Mature Fields and Marginal Oil Wells: Key Resources for CO_2–EOR and CO_2 Storage

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Mature Fields and Marginal Oil Wells: Key Resources for CO_2-EOR and CO_2 Storage

The great bulk of the domestic conventional oil resource exists in mature fields and their marginal wells. These fields and wells are steadily approaching the end of their economically viable lives, particularly in a lower oil price world.

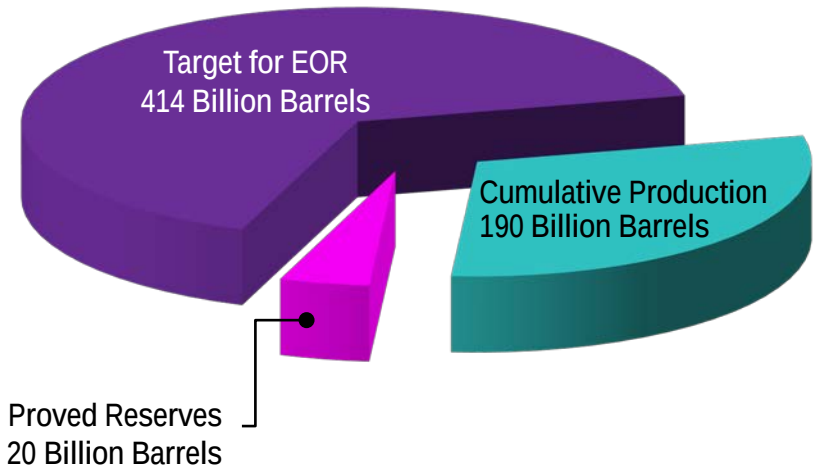
Traditional primary and secondary oil recovery methods have recovered only about a third of the oil in-place in these mature fields, leaving behind a major resource target.

A variety of enhanced oil recovery technologies can be applied to recover more of this left behind ("stranded") oil, including injection of miscible CO_2. However, these mature oil fields and their marginal wells need to remain available for effective application of CO_2-EOR.

Large Volumes of Oil Remain "Stranded" in Discovered Conventional U.S. Oil Fields

Original Oil In-Place: 624 B Barrels

Remaining Oil In-Place: 414 B Barrels



Traditional primary recovery and waterflooding have recovered only about a third of the oil in-place in discovered conventional U.S. oil fields, leaving behind a target of over 400 billion barrels.

A most promising enhanced oil recovery technology that can be used to recover this "stranded" oil is miscible/immiscible CO_2 injection.

*Does not include "tight" oil production or reserves.
Source: Advanced Resources International analyses, 2015.

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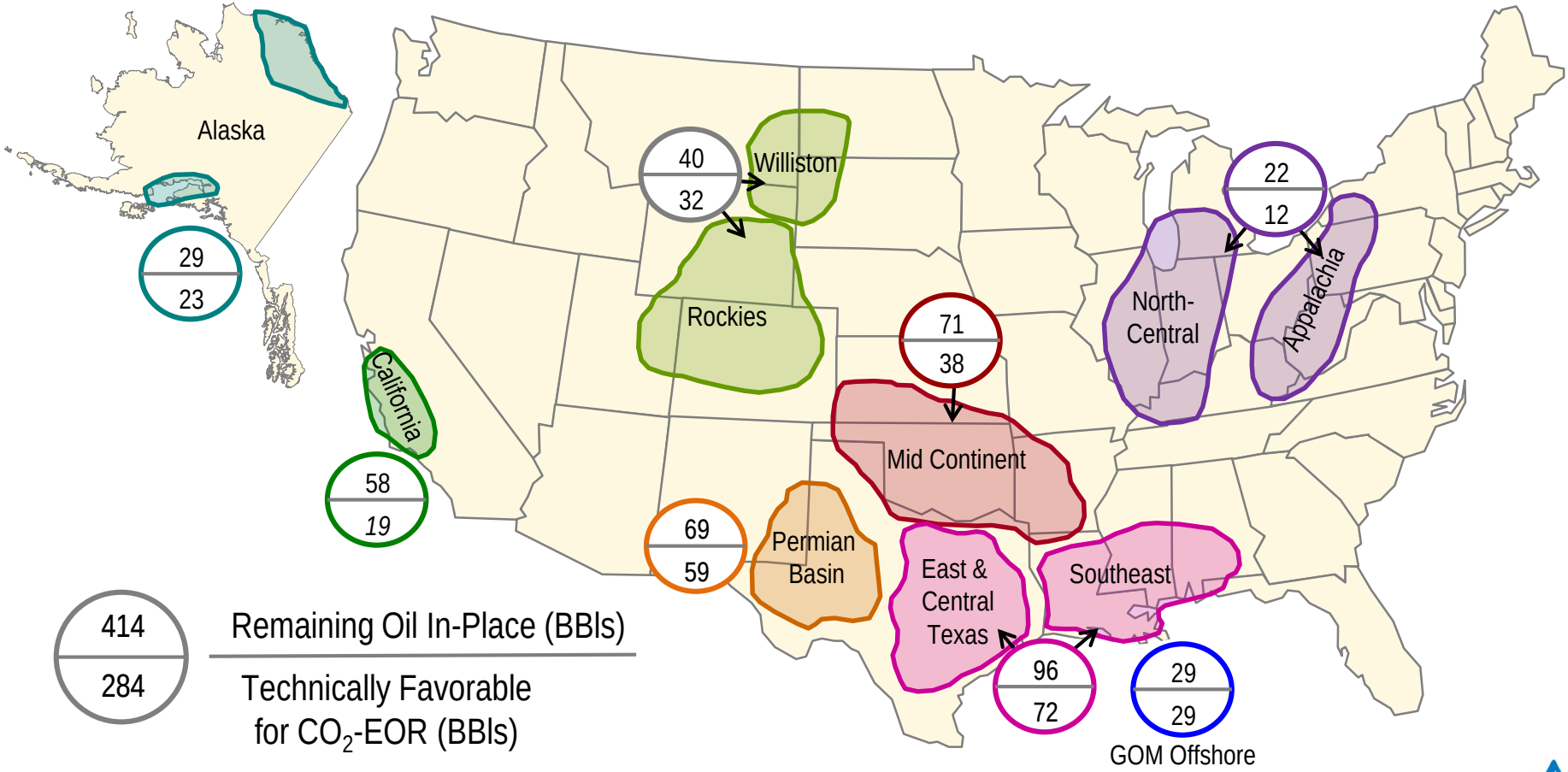
The Regional CO_2-EOR Targets

Of the 414 B barrels of remaining oil in-place, 284 B barrels is technically favorable for CO_2-EOR. Much of oil resource is in the Permian Basin, Gulf Coast, the Mid-Continent and East/Central Texas.



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The Marginal Well Population

Helping maintain the life of these mature conventional oil fields is a massive population of marginal wells, defined as producing 10 barrels of oil per day or less.

The latest Interstate Oil and Gas Compact Commission report "Marginal Wells: Fuel for Economic Growth", tabulated that:

- There were 410,000 marginal oil wells (as of 2012).
- These marginal oil wells produced 740,000 barrels of oil per day, averaging about 2 barrels per day per well.
- The oil production from these marginal wells provided $25 billion of revenues (in 2012), admittedly under a more favorable oil price regime.

Importance of Maintaining the Marginal Well Population

Maintaining the economic viability and availability of these marginal wells should be a state and national priority:

- At the state and local levels, marginal wells provide jobs and drive economic activity.
- At the national level, the significant volume of oil production from marginal wells contributes to energy security and reduced oil imports.
- Looking to the future, the availability of marginal wells will be an important factor for the success of CO_2 enhanced oil recovery technology (and the storage of CO_2) in these mature domestic oil fields.

Outlook for CO_2-Enhanced Oil Recovery

In the remainder of my presentation, I will expand on the potential size of the CO_2-EOR oil recovery and CO_2 storage opportunity in mature domestic oil fields by addressing four questions:

- *What is the Status of the CO_2-EOR Industry?*
- *How Large is the "Size of the Prize"?*
- *Can CO_2-EOR Be Economically Viable in a Lower Oil Price World?*
- *Will There Be Sufficient Supplies of CO_2?*

1. Status of the CO_2-EOR Industry

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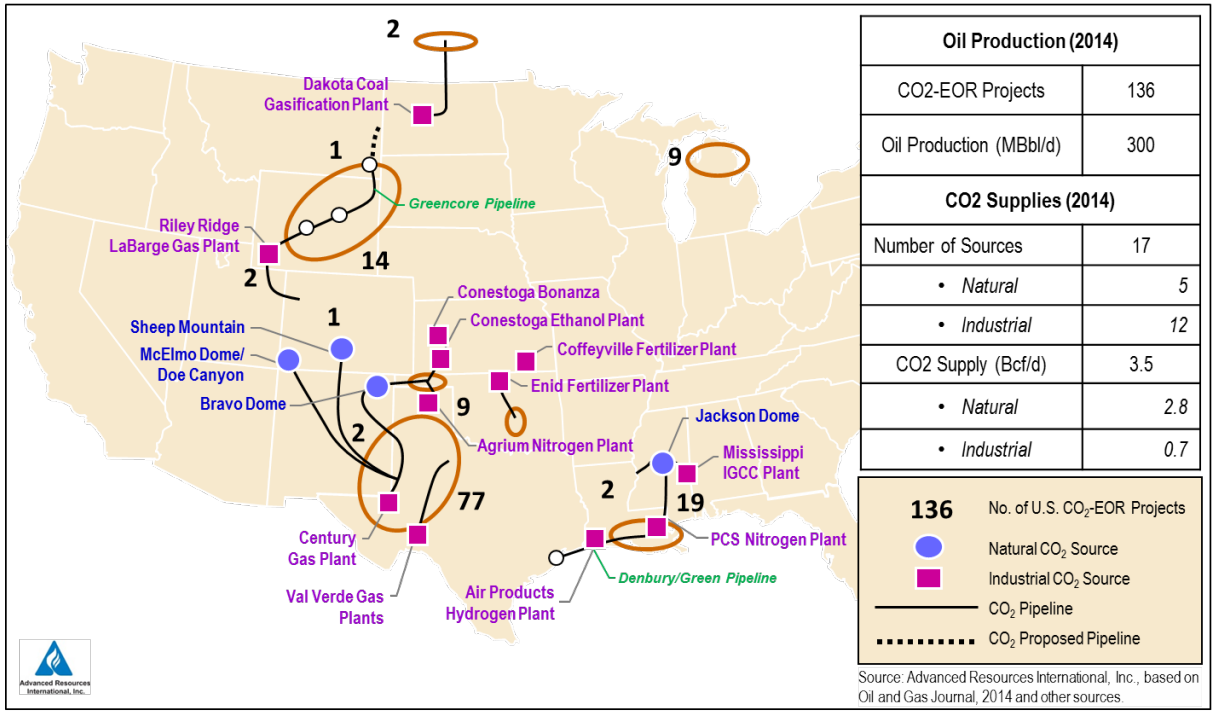
CO_2 Enhanced Oil Recovery: A Look at Today

The development of large natural sources of CO_2 (e.g., McElmo Dome, Jackson Dome, etc.) established the foundation for the CO_2-EOR industry. Capture of industrial sources of CO_2 will help drive its growth.

Current CO_2-EOR Operations and CO_2 Sources (2014)



Oil Production (2014)	
CO2-EOR Projects	136
Oil Production (MBbl/d)	300
CO2 Supplies (2014)	
Number of Sources	17
• *Natural*	*5*
• *Industrial*	*12*
CO2 Supply (Bcf/d)	3.5
• *Natural*	*2.8*
• *Industrial*	*0.7*

136 No. of U.S. CO_2-EOR Projects
Natural CO_2 Source
Industrial CO_2 Source
CO_2 Pipeline
CO_2 Proposed Pipeline

Source: Advanced Resources International, Inc., based on Oil and Gas Journal, 2014 and other sources.

Source: Advanced Resources International based on Oil & Gas Journal and other industry data, 2014.

- The 136 significant CO_2-EOR projects currently produce 300,000 barrels per day from injecting 3.5 Bcfd of CO_2, <u>with 0.7 Bcfd from industrial sources</u>.
- Lack of reliable, affordable supplies of CO_2, along with lower oil prices, are the major constraints to greater use of CO_2-EOR technology.

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The Business Side of CO_2-EOR

The CO_2-EOR business is dominated by three "big" players - - Occidental Petroleum, Kinder Morgan and Denbury Resources.

A handful of other companies - - such as Apache, Breiburn Energy, Chaparral Energy, Chevron, Core Energy, Fasken, and Hess among others - - round out the mix.

Top Three Operators of CO_2-EOR Account for Two-Thirds of CO_2-EOR Production

Operator	Total Projects	2015 Production (MBbl/d)
Oxy	33	145,000
Kinder Morgan	4	80,000
Denbury	25	42,000
Total	62	267,000

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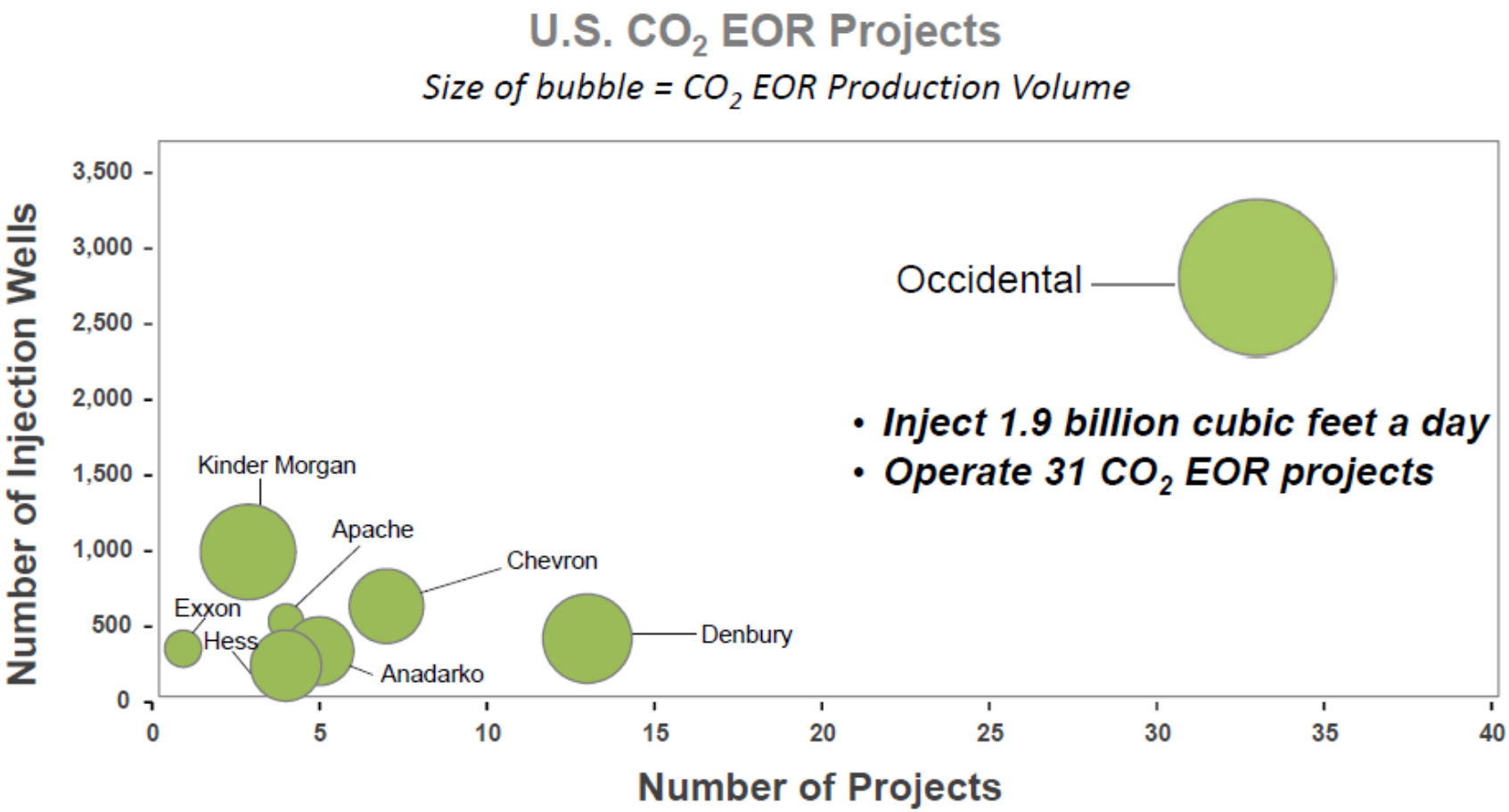
Source: Company presentations (includes NGLs).

A number of the majors and large independents - - Anadarko, ConocoPhillips, ExxonMobil/ XTO - - still operate legacy CO_2-EOR projects, but are currently much less active.

Occidental Petroleum - World Leader in Enhanced Oil Recovery



Source: Oil & Gas Journal 2012 Biennial EOR Survey

Source: Occidental Petroleum Investor Presentation, 2016.

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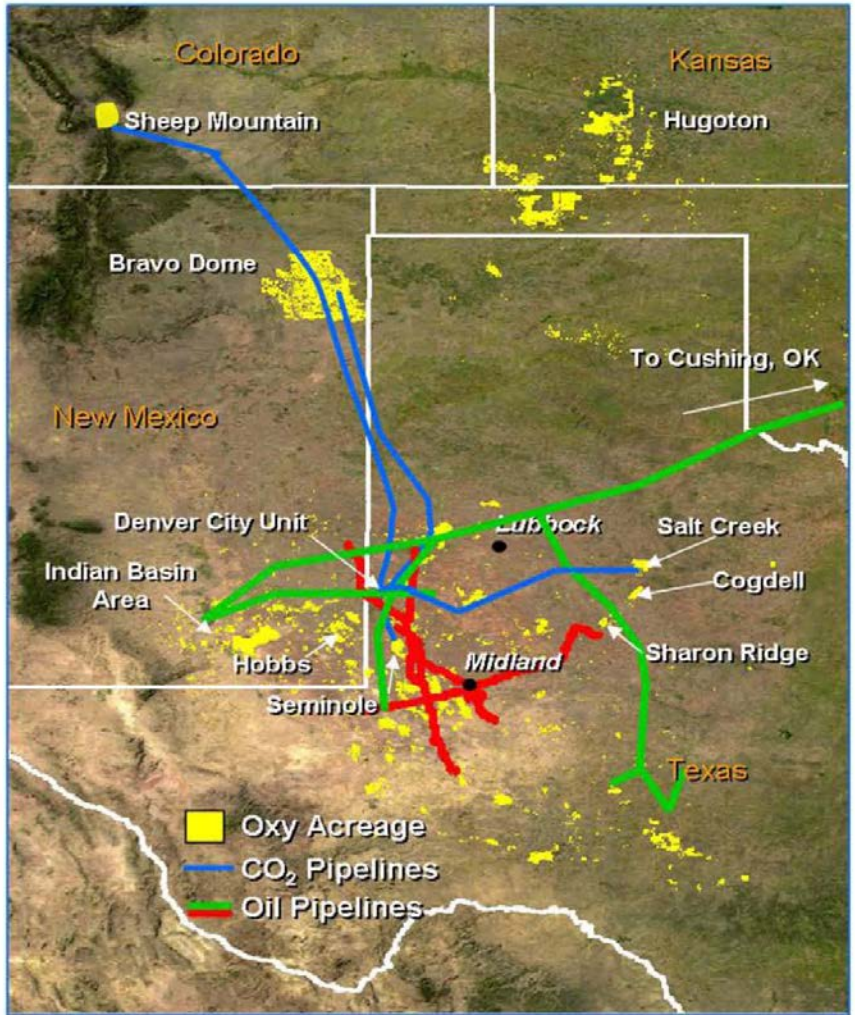
Occidental Petroleum

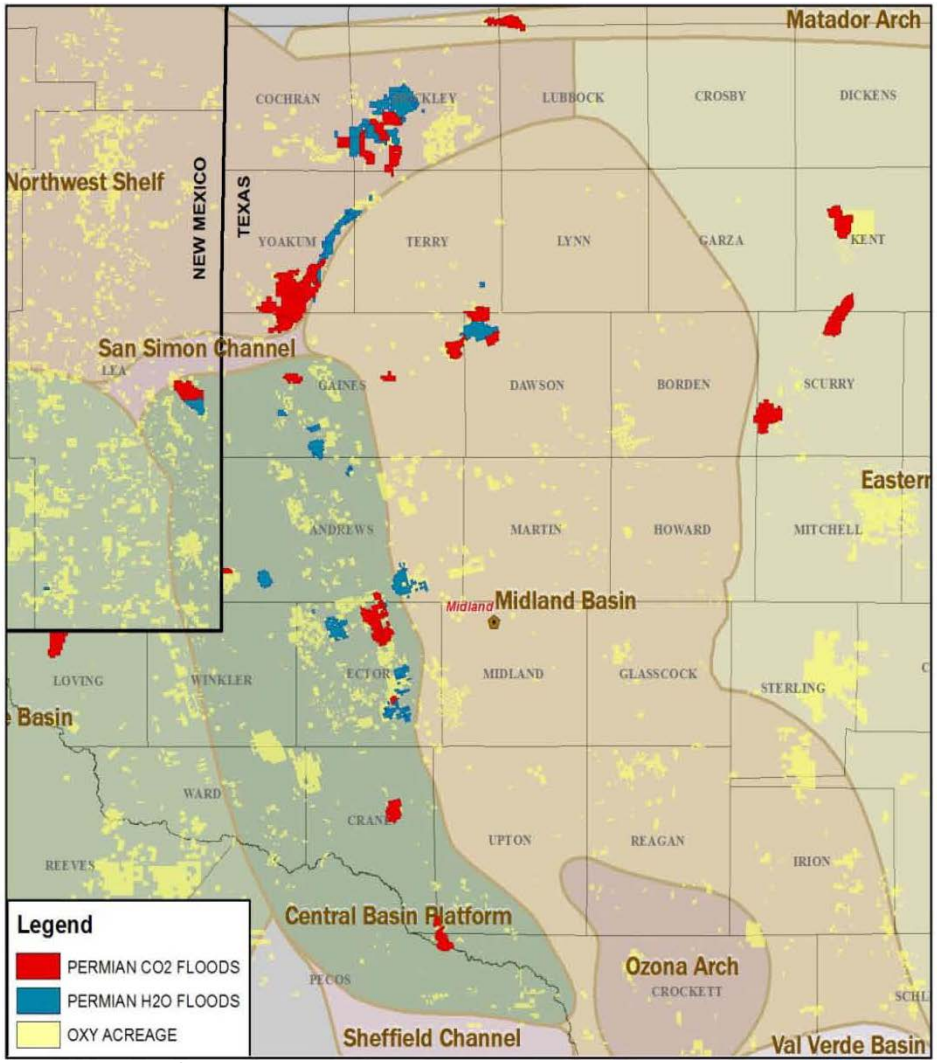


Source: OxyPermian, 2014

Occidental Petroleum operates its CO_2-EOR business as OxyPermian, located in Midland, Texas.

- Entered the CO_2-EOR business with purchase of BP's (Amoco/Arco) and Shell's oil fields, CO_2 sources and their ownership share of CO_2 pipelines.
- Investing $500 million in CO_2-EOR (in 2016) out of a capital budget of $2.9 billion.
- Producing 255,000 B/D in Permian Basin, with CO_2-EOR providing 145,000 B/D (including NGLs).
- Current strategy is to establish major growth programs in EOR with "game changing" technologies.

OxyPermian's CO_2-EOR Operations



Source: OxyPermian, 2014

CO_2-EOR is a major contribution to OxyPermian's performance:

- 60% of Oxy's Permian production
- Oxy's most profitable business unit
- Provides significant free cash flow

Oxy's strategy is vertically integrated CO_2-EOR:

- Ownership of CO_2 supply plus long-term purchase agreements
- 1,900 miles of CO_2 pipelines with 2.4 Bcf of capacity
- 33 major CO_2-EOR projects

Oxy expects large future potential from use of CO_2-EOR:

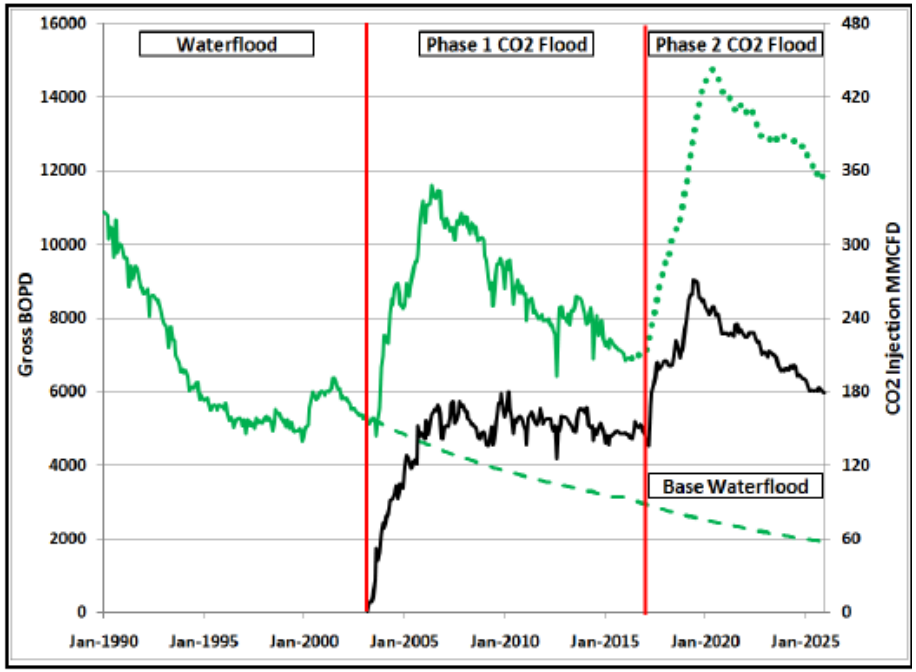
- Expansion/new CO_2-EOR projects
- ROZ (at Wasson, Hobbs, etc.)

Hobbs: CO_2 Flood and Expansion Areas

North Hobbs:

- Phase 1 added 35 MMBOE
- Phase 2A will develop 13.7 MMBOE at $13.82 per BOE (Injection in 6/2016)

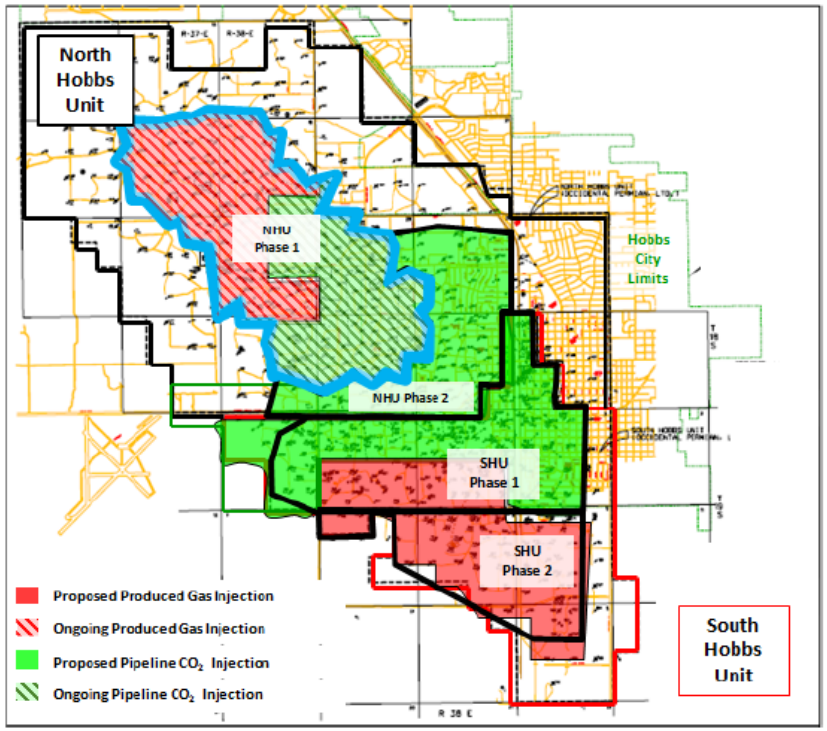
North Hobbs Oil Production



Source: OxyPermian, 2016

South Hobbs:

- Started CO_2 injection into Phase 1 in September, 2015
- Phases 1 & 2 will develop 28 MMBOE at $10.60 per BOE



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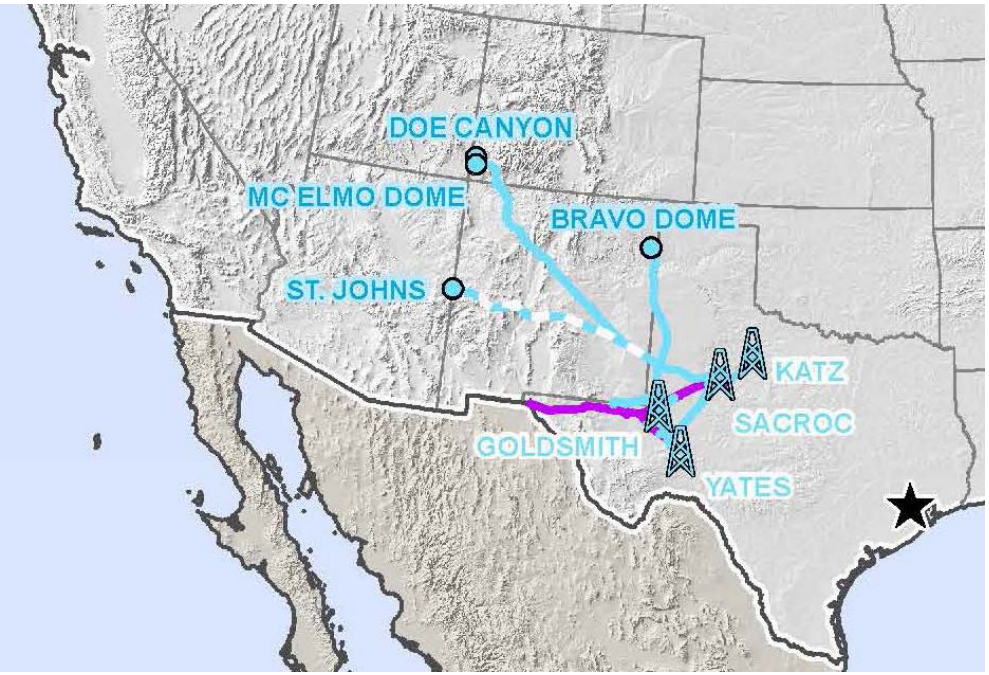
KinderMorgan Energy

KinderMorgan, a major pipeline and energy production company located in Houston, Texas, entered the CO_2-EOR supply business with the purchase of Shell's CO_2 pipelines and supplies. It subsequently entered the E&P business with the acquisition of SACROC from Devon in mid-2000.



Source: KinderMorgan, 2014

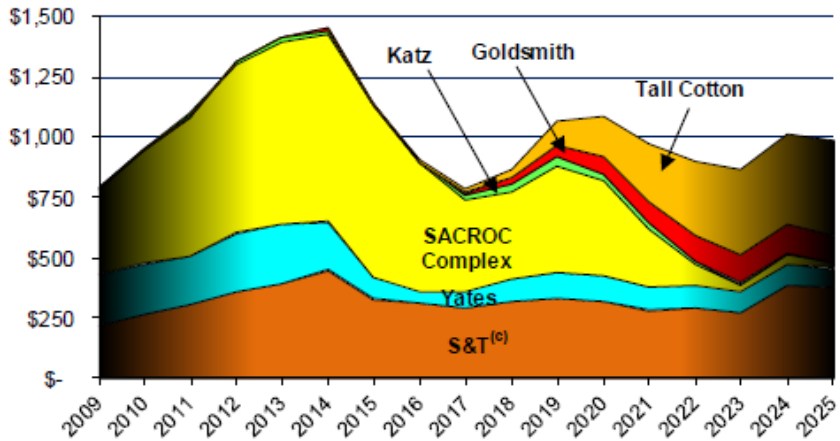
- Owns 8.5 billion barrels of OOIP resources in four key Permian Basin oil fields, plus ROZ resources.
- Current CO_2-EOR oil production of 80,000 B/D (including NGLs):
  - 34,000 B/D SACROC oil
  - 21,000 B/D SACROC NGLs
  - 19,000 B/D Yates
  - 6,000 B/D Katz/GLSAU/Tall Cotton
- Capital investment (in 2016) of $880 million:
  - $320 MM for CO_2 S&T
  - $560 MM for E&P/$CO_2$-EOR

KinderMorgan: 10 Year Outlook

Development Plan (2016-2025)

	10 Year		
	Net BOE[a] (MMBoe)	KM Share CapEx (MM) [d]	Cap CO_2 & Overhead (MM)
SACROC Complex	63	$802	$304
Yates Group	26	$221	$93
Katz	9	$37	$26
GLSAU	19	$404	$206
Tall Cotton	45	$1,363	$553
CO_2 S&T	-	$1,276	$115
Total	162	$4,103	$1,297

Discounted Cash Flow ($MM)



Oil prices in 2016 at $38/Bbl, 2017 at $45/Bbl, 2018 at $55/Bbl, 2019+ at $65/Bbl.

Source: KinderMorgan, 2016

KinderMorgan has set forth an ambitious 10 year program for its CO_2 E&P and S&T business units:

- Expectations for annual DCF of about $1 billion/year for next 10 years.
- Investing $4.1 billion in CAPEX in next 10 years.
- Looking to the ROZ and Goldsmith Field to replace declines in SACROC oil production.

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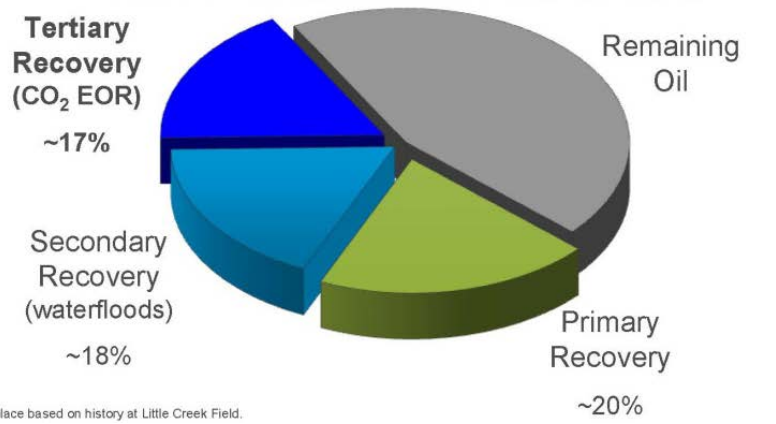
Denbury Resources

Integrated Operations

Denbury's CO_2-EOR strategy is to be fully integrated - - CO_2 supply, transportation, oil assets and field operations.



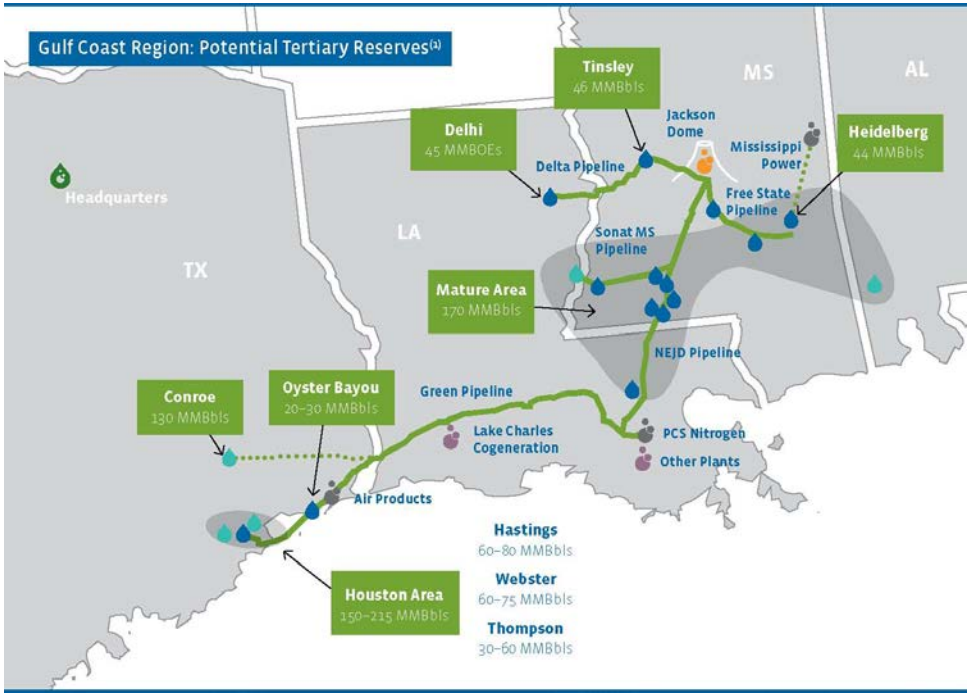
(1) Recovery of original oil in place based on history at Little Creek Field.

Denbury Resources, a recently launched medium-size independent oil and gas company, is headquartered in Plano, Texas.

"Our primary focus is on enhanced oil recovery utilizing carbon dioxide (CO_2 EOR). Our goal is to increase the value of acquired properties through a combination of exploitation, drilling and proven engineering extraction practices, with the most significant emphasis relating to tertiary recovery operations."

Source: Denbury Resources, 2014

Denbury's Gulf Coast CO_2-EOR Activities and Assets



Source: Denbury Resources, 2014

Denbury is the leading CO_2-EOR operator in the Gulf Coast:

- 1,100 miles of CO_2 pipelines, including the recently completed Green Pipeline.
- About 0.7 Bcfd of natural CO_2 production plus notable anthropogenic sources:
  - Air Products Hydrogen: 50 MMcfd
  - PCS Nitrogen: 20 MMcfd
  - MS Power (Kemper): 115 MMcfd (2016)
  - Future (280 MMcfd)
- About 42,000 B/D of production from 14 CO_2-EOR projects.
- Expects 70,000 B/D of additional production (peak) from new CO_2-EOR projects (Conroe, Webster, etc.)

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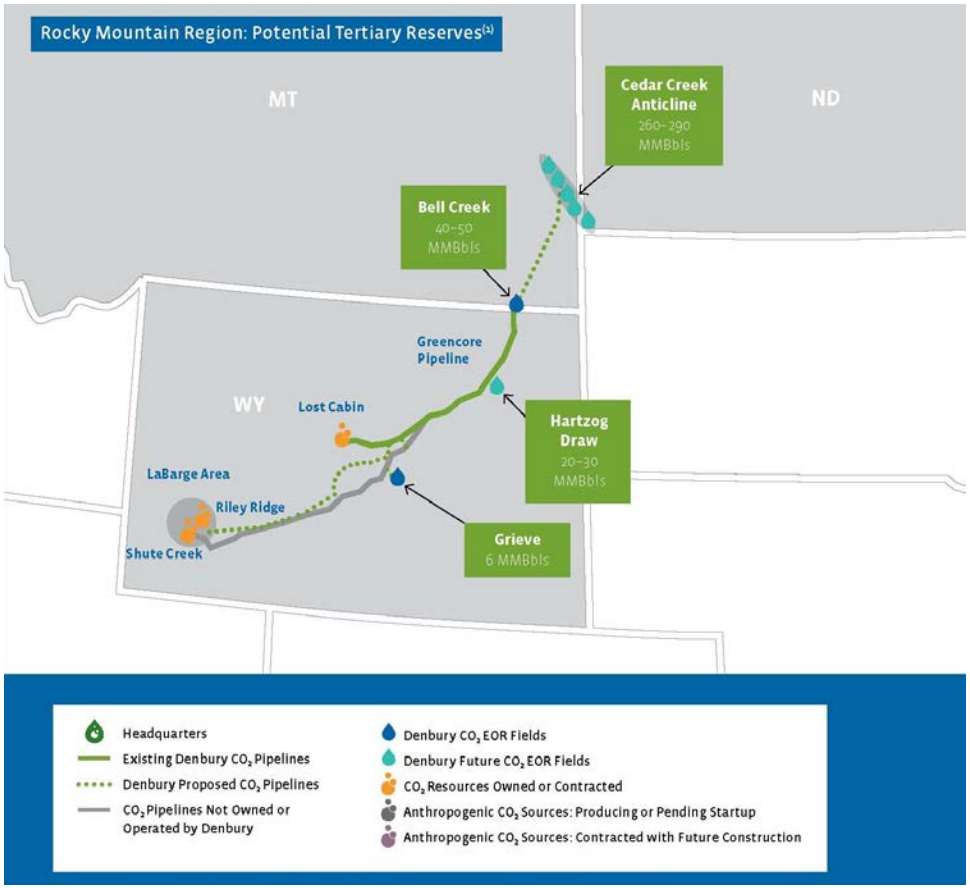
Denbury's Rocky Mountain CO_2-EOR Activities and Assets



(1) Potential, proved and produced-to-date tertiary reserves estimated as of 12/31/13 based on a range of recovery factors. Proved reserves based on year-end 12/31/13 SEC reporting.

Source: Denbury Resources, 2014

Denbury recently entered the Rockies CO_2-EOR business with purchase of Encore and swap of Bakken Shale assets for Exxon's oil fields and CO_2 supply.

- Purchased of Cedar Creek Anticline from ConocoPhillips
- Constructed Greencore CO_2 pipeline with CO_2 supplies from Lost Cabin gas processing plant and Riley Ridge.
- Operating three CO_2 floods:
  - Bell Creek (Montana)
  - Hartzog (Wyoming)
  - Grieve (Wyoming)

2. Size of the Prize

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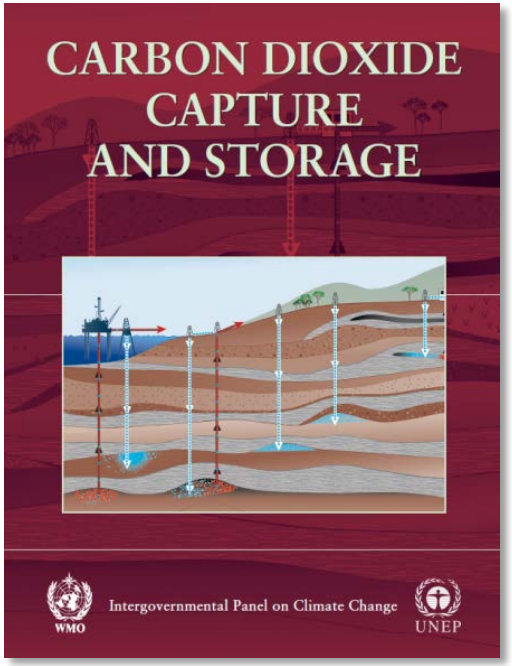
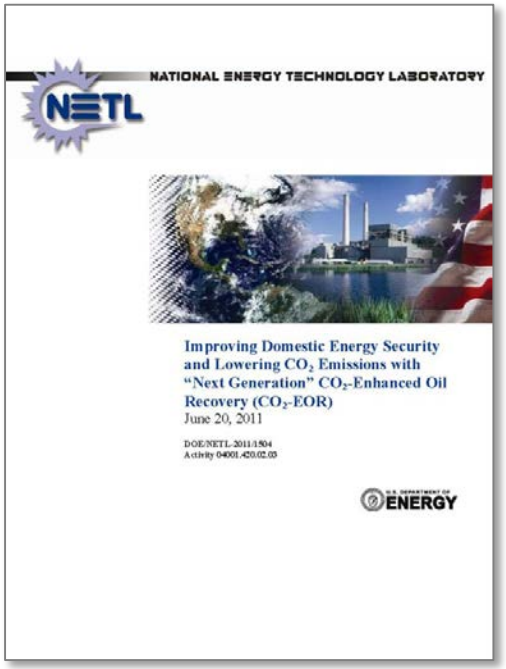
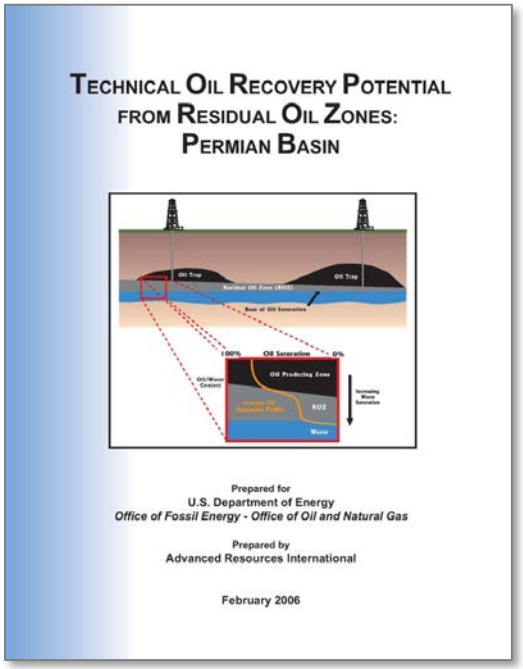
CO_2 Demand/Storage with CO_2-EOR

The first IPCC report set in-place a perspective that the CO_2 storage potential offered in mature oil fields by CO_2-EOR was **a small, niche opportunity**.

Two reports by Advanced Resources Int'l and Melzer Consulting for U.S. DOE/NETL, <u>helped change the perception</u> that CO_2 demand and associated storage by CO_2-EOR is a limited, niche opportunity.







The Size of the "Main Pay" CCUS "Prize"

- With "Current Technology," the economically viable* oil recovery and demand for CO_2 from the main pay of domestic oil fields (lower-48) is:
  - 22 billion barrels of crude oil
  - 9 billion metric tons of CO_2
- Use of "Next Generation" technologies increases these values to:
  - 78 billion barrels of crude oil
  - 26 billion metric tons of CO_2
- This demand for CO_2 is equal to CO_2 capture from 45 to 130 GWs of coal-fired power.

Oil Recovery and CO_2 Demand: Current and "Next Generation" EOR Technology

Resource Area	Economic Oil Recovery (BBbls)*		Demand for Purchased CO_2 (Billion Metric Tons)	
	Current Tech.	Next Gen. Tech.	Current Tech.	Next Gen. Tech.
Lower-48, Onshore	21	63	9	21
Lower-48, Offshore	1	15	**	5
Total	22	78	9	26

*At oil prices of $80 to $90/B, CO2 costs of $36 to $40/mt and 20% ROR (before tax).
**Less than 0.5 Bmt.
Source: Advanced Resources International, Inc. (2011).

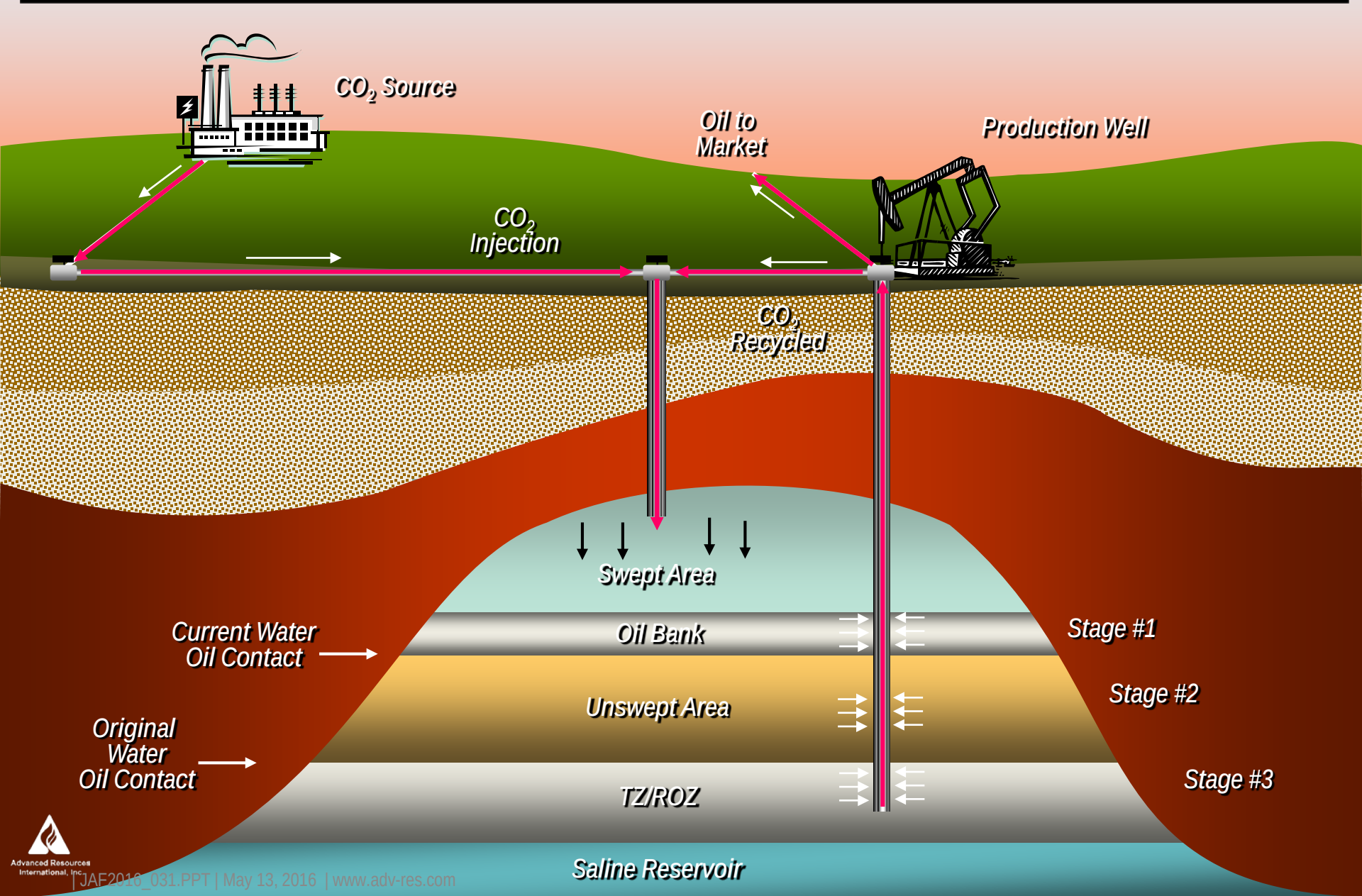
Advances in CO_2-EOR Recovery Technologies

Recovering more of the oil "left behind" after industry's and nature's waterfloods rests on successful development and integrated application of four "next generation" CO_2–EOR technologies:

1. Improved reservoir conformance to reduce unproductive channeling of CO_2 through high permeability flow paths.
2. Advanced CO_2 flood designs to target the high remaining oil saturation reservoir segments bypassed, or poorly swept, by the waterflood.
3. Enhanced mobility control to reduce viscous fingering and to improve the mobility ratio.
4. Development and use of fluids and chemicals that reduce the CO_2/oil minimum miscibility pressure (MMP).

Application of these technologies would benefit greatly from the design of "smart wells" and real-time feedback of information from the reservoir.

"Next Generation" CO_2-EOR and Storage Technology



3. Economics of CO_2-EOR

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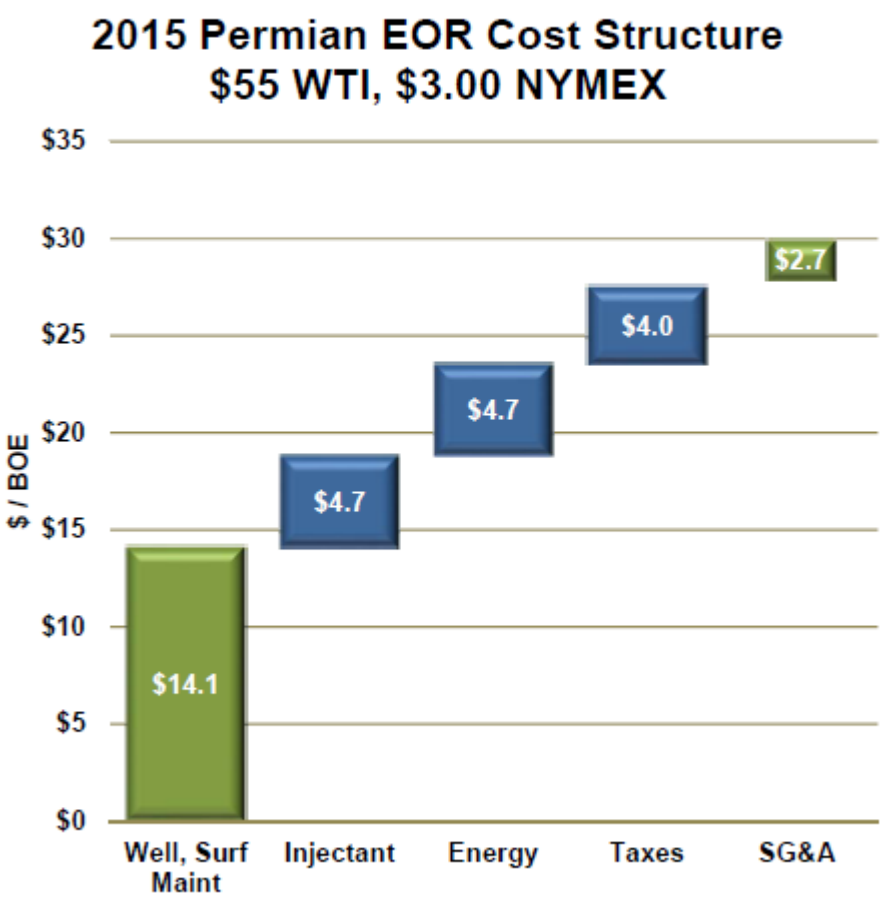
Can CO_2-EOR Be Economically Viable in a Lower Oil Price World?

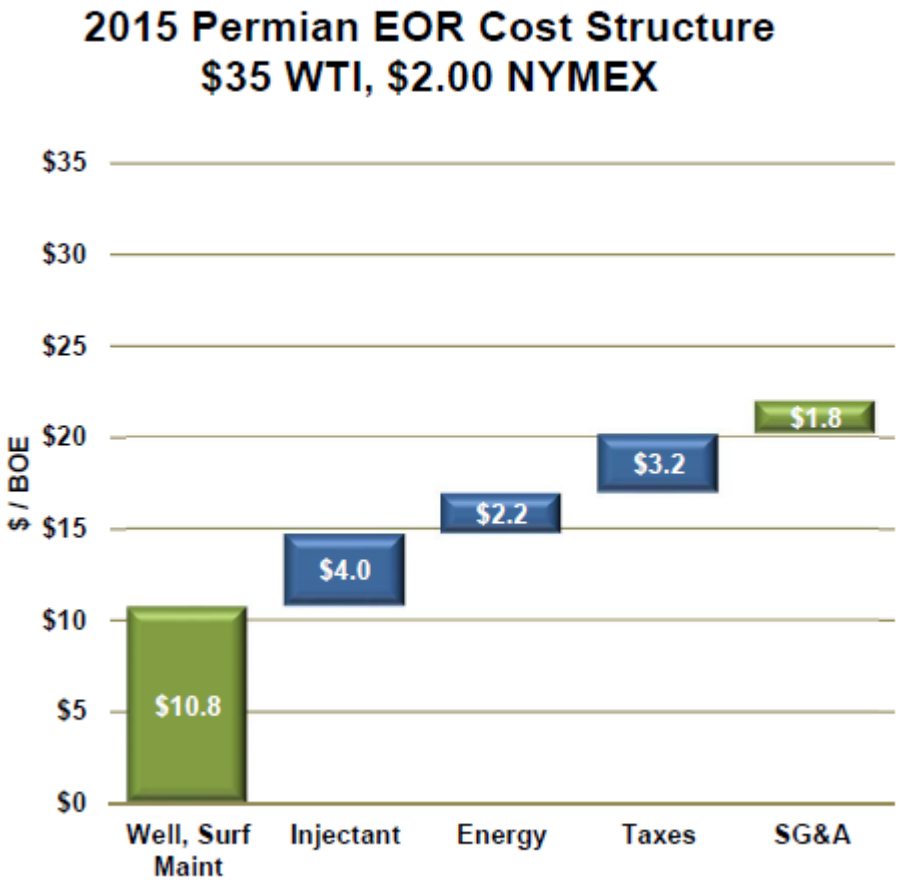
Information from the "Big Three" CO_2-EOR operators - - OxyPermian, Kinder Morgan and Denbury - - shows that:

- Oxy's "main pay" Permian Basin CO_2-EOR can operate profitably at $22 to $30/B (not including investment and return).
- Oxy's ROZ Permian Basin CO_2-EOR has front-end development costs of $3 to $7/B.
- Kinder Morgan can profitably operate its Permian Basin CO_2-EOR projects at $20/B (not including investment and return).
- Denbury's CO_2-EOR operating costs plus G&A (not including capital or return on capital) have declined from about $30/B in prior years to $25/B in 2015 and further to about $21/B in 1Q 2016.

Occidental Petroleum - Permian CO_2-EOR Cost Structure

Permian EOR can operate at cash costs as low as $22 per BOE





Sensitive to O&G Prices Partially Discretionary

Source: Occidental Petroleum Investor Presentation, 2016.

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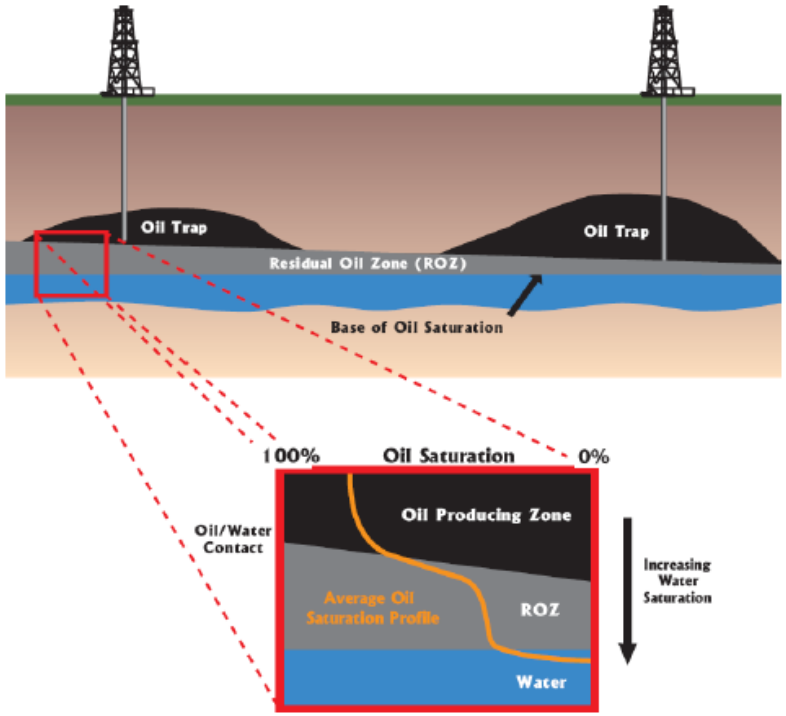
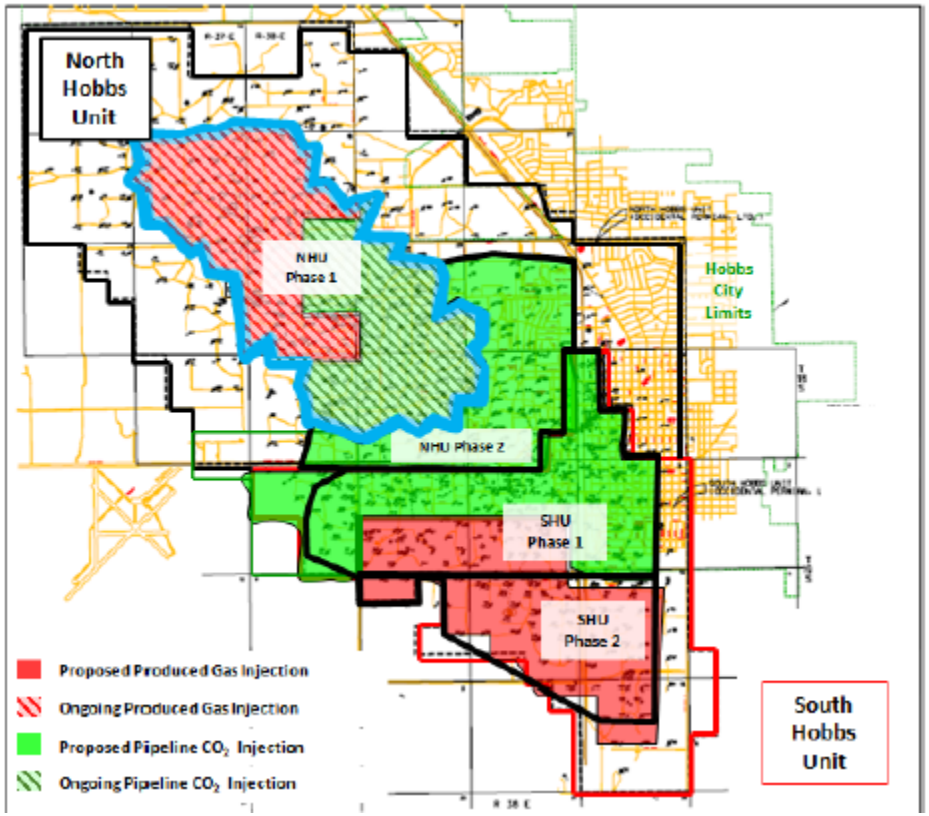
Occidental Petroleum – Economics of CO_2-EOR for ROZ

ROZ Projects development cost ranges from $3 - $7 per BOE



"Stranded Oil in the Residual Oil Zone by L. Stephen Melzer, Advanced Resources International and the U.S. Department of Energy, February 2006.

South Hobbs
Residual Oil Zone ("ROZ") Potential:



Source: Occidental Petroleum Investor Presentation, 2016.

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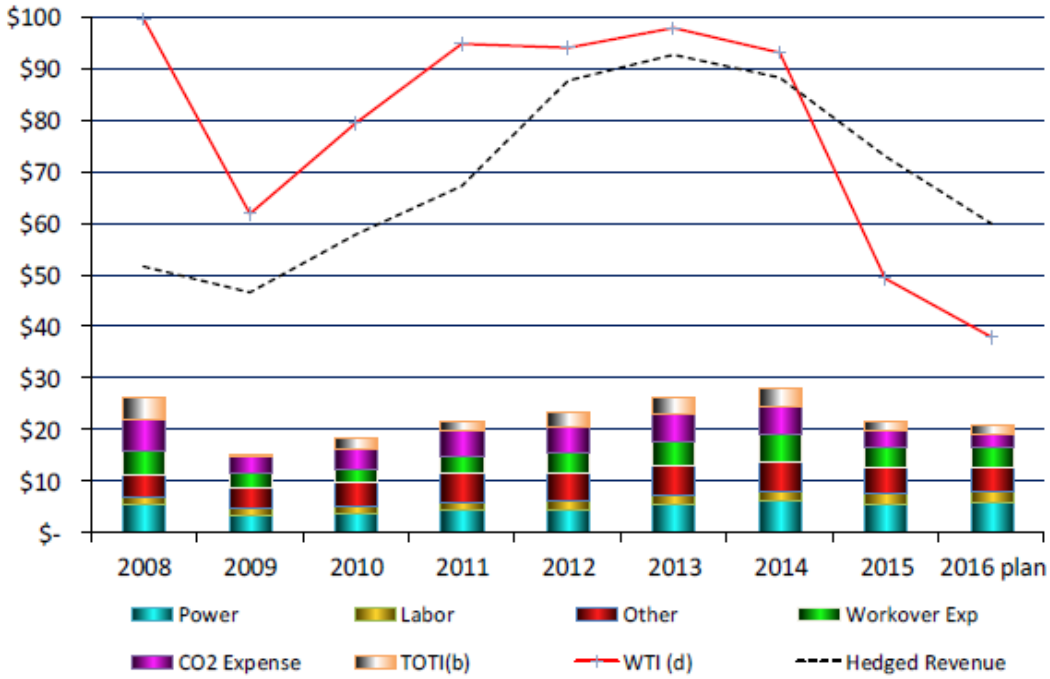
KinderMorgan: The Business Side of CO_2-EOR

Oil and Gas Cash Cost Structure* ($/Net Boe)



KinderMorgan's CO_2-EOR Business Unit shows attractive economics:

- Operating costs, including CO_2, power, workover/labor and production taxes of about $20/B.
- Net cash margin of $20/B (at WTI).
- Three year IRR of nearly 22%.

*Costs and Revenue per net Boe, including hedges where applicable

Source: KinderMorgan, 2016

KinderMorgan: Returns on Invested Capital

Kinder Morgan's CO_2 Business Unit Provides Company Leading Returns

Segment Return on Investment	2013	2014	2015	Average 2013-2015
Natural Gas Pipes	10.9%	10.9%	10.3%	10.7%
Products Pipelines	12.4	12.3	12.6	12.4%
Terminals	12.1	11.2	10.2	11.2%
CO2	25.9	22.8	16.2	21.6%
KM Canada	14.8	11.5	9.7	17.0%
Total Company	11.9%	11.4%	10.3%	11.2%

Source: KinderMorgan, 2016

KinderMorgan: Return on Investment By CO_2 Project

IRR % vs Oil Price

$/Bbl	$30 flat	$40 flat	$50 flat
SACROC Infill	0%	9%	53%
SACROC-Bypass	11%	30%	54%
SACROC P5	0%	2%	19%
Yates HDH	34%	66%	100%
GLSAU 4a	0%	0%	7%
Tall Cotton Ph 2	0%	8%	21%

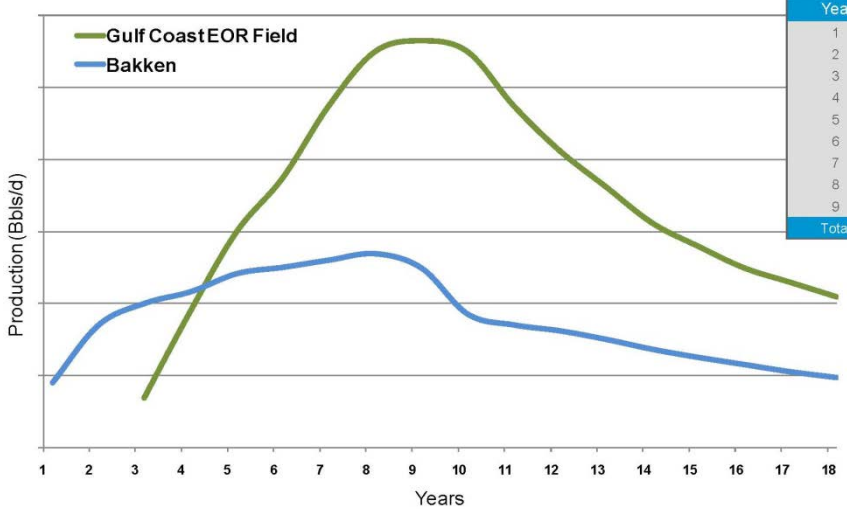
- Forecasted operating costs do not incorporate further cost savings expected in a $40/Bbl or lower price environment
- Budgeted 2016 operating costs:
  - SACROC = $18.24 /Bbl
  - Yates = $13.43 /Bbl

Source: KinderMorgan, 2016

Economics of CO_2-EOR: Denbury's CO_2-EOR Operating Costs

Denbury's view is that CO_2-EOR provides a better NPV than the Bakken Shale. Denbury's CO_2-EOR CO_2 operating costs plus G&A range have declined to $25 per barrel.

Projected Production Profile with Same Capital Spending



Capital Spending per Year Based on EOR Spending Pattern	
Year	$MM
1	83
2	83
3	60
4	60
5	68
6	52
7	52
8	52
9	45
Total	$555

Note: Assumes 700 BOEPD initial 30 day rate for Bakken wells.

Source: Denbury Resources, 2014

	2014 ($/BOE)	2015 ($/BOE)
A. Oil Prices		
NYMEX ($/B)	$99	$49
Realized ($/B)	$102	$49
B. CO2 Expenses		
1 CO2 Costs	$7	$5
2 Power/Fuel	$7	$7
3 Repairs/Worker Maintenance*	$8	$3
4 Labor/ Chemicals/ Overhead/G&A	$8	$10
5 Total Expenses	$30	$25

*Excludes costs for Delhi field remediation.

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4. Sources of CO_2 for EOR

Will There Be Sufficient Supplies of CO_2?

Increased volumes of natural, industrial and anthropogenic CO_2 are available for the Permian Basin, the Mid-Continent, the Rockies and the Gulf Coast.

Significant efforts are underway to lower the costs of CO_2 capture from power plants and other industrial facilities, including:

- ExxonMobil's Fuel Cell based CO_2 capture technology
- Advanced solid sorbents and amines
- Membranes and other methods

In addition, a series of CO_2 capture (and storage) incentives are under discussion that would "buy-down" the costs of CO_2 capture by $20 to $40 per metric ton.

KinderMorgan: Expanding CO_2 Supplies for the Permian Basin

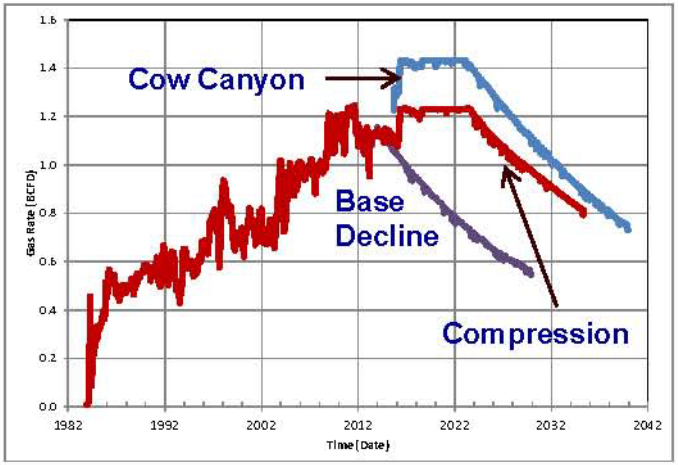
*Current Production 1,300 MMcf/d**	(MMcf/d) New Volumes	($MM) Total Cost	($MM) Already Approved
New Sources			
Yellow Jacket Boosters	90	$214	$ 214
Cow Canyon	200	$ 380	$ 56
St. Johns	300	$ 982	$73
Additional 4 Corners Area Expansions	60	$ 184	$11
Recapture Projects	78	$ 96	$ 16
Total	728	$ 1,856	$ 370

*Completion of Doe Canyon expansion added 90 MMcf/d and eliminated curtailments in 4Q 2013

KinderMorgan has expanded its 1.3 Bcfd of CO_2 production by 200 MMcfd by investing $590 million at McElmo Dome. Future CO_2 supply opportunities include:

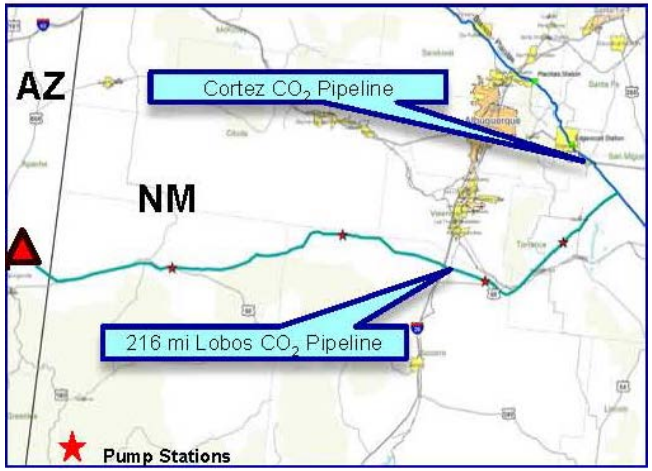
- Investing $1 billion for St. Johns, including the 216 mile Lobos CO_2 Pipeline
- Expanding the Cortez Pipeline ($327 MM)

McElmo Dome: Cow Canyon



Source: KinderMorgan, 2014

St Johns CO_2 Field



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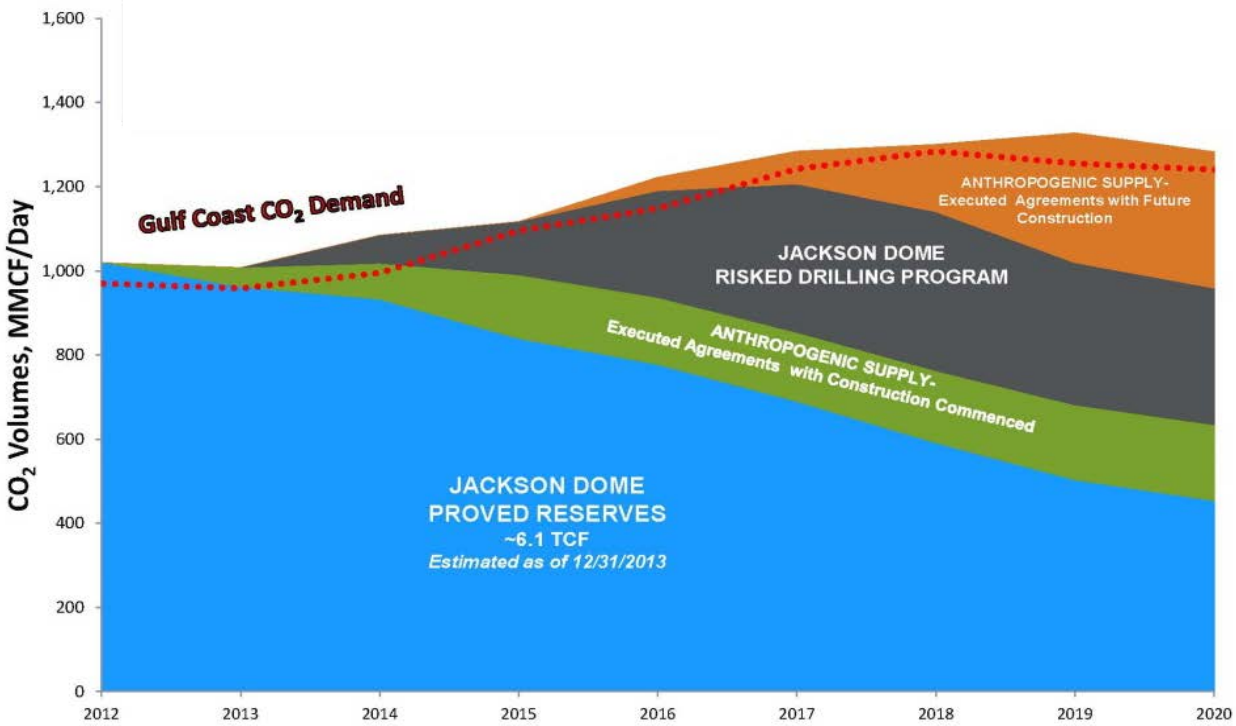
Denbury Resources: Gulf Coast CO_2 Supplies

Denbury Resources: Jackson Dome holds 5.5 Tcf of proved CO_2 reserves and an additional 2.5 Tcf of probable and possible CO_2 reserves. Denbury will purchase and use about 0.2 Bcfd of industrial CO_2 once the Kemper IGCC plant comes on stream.



Note: Forecast based on internal management estimates and includes fields currently owned. Actual results may vary.

Source: Denbury Resources, 2014

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