CO₂-EOR and CCUS: Worldwide Potential and Commercial Drivers

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Special Session: CO2-EOR as a Pathway for CCUS

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Amsterdam, The Netherlands
Incremental Crude Oil Production from Current U.S. CO₂-EOR Projects

While Permian Basin still accounts for the most production from CO₂-EOR in the U.S., growth is occurring in all regions.

Source: Includes Advanced Resources Int'l. adjustments to Oil and Gas Journal EOR Survey, 2014.
Current CO₂-EOR Operations and CO₂ 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

Source: Advanced Resources International, Inc., based on Oil and Gas Journal, 2014 and other sources.
Projected CO₂-EOR Operations and CO₂ Sources (2020)

Oil Production (2020)

- CO₂-EOR Projects: 147
- Oil Production (MBbl/d): 638

CO₂ Supplies (2020)

- Number of Sources: 30
  - Natural: 6
  - Industrial: 24
- CO₂ Supply (Bcf/d): 6.5
  - Natural: 3.4
  - Industrial: 3.1

Source: Advanced Resources International, Inc., based on Oil and Gas Journal, 2014 and other sources.
Rapidly Increasing Utilization and Storage of Anthropogenic CO$_2$ with EOR

As part of a recent study for U.S. DOE/NETL, Advanced Resources tabulated the announced new sources of CO$_2$ supply scheduled to come on-line by 2020.

- Expansion of natural sources (St. Johns, Doe Canyon, Jackson Dome, etc.)
- Installation of CO$_2$ capture on industrial plants (Air Products hydrogen, Coffeyville fertilizer, Lost Cabin gas processing, Kemper Co. IGCC, etc.)

As such, we envision significant growth in CO$_2$ supplies for EOR:

- 4.4 Bcfd by 2015
- 6.8 Bcfd by 2020
Near-Term Outlook for Oil Production from CO₂-EOR

Increased CO₂ supplies are enabling industry to launch new CO₂-EOR projects and expand existing CO₂ floods:

- Bell Creek, Montana
- Burbank and NE Hardesty, Oklahoma
- Seminole ROZ Stages 1-3, Goldsmith, West TX
- Webster, Conroe, Thompson, East TX

These and other announced new/expanded CO₂ floods will drive significant growth in near-term CO₂-EOR based oil production:

- 430,000 B/D by 2015
- 650,000 B/D by 2020

Source: Advanced Resources International (2013)
How Big is the CO₂-EOR Target?

Pretty Small Set of Targets
Assessment of U.S. and Worldwide CO₂-EOR Potential

Two key reports on CO₂-EOR prepared by Advanced Resources Int’l.
**“Next Generation” CO₂ Enhanced Oil Recovery**

Use of more efficient CO₂-EOR technologies and extension of these technologies to new oil resource settings constitutes “next generation” CO₂-EOR:

1. Scientifically-based advances in CO₂-EOR technology
2. Integrating CO₂ capture with CO₂ utilization by CO₂-EOR
3. Application of CO₂-EOR to residual oil zones (ROZs)
5. Deployment of CO₂-EOR in tight (shale) oil formations.

Use of “next generation” CO₂-EOR will expand oil production and CO₂ storage capacity in the U.S.
Permian Basin ROZ Below Existing Oil Fields

**Oil Saturation Profile in the TZ/ROZ (Wasson Denver Unit Well Log)**

- Main Pay Zone (MPZ)
- Transition Zone (TZ)
- Residual Oil Zone (ROZ)
- Base of Producing OWC
- Base of Ultimate OWC

**Wasson Denver Unit Oil Resources (Billion Barrels)**

<table>
<thead>
<tr>
<th></th>
<th>Main Pay Zone</th>
<th>TZ/ROZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>OOIP</td>
<td>2.4</td>
<td>3.0</td>
</tr>
<tr>
<td>P/S Recovery</td>
<td>1.1</td>
<td>1.5*</td>
</tr>
<tr>
<td>&quot;Stranded&quot;</td>
<td>1.3</td>
<td>1.5</td>
</tr>
<tr>
<td>EOR Potential</td>
<td>0.5**</td>
<td>0.5***</td>
</tr>
</tbody>
</table>

*Produced by nature. **Approximately 0.3 billion barrels already produced/proven to date. ***Numerous ROZ projects underway.

**Seminole Unit (San Andres) ROZ Project**

(Three Hess Oil operated miscible CO₂ floods in the ROZ interval show successful oil response.)

<table>
<thead>
<tr>
<th>Project</th>
<th>Acres</th>
<th>CO₂ Injection Patterns</th>
<th>Oil Production (B/D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>500</td>
<td>10</td>
<td>1,200 1,200</td>
</tr>
<tr>
<td>Phase 2</td>
<td>480</td>
<td>9</td>
<td>1,700 1,800</td>
</tr>
<tr>
<td>Stage 1</td>
<td>2,320</td>
<td>29</td>
<td>1,000 3,500</td>
</tr>
</tbody>
</table>
16 of the 42 billion barrel ROZ resource below 88 large existing oil fields in just 3 hydrocarbon basins is technically recoverable, creating a market for 7 Gt of CO₂.

<table>
<thead>
<tr>
<th>Basin</th>
<th>Technically Recoverable ROZ Oil/CO₂ Demand - - Below Existing Oil Fields</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Assessed Fields</td>
<td>ROZ OIP</td>
<td>Technically Recoverable*</td>
<td>Crude Oil</td>
</tr>
<tr>
<td></td>
<td>(No. of Fields)</td>
<td>(Billion Barrels)</td>
<td>(Billion Barrels)</td>
<td>(Gt)</td>
</tr>
<tr>
<td>Permian¹</td>
<td>55</td>
<td>30.7</td>
<td>11.9</td>
<td>~5</td>
</tr>
<tr>
<td>Big Horn²</td>
<td>13</td>
<td>4.4</td>
<td>1.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Williston³</td>
<td>20</td>
<td>6.8</td>
<td>3.3</td>
<td>1.5</td>
</tr>
</tbody>
</table>

*With current CO₂-EOR technology.

Sources:
ARI and Melzer estimate that up to 100 million barrels of OOIP exist in the ROZ “Fairways” of the Permian Basin.
## U. S. Oil Recovery and CO₂ Storage From "Next Generation" CO₂-EOR Technology*

<table>
<thead>
<tr>
<th>Reservoir Setting</th>
<th>Oil Recovery*** (Billion Barrels)</th>
<th>CO₂ Demand/Storage*** (Billion Metric Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Technical</td>
<td>Economic**</td>
</tr>
<tr>
<td>L-48 Onshore</td>
<td>104</td>
<td>60</td>
</tr>
<tr>
<td>L-48 Offshore/Alaska</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>Near-Miscible CO₂-EOR</td>
<td>1</td>
<td>*</td>
</tr>
<tr>
<td>ROZ (below fields)****</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>136</td>
<td>80</td>
</tr>
<tr>
<td>Additional From ROZ “Fairways”</td>
<td>40</td>
<td>20</td>
</tr>
</tbody>
</table>

*The values for economically recoverable oil and economic CO₂ demand (storage) represent an update to the numbers in the NETL/ARI report “Improving Domestic Energy Security and Lowering CO₂ Emissions with "Next Generation" CO₂-Enhanced Oil Recovery (CO₂-EOR) (June 1, 2011).

**At $85 per barrel oil price and $40 per metric ton CO₂ market price with ROR of 20% (before tax).

***Includes 2.6 billion barrels already being produced or being developed with miscible CO₂-EOR and 2,300 million metric tons of CO₂ from natural sources and gas processing plants.

**** ROZ resources below existing oilfields in three basins; economics of ROZ resources are preliminary.
### U.S. Demand for CO₂:
Number of 1 GW Size Coal-Fired Power Plants

<table>
<thead>
<tr>
<th>Reservoir Setting</th>
<th>Number of 1GW Size Coal-Fired Power Plants***</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Technical</td>
</tr>
<tr>
<td>L-48 Onshore</td>
<td>170</td>
</tr>
<tr>
<td>L-48 Offshore/Alaska</td>
<td>31</td>
</tr>
<tr>
<td>Near-Miscible CO₂-EOR</td>
<td>5</td>
</tr>
<tr>
<td>ROZ**</td>
<td>34</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>240</td>
</tr>
<tr>
<td>Additional From ROZ “Fairways”</td>
<td>86</td>
</tr>
</tbody>
</table>

*At $85 per barrel oil price and $40 per metric ton CO₂ market price with ROR of 20% (before tax).
** ROZ resources below existing oilfields in three basins; economics of ROZ resources are preliminary.
***Assuming 7 MMmt/yr of CO₂ emissions, 90% capture and 30 years of operation per 1 GW of generating capacity; the U.S. currently has approximately 309 GW of coal-fired power plant capacity.

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**Technical Demand/Storage Capacity**

<table>
<thead>
<tr>
<th>Total CO₂</th>
<th>Anthropogenic CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>240</td>
<td>228</td>
</tr>
</tbody>
</table>

**Economic Demand/Storage Capacity**

<table>
<thead>
<tr>
<th>Total CO₂</th>
<th>Anthropogenic CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>133</td>
<td>121</td>
</tr>
</tbody>
</table>

---

*Assuming 7 MMmt/yr of CO₂ emissions, 90% capture and 30 years of operations per 1 GW of generating capacity.
**At an oil price of $85/B, a CO₂ market price of $40/mt and a 20% ROR, before.
Source: Advanced Resources Int’l (2011).
**CO₂-EOR – Compelling Economics**

**WTI Breakeven Price for a 20% Before-Tax Rate of Return ($ per Bbl)**

![Bar Chart](image)

Source: Denbury Resources (2012)

(1) Source: KeyBanc as of 10/17/12, Defined as the threshold WTI oil price necessary to generate a 20% before-tax rate of return. Excludes acreage costs.
(2) Internal estimate for indicative large CO₂ EOR development project in the Gulf Coast Region.
### Distribution of Economic Value of Incremental Oil Production from CO₂-EOR

<table>
<thead>
<tr>
<th>Notes</th>
<th>Oil Industry</th>
<th>Federal/State</th>
<th>Power Plant/Other</th>
<th>Private Royalties</th>
<th>U.S. Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Domestic Oil Price ($/B)</td>
<td>$85.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Less: Royalties</td>
<td>($14.90)</td>
<td>$2.50</td>
<td>-</td>
<td>$12.40</td>
</tr>
<tr>
<td>3</td>
<td>Production Taxes</td>
<td>($3.50)</td>
<td>$4.10</td>
<td>-</td>
<td>$0.60</td>
</tr>
<tr>
<td>4</td>
<td>CO₂ Purchase Costs</td>
<td>($14.00)</td>
<td>-</td>
<td>$12.60</td>
<td>$1.40</td>
</tr>
<tr>
<td>5</td>
<td>CO₂ Recycle Costs</td>
<td>($9.60)</td>
<td>-</td>
<td>-</td>
<td>$9.60</td>
</tr>
<tr>
<td>6</td>
<td>O&amp;M/G&amp;A Costs</td>
<td>($9.00)</td>
<td>-</td>
<td>-</td>
<td>$9.00</td>
</tr>
<tr>
<td>7</td>
<td>CAPEX</td>
<td>($6.00)</td>
<td>-</td>
<td>-</td>
<td>$6.00</td>
</tr>
<tr>
<td>8</td>
<td>Total Costs</td>
<td>($57.00)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Net Cash Margin</td>
<td>$28.00</td>
<td>$6.60</td>
<td>$12.60</td>
<td>$11.80</td>
</tr>
<tr>
<td>8</td>
<td>Income Taxes</td>
<td>($9.80)</td>
<td>$13.90</td>
<td>-</td>
<td>($4.10)</td>
</tr>
<tr>
<td>8</td>
<td>Net Income ($/B)</td>
<td>$18.20</td>
<td>$20.50</td>
<td>-</td>
<td>$7.70</td>
</tr>
</tbody>
</table>

1. Assumes $85 per barrel of oil.
2. Royalties are 17.5%; 1 of 6 barrels produced are from federal and state lands.
3. Production and ad valorem taxes of 5%, from FRS data.
4. CO₂ cost of $40/metric ton, including transport; 0.35 tonne of purchased CO₂ per barrel of oil.
5. CO₂ recycle cost of $16/metric ton; 0.6 tonne of recycled CO₂ per barrel of oil.
6. Other O&M/G&A expenses from ARI CO₂-EOR cost models.
7. CAPEX from ARI CO₂-EOR cost models.
8. Combined federal and state income taxes of 35%, from FRS data.
Oil Recovery and CO₂ Storage Potential in World’s Oil Basins*

The world’s oil basins* could produce nearly 1,300 billion barrels of oil from “next generation” CO₂-EOR technology and store 35 years worth of nearly 1,800 GW of coal-fired power plant emissions.

<table>
<thead>
<tr>
<th>Region</th>
<th>Technical CO₂-EOR Oil Recovery (Billion Barrels)</th>
<th>Associated CO₂ Demand/Storage Capacity (Billion Metric Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Asia Pacific</td>
<td>47</td>
<td>13</td>
</tr>
<tr>
<td>2. C. &amp; S. America</td>
<td>93</td>
<td>27</td>
</tr>
<tr>
<td>3. Europe</td>
<td>41</td>
<td>12</td>
</tr>
<tr>
<td>4. FSU</td>
<td>232</td>
<td>66</td>
</tr>
<tr>
<td>5. M. East/N. Africa</td>
<td>595</td>
<td>170</td>
</tr>
<tr>
<td>6. NA/Other</td>
<td>38</td>
<td>11</td>
</tr>
<tr>
<td>7. NA/U.S.</td>
<td>177</td>
<td>51</td>
</tr>
<tr>
<td>8. S. Africa/Antarctica</td>
<td>74</td>
<td>21</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,297</strong></td>
<td><strong>370</strong></td>
</tr>
</tbody>
</table>

* Includes potential from discovered and undiscovered fields, but not future growth of discovered fields.

Source: IEA GHG Programme/Advanced Resources International (2009)
CO₂-EOR and CCUS: Worldwide Potential and Commercial Drivers

CO₂-EOR Technology: A Closed-Loop System

Purchased CO₂
Anthropogenic and/or Natural Sources

Injected CO₂

Recycled CO₂
from Production Well

Zone of Efficient Sweep

Immobile Oil

CO₂ Stored in Pore Space

CO₂ Dissolved (Sequestered) in the Immobile Oil and Gas Phases

Driver
Water

CO₂
Water

Miscible Zone

Oil Bank

Additional Oil Recovery

Recycled CO₂ from Production Well
While CCS Needs the U to make CCUS Viable, CO₂-EOR Also Needs the CO₂ from CCUS

- While CCS needs the U to make CCUS, CO₂-EOR also needs the CO₂ from CCUS
- Growth in production from CO₂-EOR is now limited by the availability of reliable, affordable CO₂.
- If increased volumes of CO₂ do not result from CCUS, then these benefits from CO₂-EOR will not be realized.
- The Global CCS Institute reports 60 large-scale integrated projects (LSIPs) at various stages of the asset life cycle
- Of the projects in operation, under construction, or nearing final investment decisions, 74% (20 of 27) are using or intend to use captured CO₂ for CO₂-EOR.
Advanced Power Plants Plan to Use EOR for CO₂ Storage

**Southern Company’s Kemper County IGCC Plant**
- 582 MW fueled by Mississippi Lignite
- Will capture 65% of CO₂
- Will sell 1.1 to 1.5 million tons of CO₂ per year for EOR (170-225 MMcf/d)
- Project expected to cost $2.4 B and be operational in 2015

*Source: Mississippi Power, Denbury Resources*

**Summit’s Texas Clean Energy IGCC Project**
- 400 MW IGCC with 90% capture
- Located near Odessa in Permian Basin
- Sell 2.5 million tons of CO₂ per year to EOR market
- Expected cost $1.75 B; $350 MM award under CCPI Round 3

*Source: Siemens Energy*
Boundary Dam – First of its Kind

- Project involves the refurbishment of a power unit with CO₂ captured used for EOR
- Will provide supplement CO₂ supply to the Weyburn–Midale CO₂-EOR projects
- Project went on-stream in early October

Source: http://saskpowerccs.com
Steps to Achieving Lower Cost, Publicly-Acceptable CO₂ Supply for CO₂-EOR

- Sell more CO₂ to CO₂-EOR projects
  - Through better utilization and better economics with “next generation” CO₂-EOR technologies

- Pursue economies of scale for CO₂ transport; using existing infrastructure to the extent possible

- Gain public acceptance
  - Requires rigorous site selection, monitoring, and public outreach
  - But without imposing regulatory requirements that inhibit CO₂-EOR deployment

- Reduce the costs of CO₂ capture!!!
  - Requires doing projects, which cannot happen today w/o CO₂-EOR
“Learning by Doing” for Energy Industries

- LNG* 1970-2000: 13%
- Ethanol 1978-1996: 15%
- Solar Thermal 1985-1991: 3%
- Solar PV**: 23%
- PV inverters 1995-2002: 6%
- Wind Power 1981 - 2001: 13%

* LNG capital cost measured in USD/t and capacity measured in bcm.
**Other sources indicate learning rates as low as 18% for solar PV.

Source: Worldwatch Institute; IEA; BTM Consult; ABS; NREL; IIIE; ABI; Drewry 2007; UN Berkeley ERG; Navigant Consulting.
Overcoming Barriers to Large Volume CO$_2$ Supplies for CO$_2$-EOR

- Competitive Costs for CO$_2$ Capture
- Demonstrated CO$_2$-EOR Economics
- Proof of Safe and Reliable Storage
- Appropriate Regulatory Framework
- Market Acceptance

Today’s Emphasis

Future Challenges

FINISH
Affordable, Reliable CO$_2$ Supplies for EOR Market
Concluding Thoughts and Observations

1. **CO₂-EOR Offers Large CO₂ Storage Capacity Potential.** CO₂-EOR in oil fields can accommodate a major portion of the CO₂ captured from industrial facilities for the next 30 years.

2. **CO₂ is Stored with CO₂-EOR.** The amount stored depends on the priority placed on maximizing/optimizing storage.

3. **CCS Benefits from CO₂-EOR.** The revenues (or cost reduction) from sale of CO₂ to EOR helps CCS economics, overcomes some barriers, while producing oil with a lower CO₂ emissions “footprint.”

4. **CO₂-EOR Needs CCUS.** Large-scale implementation of CO₂-EOR is dependent on CO₂ supplies from industrial sources.

5. **Both CCUS and CO₂-EOR Still Need Supportive Policies and Actions.** Focused R&D investment, supportive policies and pre-built CO₂ pipelines can greatly accelerate the integrated use of CO₂-EOR and CCUS.
CO₂-EOR and CCUS: Worldwide Potential and Commercial Drivers

Office Locations

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Introduction

- **Utilizing and Storing CO₂ with EOR is Finally Gaining Traction.** Utilizing and storing anthropogenic (industrial) CO₂ with CO₂-EOR is finally “gaining traction”.

- **Overcoming the “Niche Opportunity” Mindset.** Many still believe that CO₂ utilization/storage will play a small, “niche” role.

- **Large CO₂-EOR Potential.** Based on detailed field-level studies, the size of the oil recovery and CO₂ storage potential offered by CO₂-EOR is “quite large and growing”, particularly as we begin to recognize its full potential.

- **Leads to Potential Large Demand for Industrial CO₂ for CO₂-EOR.** However, this potential cannot be realized without plentiful, affordable CO₂.
Main Topics of Presentation

- What is the potential for CO₂-EOR?
- How much CO₂ storage could result from CO₂-EOR?
- Is CO₂ effectively stored during CO₂-EOR operations?
- Who will benefit from pursuing CCUS with CO₂-EOR?
- What will it take to realizing these benefits?
Most U.S. Potential From Traditional CO$_2$-EOR in the U.S Lower-48 Onshore is in Texas*

<table>
<thead>
<tr>
<th>State</th>
<th>Economic Oil Recovery (B Bbls)</th>
<th>CO$_2$ Demand/Storage (MM mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>State-of-the Art</td>
<td>Next Generation</td>
</tr>
<tr>
<td>Lower 48 Onshore</td>
<td>24.0</td>
<td>60.0</td>
</tr>
<tr>
<td>Permian Basin</td>
<td>6.4</td>
<td>13.2</td>
</tr>
<tr>
<td>E &amp; C Texas</td>
<td>5.9</td>
<td>13.5</td>
</tr>
<tr>
<td>Texas Total</td>
<td>12.3</td>
<td>26.7</td>
</tr>
<tr>
<td>% L48 Onshore in TX</td>
<td>51%</td>
<td>45%</td>
</tr>
</tbody>
</table>

* The values for economically recoverable oil and economic CO$_2$ demand (storage) represent an update to the numbers in the NETL/ARI report “Improving Domestic Energy Security and Lowering CO$_2$ Emissions with “Next Generation” CO$_2$-Enhanced Oil Recovery (CO$_2$-EOR) (June 1, 2011). At $85 per barrel oil price and $40 per metric ton CO$_2$ market price with ROR of 20% (before tax).
“Next Generation” CO₂-EOR Technologies

1. Advanced reservoir characterization (to map residual oil and reservoir heterogeneity)
2. Combination horizontal/vertical wells plus “smart” well technology (to better contact bypassed oil)
3. CO₂ mobility and flow path control agents (to improve reservoir conformance)
4. Increased volumes of efficiently targeted CO₂ (to improve oil recovery efficiency)
5. Near-miscible CO₂-EOR technology (to expand CO₂-EOR to additional oil reservoirs)
6. Advanced reservoir surveillance and diagnostics technology (to “see and steer” the CO₂ flood)
Significant Volumes of CO₂ Are Already Being Injected for CO₂-EOR

| Location of Oil Fields | Location of CO₂ Sources | CO₂ Supply |  |
|-----------------------|-------------------------|------------|
|                       |                         | Geologic   | Anthropogenic |
| Permian Basin (Texas, New Mexico, Oklahoma, Utah) | Geologic (CO, NM) and Gas Processing, Fertilizer Plant (TX) | 1,730 | 175 |
| Rockies               | Gas Processing (Wyoming) | 50 | 320 |
| Gulf Coast            | Geologic (Mississippi)  | 960 | 125 |
| Michigan              | Gas Processing (Michigan) | - | 10 |
| Oklahoma              | Fertilizer Plant (Oklahoma) | 35 | 115 |
| Saskatchewan          | Coal Gasification (North Dakota) | - | 150 |
| **TOTAL (million cubic feet/day)** |                         | **2,775** | **895** |
| **TOTAL (million tonnes/year)** |                         | **54** | **17** |

* Source: Advanced Resources International, 2012

**MMcfd of CO₂ can be converted to million tonnes per year by first multiplying by 365 (days per year) and then dividing by 18.9 * 10^3 (Mcf per tonne)
## Distribution of Benefits from “Next Generation” CO₂-EOR

<table>
<thead>
<tr>
<th>Revenue Recipient</th>
<th>Value Chain Function</th>
<th>Revenues Per Barrel ($)</th>
<th>TOTAL* ($ billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power/Industrial Companies</td>
<td>Sale of Captured CO₂ Emissions</td>
<td>$13.20</td>
<td>$1,320</td>
</tr>
<tr>
<td>Federal/State Treasuries</td>
<td>Severance/Income Taxes</td>
<td>$19.80</td>
<td>$1,980</td>
</tr>
<tr>
<td>U.S. Economy</td>
<td>Services, Materials and Sales</td>
<td>$26.50</td>
<td>$2,650</td>
</tr>
<tr>
<td>Other</td>
<td>Private Mineral Rights</td>
<td>$7.70</td>
<td>$770</td>
</tr>
<tr>
<td>Oil Industry</td>
<td>Return of/on Capital</td>
<td>$17.80</td>
<td>$1,780</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$85.00</strong></td>
<td><strong>$8,500</strong></td>
</tr>
</tbody>
</table>

*Assuming 100 billion barrels of economically feasible oil recovery; oil prices of $85 per barrel and CO₂ sales price of $40/metric tons. Source: Advanced Resources International, Inc. (2011)
Integrating CO₂-EOR and CO₂ Storage Could Increase Storage Potential
## Life Cycle Analyses of the Integration of “Next Generation” CO₂ Storage with EOR

<table>
<thead>
<tr>
<th></th>
<th>“Next Generation”</th>
<th>“Second Generation” CO₂-EOR &amp; Incremental Storage</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO₂-EOR</td>
<td>CO₂-EOR Inc. Storage</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>CO₂ Storage (million metric tons)</td>
<td>32</td>
<td>76</td>
<td>33</td>
<td>109</td>
</tr>
<tr>
<td>Storage Capacity Utilization</td>
<td>22%</td>
<td>53%</td>
<td>23%</td>
<td>76%</td>
</tr>
<tr>
<td>Oil Recovery (million barrels)</td>
<td>92</td>
<td>180</td>
<td>-</td>
<td>180</td>
</tr>
<tr>
<td>% Carbon Neutral*</td>
<td>74%</td>
<td>90%</td>
<td>-</td>
<td>129%</td>
</tr>
</tbody>
</table>

*Includes the entire life-cycle CO₂ emissions, including those associated with CO₂-EOR operations, crude transport, refining, and the combustion of the incremental oil produced.
Costs of CCS Technology Will Only Decline From “Learning While Doing”
Potential Barriers to Lower Cost, Publicly Acceptable CO\textsubscript{2} Supplies for CO\textsubscript{2}-EOR

- Limitations of today’s CO\textsubscript{2}-EOR technology
- Increased operator knowledge, comfort with, and willingness to pursue CO\textsubscript{2}-EOR
  - Reducing the uncertainty of CO\textsubscript{2}-EOR economics
- Achieving both requires research on and demonstration of “next generation” CO\textsubscript{2}-EOR technologies
  - As well as possible financial incentives to promote CO\textsubscript{2} supplies for CO\textsubscript{2}-EOR
- Willingness/ability of regulators to permit/encourage CO\textsubscript{2}-EOR and associated CO\textsubscript{2} storage
Overcoming Regulatory Barriers to Supplying CO₂ for CO₂-EOR

- Defining and establishing ownership of subsurface pore space
- Establishing clear regulations for the long-term liability for CO₂ stored with CO₂-EOR
- Clarifying the relationship between CCS and CO₂-EOR regulations
  - Consistency between power plant GHG NSPS, UIC rules, and GHG emission reporting rules
  - Consistency between State & Federal requirements
  - Clear requirements for transition from Class II (EOR) to Class VI regulatory requirements
  - Recognize “incidental” CO₂ storage with CO₂-EOR