PS Anthropogenic CO_2 for Enhanced Oil Recovery: An Under-Utilized Resource for Greener Fuels*

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Abstract

World oil basins have the potential to recover over 1 trillion barrels of oil with enhanced oil recovery (EOR) using CO_2 from known and undiscovered oil in place (Godec et al, 2011). The ability to recover these oil reserves is limited by the availability of CO_2 resources. At 1.5 barrels of oil produced/metric ton of CO_2, the required CO_2 for EOR in all basins would be over 700 billion metric tons. Assuming the recovery took 100 years, the market demand for CO_2 could be over 7 billion metric tons/year. Atmospheric anthropogenic CO_2 releases in 2011 were ~31.3 billion metric tons; stationary electricity and industrial sources of CO_2 totaled ~14.5 billion metric tons (IEA, 2013). This suggests that there is likely enough man-made CO_2 available for potential world demand. CO_2 used in EOR is typically of geologic origin, of relatively high purity (~95% CO_2), and sells for between 2% to 3% of the value of a barrel of recovered oil per 1000 ft3 of gas (Permian Basin of west Texas). This equates to ~$32US to ~$48US per delivered metric ton (crude oil valued at $85US/barrel). Most methods of CO_2 capture from industrial sources cost over $50US per metric ton prior to compression and transport; compression and pipeline costs represent an additional cost of ~$15US per ton. Lower cost methods of CO_2 capture are needed for widespread use of CO_2 in EOR. CO_2 is commonly recognized to have the potential to recover an additional 15 to 20% of original oil in place, with oil production ranging from 1–3 barrels/metric ton of CO_2 lost to the reservoir. The long-term oil recovery potential of CO_2 is not well understood because of the lack of low cost CO_2 for flooding. CO_2 flooding is common in the Permian Basin due to the nearby geologic CO_2 sources. CO_2 is typically only effective in recovering medium and light crude oil. Medium and light oil produced at rates of less than 2.0 to 2.8 barrels respectively; per metric tons lost are likely CO_2 negative. CO_2 negative is when it takes more CO_2 to recover the oil than it will produce upon combustion. Negativity can be calculated based upon oil density, carbon content, conversion of carbon to CO_2, and the comparison of combustion produced CO_2 to lost CO_2. Crude oil is variable but a general understanding of the negativity of EOR with CO_2 can be developed. The use of man-made CO_2 for oil recovery offers the potential for greener fuels.

Reference Cited

Godec, M., v. Kuuskraa, T.V. Leeuwen, L.S. Melzer, and N. Wildgust, 2011, CO_2 storage in depleted oil fields: The worldwide potential for carbon dioxide enhanced oil recovery: Energy Procedia, 10th International Conference on Greenhouse Gas Control Technologies, v. 2011, p. 2162–2169, Web Accessed, August 8, 2015, http://www.sciencedirect.com/science/article/pii/S1876610211002992.

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Savannah River National Laboratory™
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World oil basins have the potential to recover over 1 trillion barrels of oil with enhanced oil recovery (EOR) using CO2 from known and undiscovered oil in place (Godec et al, 2011). The ability to recover these oil reserves is limited by the availability of CO2 resources. At 1.5 barrels of oil produced/metric ton of CO2, the required CO2 for EOR in all basins would be over 700 billion metric tons. Assuming the recovery took 100 years, the market demand for CO2 could be over 7 billion metric tons/year. Atmospheric anthropogenic CO2 releases in 2011 were ~31.3 billion metric tons; stationary electricity and industrial sources of CO2 totaled ~14.5 billion metric tons (IEA, 2013). This suggests that there is likely enough man-made CO2 available for potential world demand.

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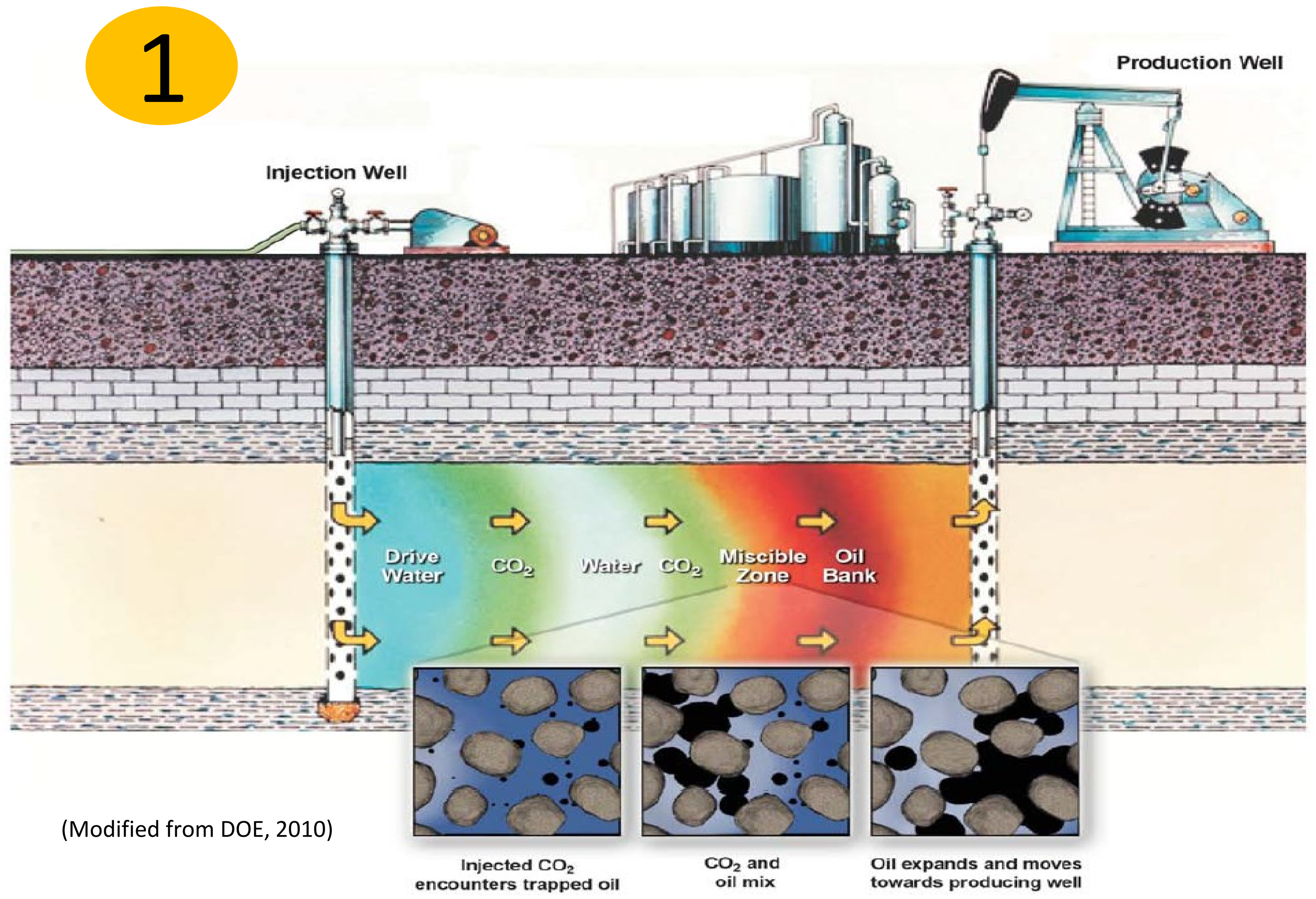
CO2 is typically only effective in recovering medium and light crude oil. Medium and light oil produced at rates of less than 2.0 to 2.8 barrels respectively; per metric tons lost are likely CO2 negative. CO2 negative is when it takes more CO2 to recover the oil than it will produce upon combustion. Negativity can be calculated based upon oil density, carbon content, conversion of carbon to CO2, and the comparison of combustion produced CO2 to lost CO2. Crude oil is variable but a general understanding of the negativity of EOR with CO2 can be developed. The use of man-made CO2 for oil recovery offers the potential for greener fuels.

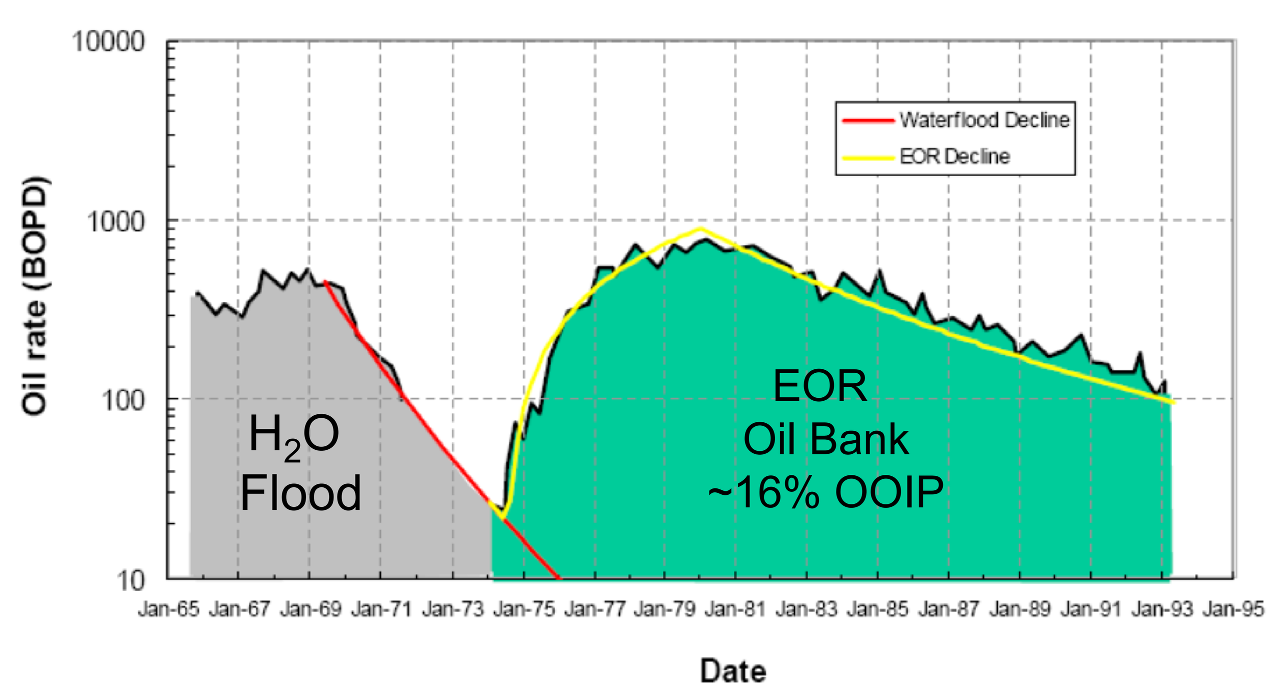
What is Enhanced Oil Recovery (EOR) with CO_2?

1



(Modified from DOE, 2010)

Twofreds CO_2 Flood
(Sandstone Reservoir)



Modified from Lake and Walsh, 2008

2 Recoverable Oil Volume?

Region	CO_2-EOR Oil Recovery (Billion Barrels)	CO_2 Storage Capacity (Billion Metric Tons)
1. Asia Pacific	47	13
2. C. & S. America	93	27
3. Europe	41	12
4. FSU	232	66
5. M. East/N. Africa	595	170
6. NA/Other	38	11
7. NA/U.S.	177	51
8. S. Africa/Antarctica	74	21
TOTAL	1,297	370

* Includes potential from discovered and undiscovered fields, but not future growth of discovered fields.
Source: IEA GHG Programme/Advanced Resources International (2009)

The worlds oil basins* have the potential to recover over 1 trillion barrels of oil with EOR using CO_2 (Godec et al, 2011; Godec 2013). The ability to recover this oil is limited by the availability of CO_2.

3 Oil Recovered Per Metric Ton of CO_2

DOE near term projections of CO_2 utilization for EOR

	Daily CO_2 Used (Metric Ton)	Daily Oil Produced (Barrels)	Barrels/Metric Ton
Permian Basin Total in 2012	88077	186000	2.1
Gulf Coast Total in 2012 - 2020	134457	110000	0.8
Rockies Total in 2012	12473	36000	2.9
			1.9 Average

Data from NETL- 2014/1648

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4 Potential Annual CO_2 Demand Worldwide?

~1,200,000,000,000 Bbls
____
~1.5 Bbls*/Metric Ton

↓

~800,000,000,000
Metric Tons CO_2

↓

100 Years
Production Period

↓

**~8,000,000,000
Metric Tons/Year Demand**

5 Potential Sources of CO_2 for EOR

Current supplies of CO_2 for EOR are mostly from geologic sources. There is a small anthropogenic fraction (gas treatment, fertilizer, refinery hydrogen, coal gasification, etc.).

- ~ 33,000,000,000 metric tons are released to the atmosphere annually from anthropogenic sources.
- ~ 10,000,000,000 metric tons are released to the atmosphere annually from large stationary sources greater than 12% CO_2 in flue gas (IEA GHG, 2002).

6 CO_2 Market Potential Gross Sales?

CO_2 delivered to reservoirs in the Permian Basin typically sells for between 2% and 3% of the value of the crude oil per 1000 ft^3 of gas.

($80/Bbl x 0.02) x 19.25* = $30.80/Metric Ton

($80/Bbl x 0.03) x 19.25* = $46.20/Metric Ton

$246B to $369B Gross Annual Sales Potential

* 19,250 ft^3/metric ton

7 CO_2 Capture, Compression, and Transport Costs

Current CO_2 capture costs are greater than $50 per metric ton. Compression and pipeline transport represents an additional ~$15 per metric ton in cost.

Lower cost methods of CO_2 capture are needed for widespread use of CO_2 in EOR.

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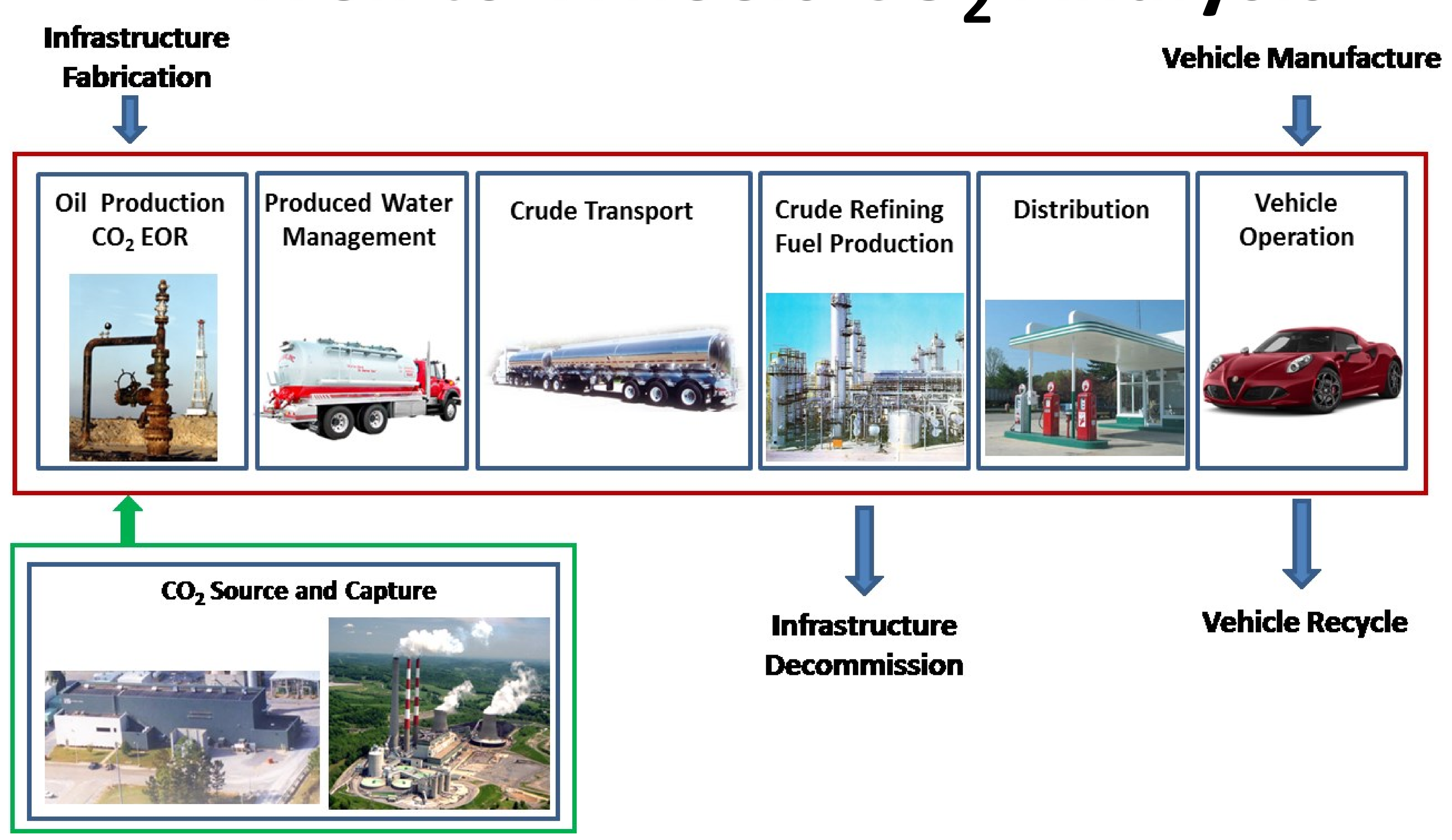
8 Well to Wheels CO_2 Analysis



"Well to Wheels" CO_2 Analysis Considering: crude carbon content; produced water and crude transport; refining and coke production; refined product distribution; and CO_2 from "best available" capture technology .....

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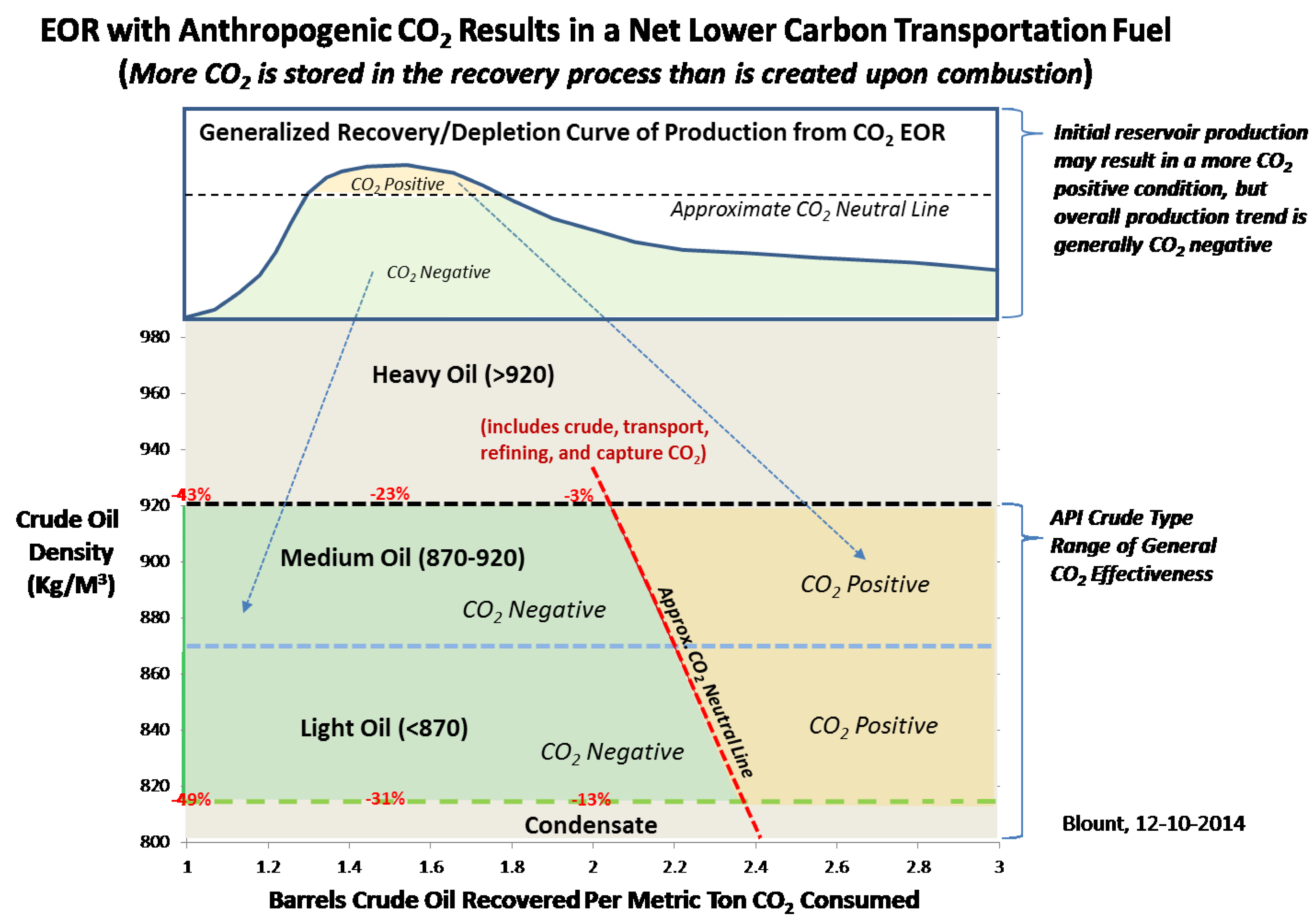

………… indicates that net CO_2 is ~ 30% less for a light oil, and ~ 23% less for a medium oil produced from EOR with CO_2.

10 Conclusions

- There is a large potential underserved demand for CO_2 as a commodity in EOR.
- The worldwide annual market could be as large as 7 to 8 Billion metric tons.
- Only anthropogenic CO_2 sources could meet this market demand; good match with stationary sources with greater than 12% in flue gas.
- Current CO_2 capture costs are too high (greater than $50/metric ton) to support the EOR market; less expensive methods of capture are needed.
- A simple "Well to Wheels" CO_2 analysis indicates that lower carbon transport fuels are possible when the CO_2 lost to the reservoir is considered.
  - ~30% of net CO_2 stored with light oil
  - ~23% of net CO_2 stored with a medium oil

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