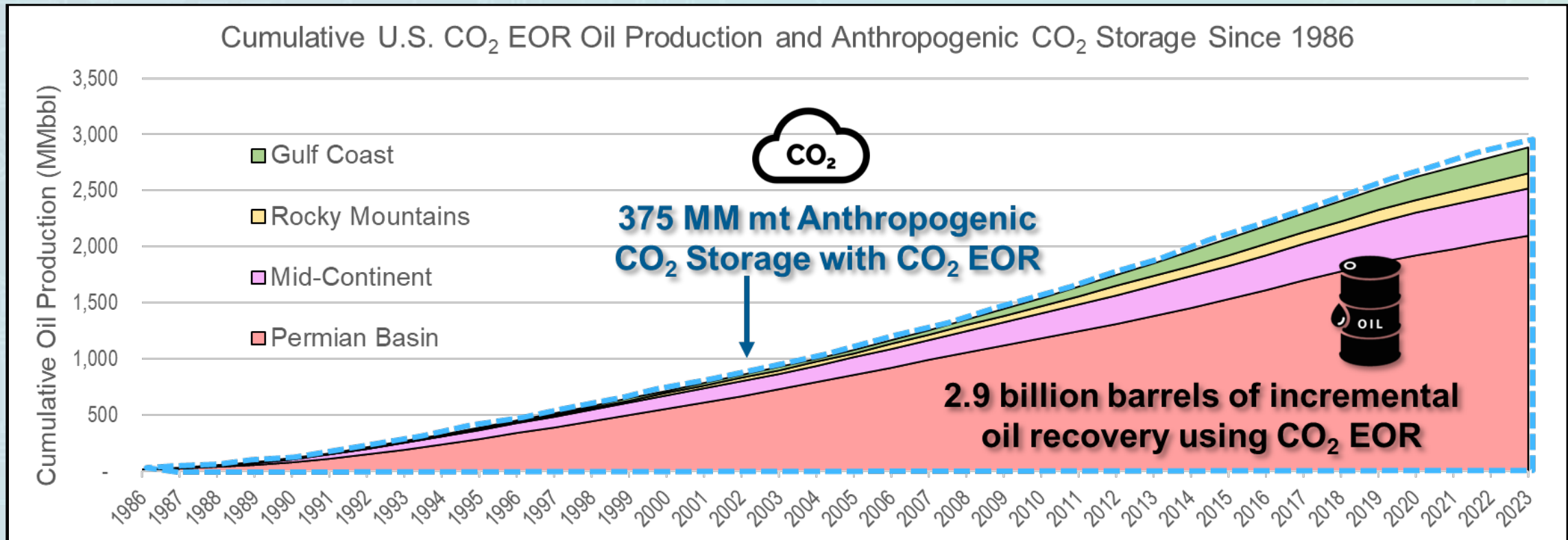
# Presentation Overview

1. Storage of Anthropogenic CO<sub>2</sub> Using CO<sub>2</sub> EOR in the U.S.
2. Carbon Capture Projects Under Development in the U.S.
3. Technically Viable CO<sub>2</sub> Storage Using CO<sub>2</sub> EOR Near Carbon Capture Projects
4. Economically Viable Carbon Storage Using CO<sub>2</sub> EOR Post 45Q
5. CO<sub>2</sub> Transportation Pipeline Infrastructure
6. Study Conclusions and Looking Ahead

# Storage of Anthropogenic CO<sub>2</sub> Using CO<sub>2</sub> EOR in the U.S.

# Storage of Anthropogenic CO<sub>2</sub> Using CO<sub>2</sub> EOR















- Since 1986, CO<sub>2</sub> EOR projects in the U.S. have stored over 375 MMmt of anthropogenic CO<sub>2</sub>.
- However, CO<sub>2</sub> EOR produces 241,000 bbl/d and is declining annually by ~2%; additional industrial CO<sub>2</sub> supplies are needed for increased CO<sub>2</sub> storage and incremental oil production.

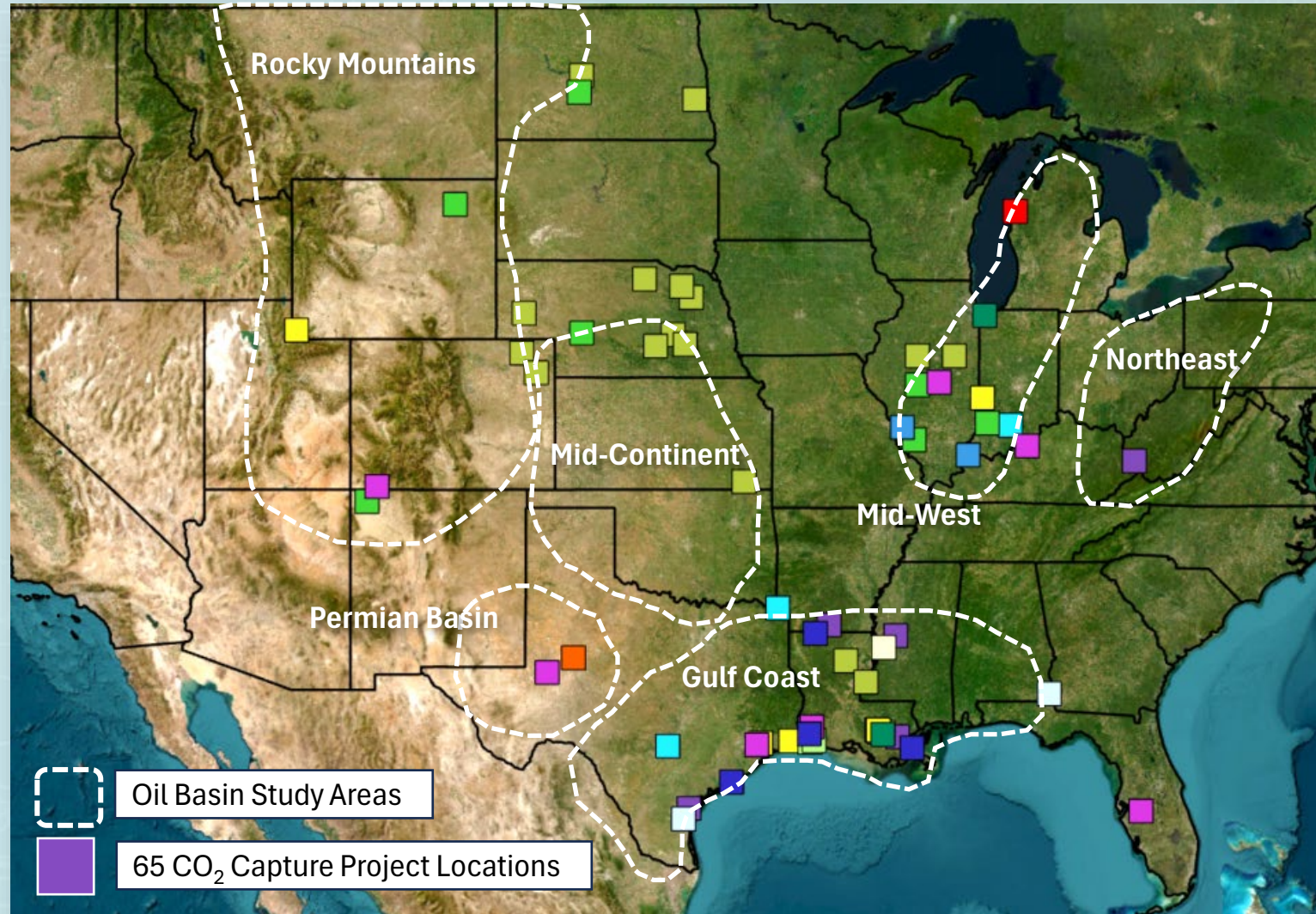


# Carbon Capture Projects Under Development in the U.S.

# U.S. Carbon Capture Projects Under Development

- We identified 65 carbon capture projects in six study areas planning to store CO<sub>2</sub> in saline aquifers.
- All 65 projects will benefit from 45Q credits and have an estimated operational date between 2025 and 2031.

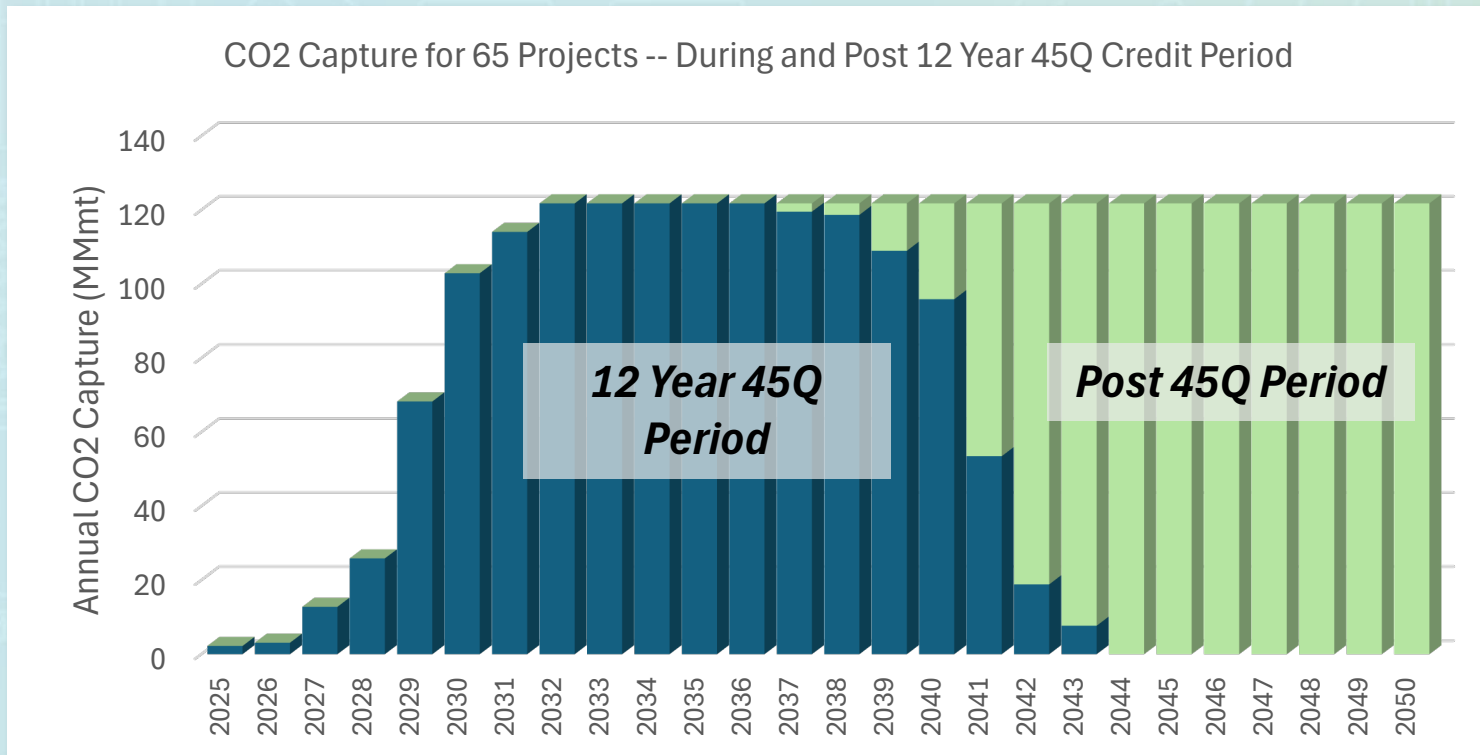
 Ammonia (9)	 Hydrogen (6)
 Biofuels (15)	 LNG Processing (2)
 Biomass Power (2)	 Natural Gas Power (7)
 Cement (3)	 Natural Gas Processing (4)
 Coal Power (7)	 Oil Refining (1)
 DAC (4)	 Pulp and Paper (1)
 Ethanol (2)	 Steel (2)



# U.S. Carbon Capture Projects Under Development

- These 65 carbon capture projects have an estimated maximum capture capacity of nearly 122 million metric tons (MMmt) of CO<sub>2</sub> per year from 14 different types of industrial sources.
- **45Q credits for all 65 CO<sub>2</sub> capture projects will sunset between 2037 and 2044; all projects will need alternatives, like CO<sub>2</sub> EOR, to continue economic carbon capture and storage.**

CO2 Capture Facility Type	Projects	CO2 Capture Capacity (MMmt/y)	Project Start Dates
Ammonia	9	24.8	2025 – 2032
Biofuels	15	17.6	2025 - 2031
Biomass Power	2	1.1	2030
Cement	3	6.1	2028 - 2030
Coal Power	7	22.2	2026 - 2031
Direct Air Capture	4	2.0	2029 - 2030
Ethanol	2	0.7	2025
Hydrogen	6	19.7	2027 - 2030
LNG Processing	2	4.5	2028 - 2029
Natural Gas Power	7	17.0	2027 - 2032
Natural Gas Processing	4	4.9	2027 - 2029
Oil Refining	1	0.1	2028
Pulp and Paper	1	0.1	2030
Steel	2	0.9	2025 - 2026
<b>Total</b>	<b>65</b>	<b>121.8</b>	



# Technically Viable CO<sub>2</sub> Storage Using CO<sub>2</sub> EOR Near Carbon Capture Projects

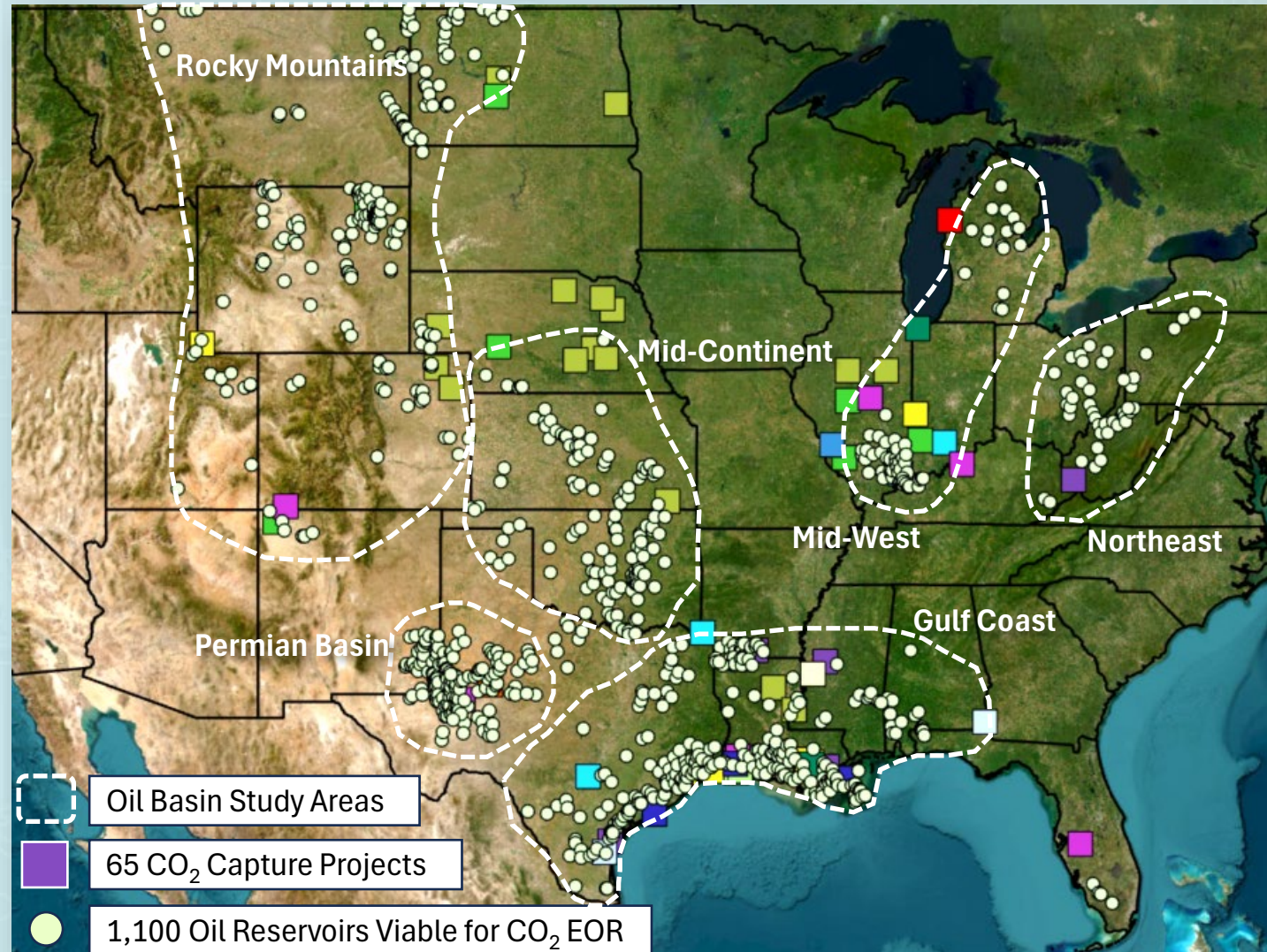
# Identifying Oil Reservoirs Viable for CO<sub>2</sub> EOR

- We identified **1,100** oil reservoirs with **193 Bbbl** of OOIP in our six study areas that are technically viable for CO<sub>2</sub> EOR.
- These reservoirs were identified using the following screening criteria:
  - OOIP over 10 million barrels per reservoir,
  - Reservoir oil gravity above 24 degrees API, and
  - Reservoir depth (> 3,000 ft) sufficient to support conditions for CO<sub>2</sub> miscibility with reservoir oil.
- Additionally, we screened out all reservoirs currently under CO<sub>2</sub> EOR operations and any reservoirs otherwise ineligible for CO<sub>2</sub> EOR operations by 2045.

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

- The 1,100 technically viable oil reservoirs in the six study areas have 193 billion barrels of OOIP.
- About two-thirds of this resource (121 Bbbl of OOIP) is contained in the Gulf Coast and Permian Basin regions.

Region	Reservoirs	OOIP (Bbbl)
Gulf Coast	398	82.3
Permian Basin	158	38.3
Mid Continent	159	37.2
Rocky Mountains	217	23.0
Mid West	132	8.9
Northeast	36	3.2
<b>Total</b>	<b>1,100</b>	<b>192.9</b>

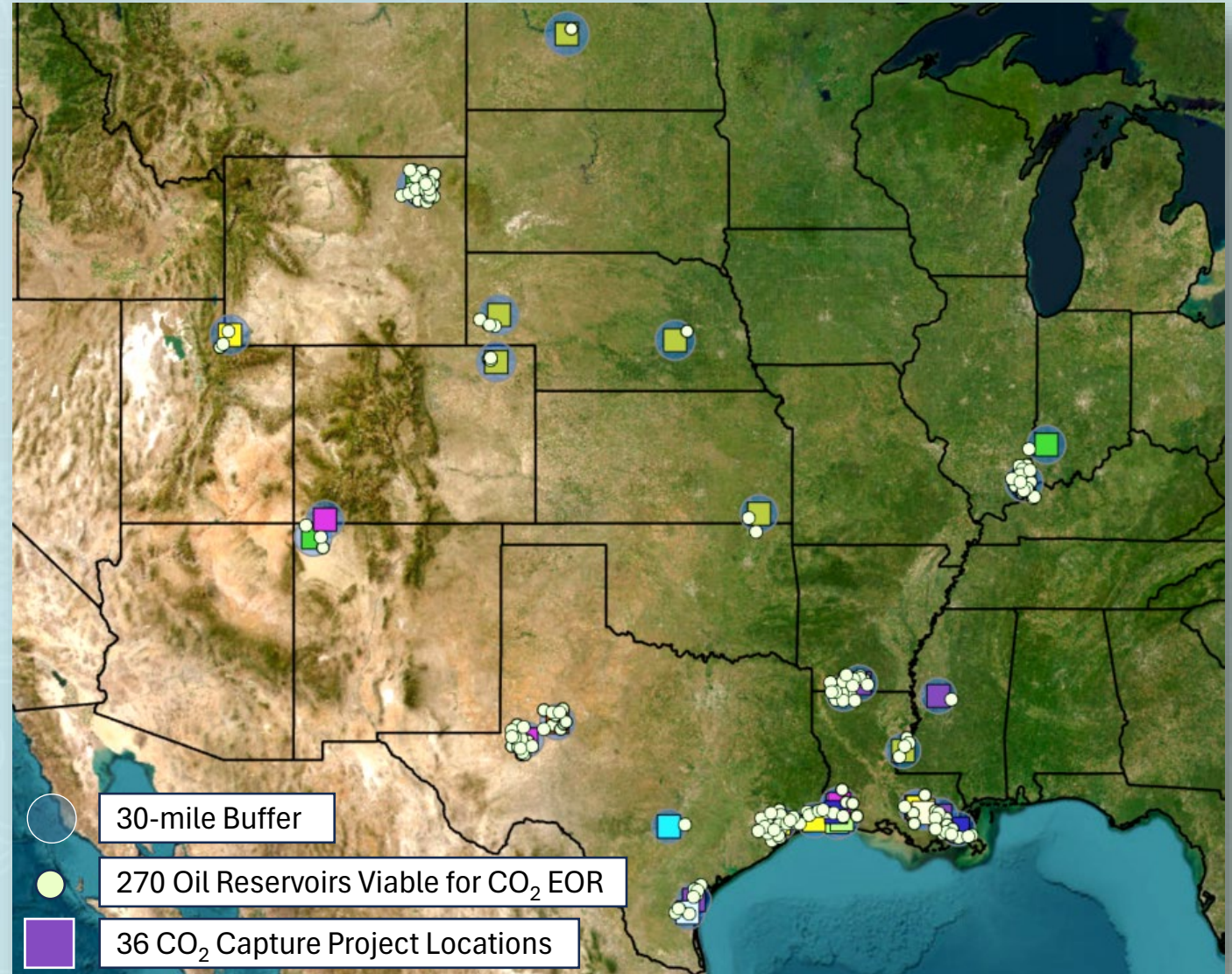


# Viability CO<sub>2</sub> EOR Reservoirs Near CO<sub>2</sub> Capture Facilities

- We identified 270 “nearby” oil reservoirs with 36.7 Bbbl of OOIP **within 30-miles of the CO<sub>2</sub> capture locations.**
- 36 CO<sub>2</sub> capture facilities with 76 MMmt/y of CO<sub>2</sub> capture capacity have CO<sub>2</sub> EOR reservoirs nearby.

CO <sub>2</sub> EOR Reservoirs	Reservoirs	OOIP (Bbbl)
All Miscible Reservoirs	1,100	193.0
<b>"Nearby" Reservoirs</b>	<b>270</b>	<b>36.7</b>

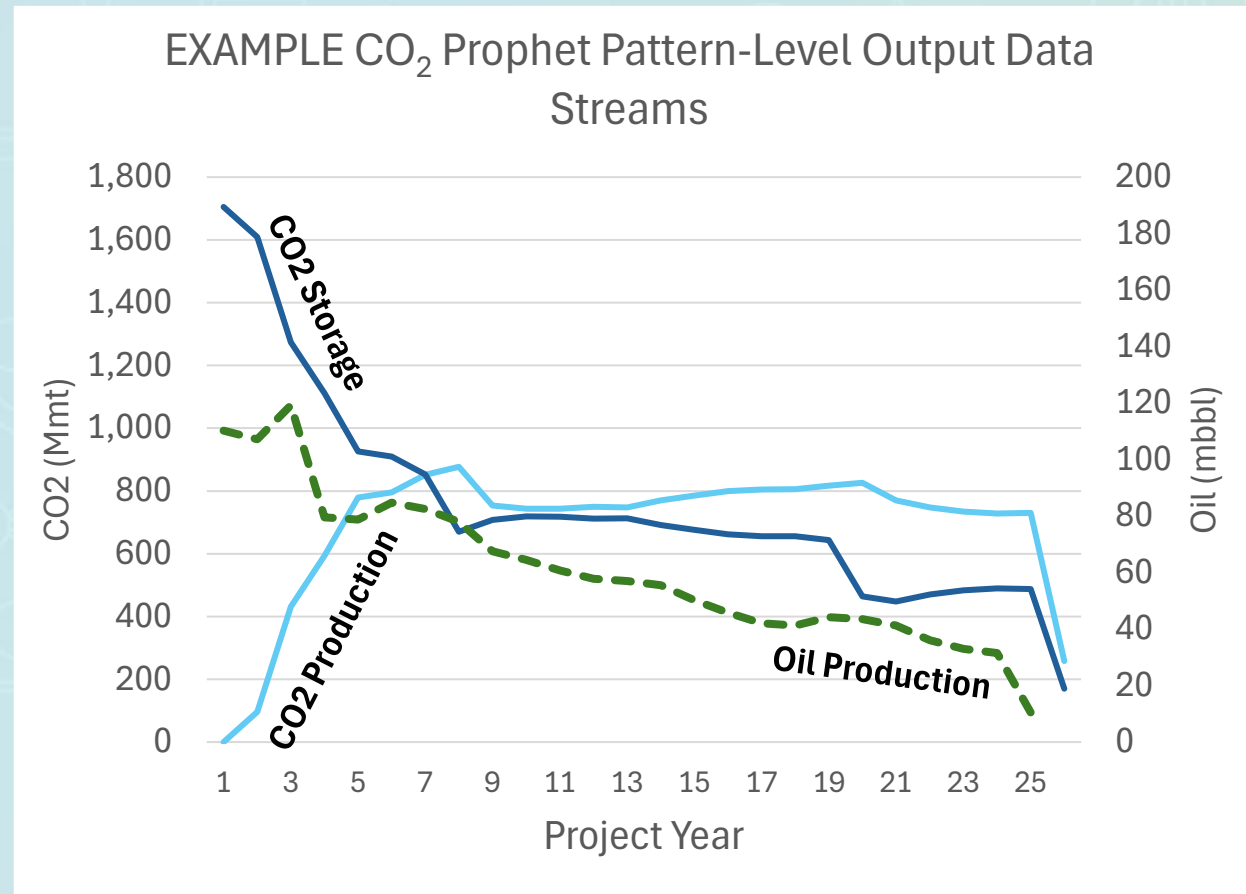
CO <sub>2</sub> Capture Facilities	Facilities	CO <sub>2</sub> Capacity (MMmt/y)
All Capture Facilities	65	122
<b>With "Nearby" Reservoirs</b>	<b>36</b>	<b>76</b>



# Economically Viable CO<sub>2</sub> Storage Using CO<sub>2</sub> EOR Post 45Q

# Modeling CO<sub>2</sub> Storage and Incremental Oil Recovery

- We used CO<sub>2</sub> Prophet to model CO<sub>2</sub> storage and incremental oil recovery for the 270 nearby candidate reservoirs.
- CO<sub>2</sub> Prophet calculates annual streamflow data for CO<sub>2</sub> injection, CO<sub>2</sub> production, and oil production at the pattern level.
- We assumed a 1.5 HCPV water-alternating-gas (WAG) CO<sub>2</sub> flood for all projects.
- The pattern-level streamflow data is extrapolated to calculate the total CO<sub>2</sub> storage demand and oil recovery potential for the full field area.



# CO<sub>2</sub> EOR Cost and Economics Model Overview

CO<sub>2</sub> EOR Cost and Economics Model assumptions include:

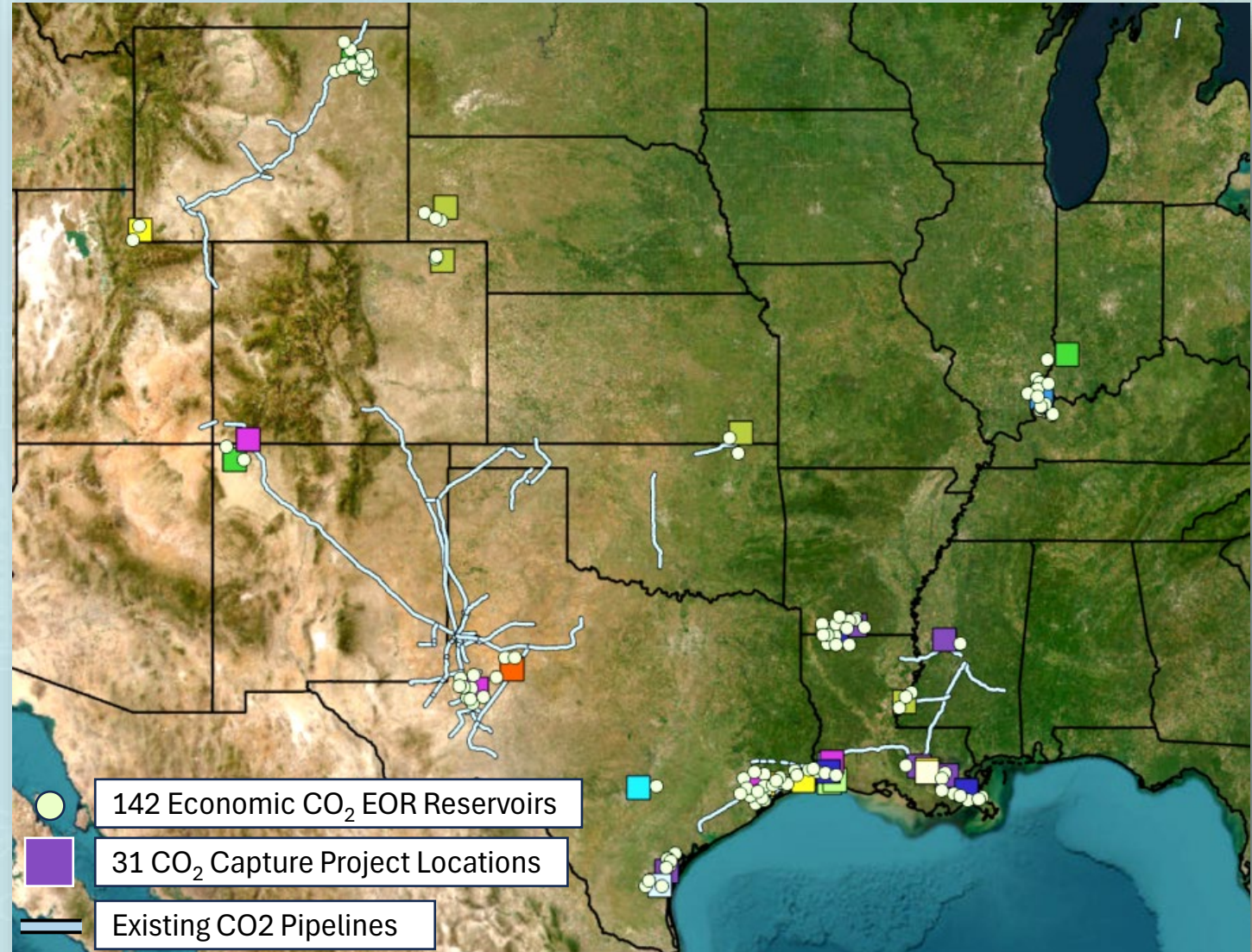
- **Project Revenue:** based on a base oil price track between \$88/bbl and \$98/bbl (EIA AEO).
- **Project Development:** each CO<sub>2</sub> EOR project is developed over 7 years.
- **Regional Costs:** CAPEX and OPEX costs use regional costs multipliers.
- **CO<sub>2</sub> Purchase Costs:** equal to the operating cost of the capture facilities (\$12/mt) assuming capitol recovery is achieved over the first 12 years of the project.
- **30-mile CO<sub>2</sub> Pipeline / CO<sub>2</sub> Recycling Plant:** costs are based on the maximum annual volume of CO<sub>2</sub> delivery and CO<sub>2</sub> recycling, respectively.
- **New Well Drilling:** Projects must drill at least 50% new CO<sub>2</sub> storage and oil production wells for each field.
- **Economic Hurdle Rate:** projects are considered “economic” at a 10% IRR or greater.

# Economically Viable CO<sub>2</sub> EOR Oil Fields

- 142 nearby reservoirs have 23.1 Bbbl of OOIP and are economically viable for CO<sub>2</sub> EOR.
- These 142 reservoirs are located near 31 CO<sub>2</sub> capture facilities with 68 MMmt/y of CO<sub>2</sub> capture capacity.

CO <sub>2</sub> EOR Reservoirs	Reservoirs	OOIP (Bbbl)
All Miscible Reservoirs	1100	192.9
"Nearby" Reservoirs	270	36.7
<b>Economic Reservoirs</b>	<b>142</b>	<b>23.1</b>

CO <sub>2</sub> Capture Facilities	Facilities	CO <sub>2</sub> Capacity (MMmt/y)
All Capture Facilities	65	122
With "Nearby" Reservoirs	36	76
<b>With Economic Reservoirs</b>	<b>31</b>	<b>68</b>



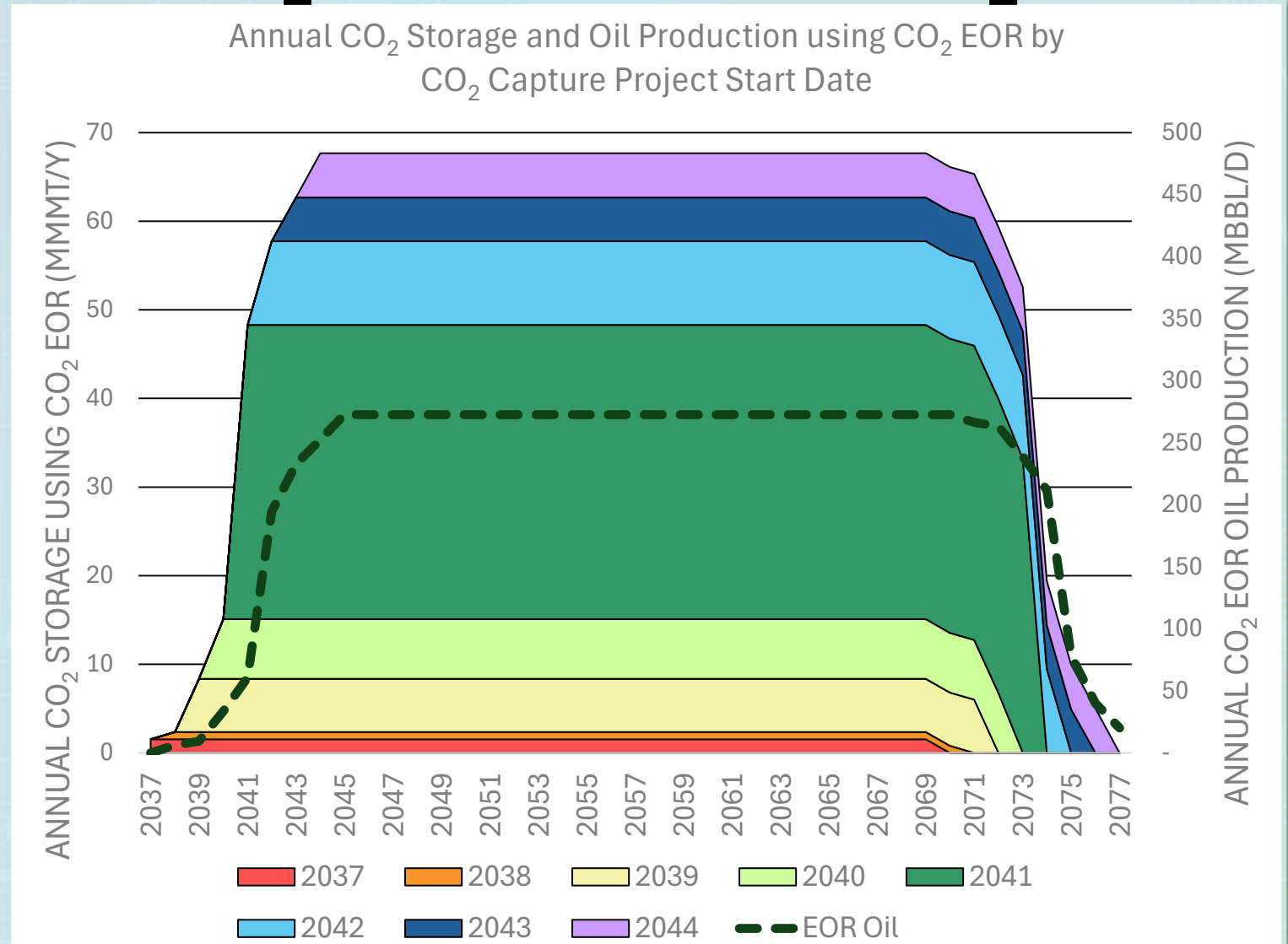
# Economically Viable CO<sub>2</sub> Storage Using CO<sub>2</sub> EOR

- Of the 270 “nearby” reservoirs 142 are economically viable for CO<sub>2</sub> EOR and have a total capacity for 2.2 billion metric tons of CO<sub>2</sub> storage using CO<sub>2</sub> EOR
- These 142 reservoirs also have economically viable incremental oil production of 3.3 billion barrels associated with CO<sub>2</sub> storage using CO<sub>2</sub> EOR.

Region	"Nearby" Miscible Reservoirs		Economically Viable Reservoirs			
	Reservoirs	OOIP (Bbbl)	Reservoirs	OOIP (Bbbl)	CO2 Storage (Bmt)	EOR Oil (Bbbl)
Gulf Coast	128	19.8	80	15.9	1.6	2.2
Permian Basin	37	12.3	13	4.1	0.4	0.7
Mid Continent	7	0.7	5	0.7	0.1	0.1
Rocky Mountains	44	2.1	21	1.2	0.1	0.2
Mid West	54	1.7	23	1.1	0.1	0.1
Northeast	-	-	0	-	-	-
<b>Total</b>	<b>270</b>	<b>36.7</b>	<b>142</b>	<b>23.1</b>	<b>2.2</b>	<b>3.3</b>

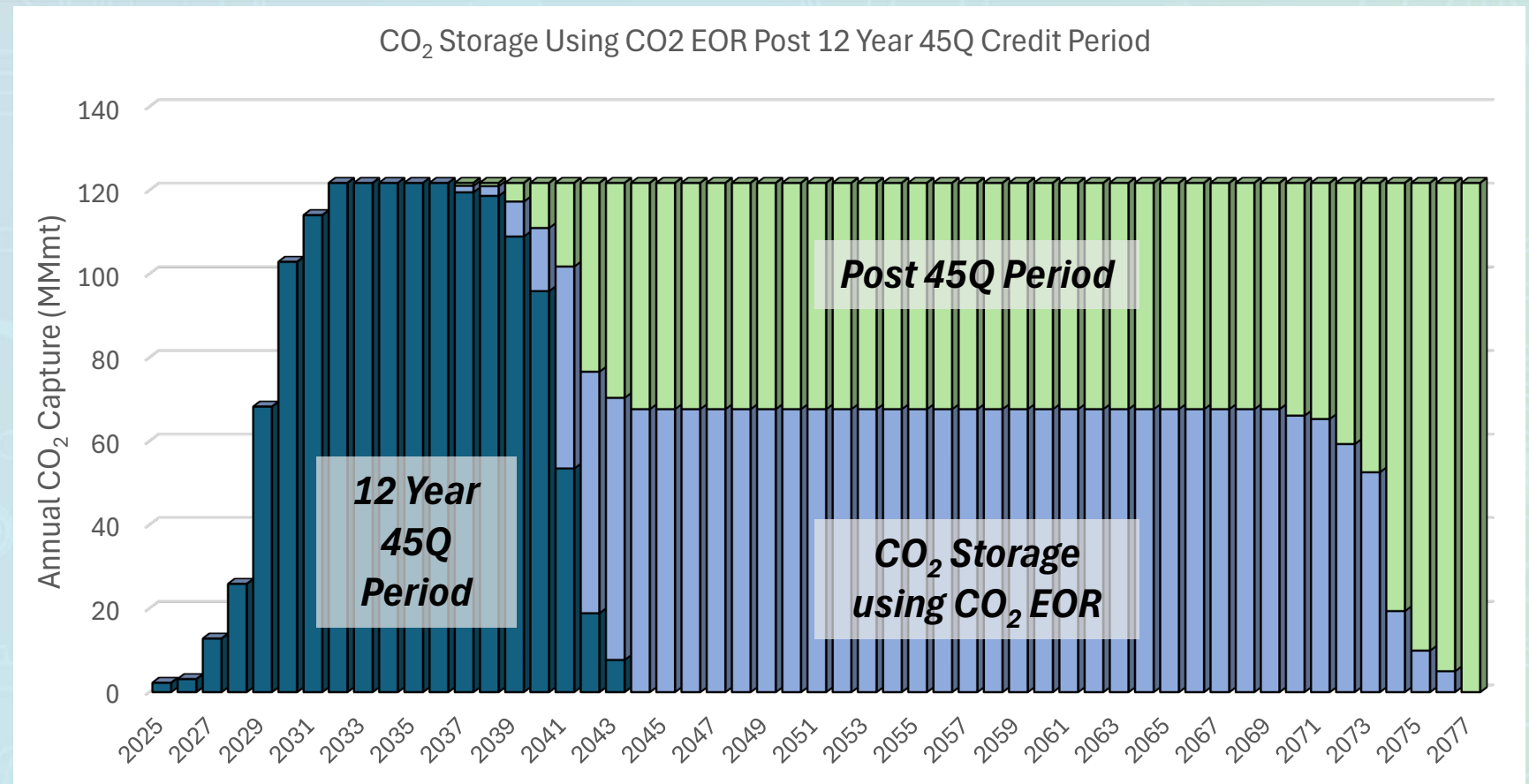
# Economically Viable CO<sub>2</sub> Storage with CO<sub>2</sub> EOR

- The chart shows annual CO<sub>2</sub> storage and oil production using CO<sub>2</sub> EOR over 40 years.
- Storage of all 67.7 MMmt of CO<sub>2</sub> per year from the 31 CO<sub>2</sub> capture facilities is enabled from 2044 to 2069 using CO<sub>2</sub> EOR.
- **Total CO<sub>2</sub> storage is 2.2 billion metric tons and total oil production is 3.3 billion barrels low-carbon oil over 40 years.**



# Economically Viable CO<sub>2</sub> Storage with CO<sub>2</sub> EOR

- CO<sub>2</sub> EOR provides an economically viable option for over half of planned CO<sub>2</sub> capture (67.7 MMmt/y) following the 12-year 45Q credit period.
- 31 of the 65 CO<sub>2</sub> capture facilities can continue to store CO<sub>2</sub> economically using CO<sub>2</sub> EOR.
- Economic storage using CO<sub>2</sub> EOR continues until 2076, storing a total of 2.2 Bmt of CO<sub>2</sub>.



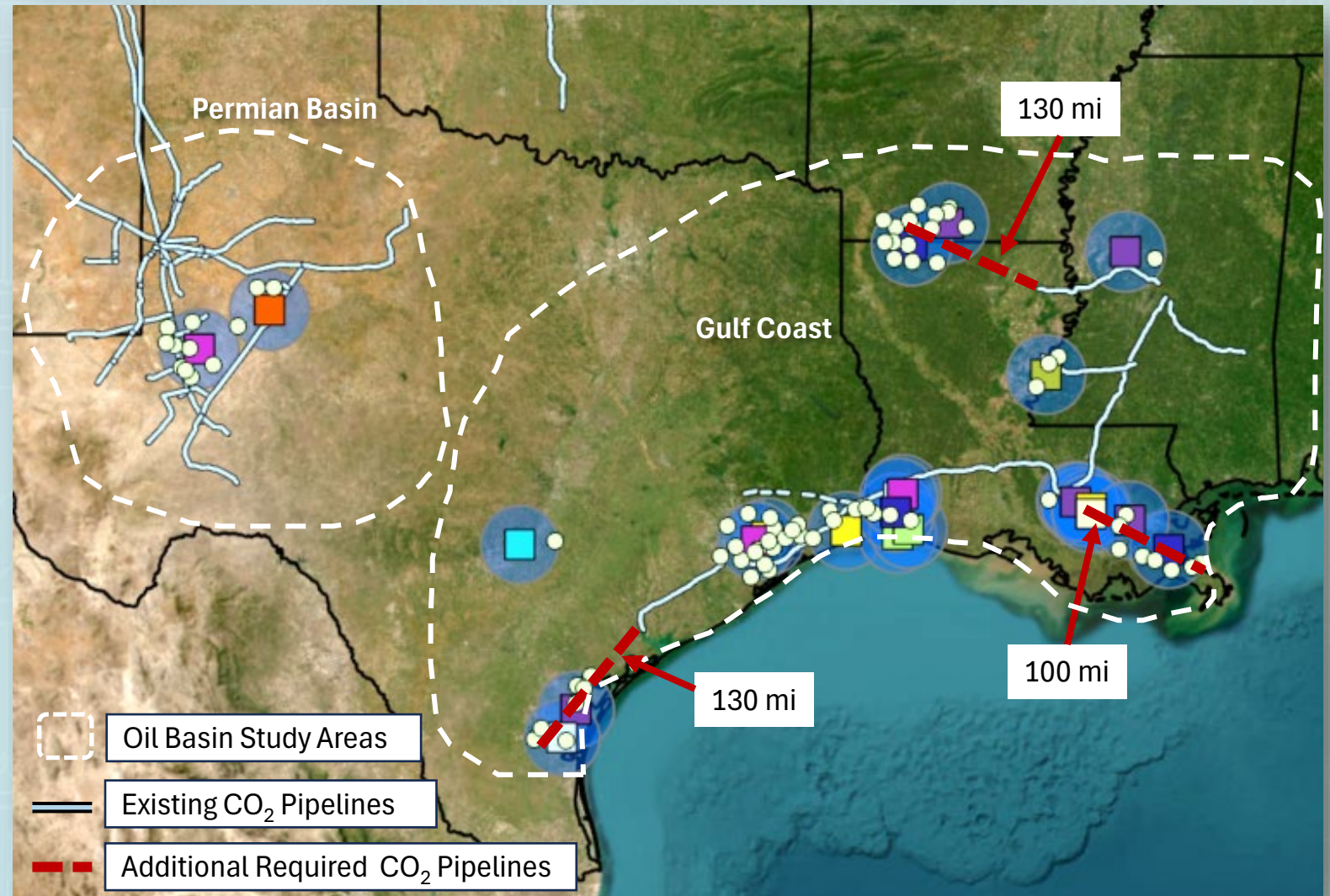
# CO<sub>2</sub> Transportation Pipeline Infrastructure

# CO<sub>2</sub> Transportation Pipeline Infrastructure

- Existing CO<sub>2</sub> transportation pipeline infrastructure in the U.S. could support the delivery of CO<sub>2</sub> from capture facilities to economic CO<sub>2</sub> EOR reservoirs.
- In the Permian Basin and Gulf Coast over half of the economic CO<sub>2</sub> EOR reservoirs are within 30 miles of an existing CO<sub>2</sub> transportation pipeline, as shown on the next slide.
- The remainder of the economic reservoirs can tie into existing CO<sub>2</sub> transportation pipeline infrastructure using larger diameter CO<sub>2</sub> pipelines up to 130 miles in length,
- These larger diameter CO<sub>2</sub> pipelines have lower transportation costs per ton due to economies of scale.

# CO<sub>2</sub> Transportation Pipeline Infrastructure

- Most of the economic CO<sub>2</sub> EOR reservoirs in the Permian Basin are located within five miles of existing CO<sub>2</sub> pipelines.
- The Gulf Coast would require three CO<sub>2</sub> trunklines between 100 mi and 130 mi to tie into existing CO<sub>2</sub> pipeline infrastructure.
- Only CO<sub>2</sub> EOR reservoirs in IN/IL and NE/CO would require totally new CO<sub>2</sub> pipeline infrastructure.



# Study Conclusions and Looking Ahead

# Study Conclusions

- **CO<sub>2</sub> EOR provides an economic option for continuing CO<sub>2</sub> capture and storage beyond the 12-year 45Q period for about half of the currently planned CO<sub>2</sub> capture and storage projects in the U.S.**
- **As additional CO<sub>2</sub> capture projects are announced the potential for CO<sub>2</sub> storage and oil production using CO<sub>2</sub> EOR will increase several fold.**
- Assessing alternative CO<sub>2</sub> storage using CO<sub>2</sub> EOR is a viable risk mitigation strategy for CO<sub>2</sub> capture projects planning to store in saline aquifers.
- Expansion of CO<sub>2</sub> EOR in the U.S. both helps achieve large-scale CO<sub>2</sub> capture and storage targets while increasing domestic production of low carbon oil, which provides significant state tax revenues.

# Looking Ahead

- The cost for CO<sub>2</sub> transportation will decrease as CO<sub>2</sub> pipeline networks are developed over time, which will enable CO<sub>2</sub> storage using CO<sub>2</sub> EOR at greater distances from capture sources -- 50 miles and beyond.
- Additional resource plays will be considered for CO<sub>2</sub> storage using CO<sub>2</sub> EOR, including the Permian Basin Residual Oil Zones (ROZ), which could provide significant economically viable CO<sub>2</sub> storage for CO<sub>2</sub> capture facilities located near ROZ areas.
- Advanced Technologies, including horizontal CO<sub>2</sub> injection and cyclical CO<sub>2</sub> injection in tight oil resources, will be the future of the CO<sub>2</sub> storage industry using CO<sub>2</sub> EOR.

# Thank You! Questions?

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