Sixth Annual Conference on Carbon Capture & Sequestration

Coupling Enhanced Oil Recovery with the Demand for CCS - - A Viable Interim Solution for Power Generating Facilities

CO2-EOR and Technology Progress: The Smart Pathway for Making CCS Affordable in the Near Term

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Introduction

Some have argued against addressing climate change and global warming in any significant way because doing so would - -

"impose large economic burdens on the U.S. economy".

George C. Marshall Institute
February 2, 2007

This presentation examines one set of coordinated actions that could dramatically reduce, or even eliminate a portion of this "large economic burden".

Two Key Sectors

This presentation examines two sectors of the U.S. economy at the center of the global warming debate:

- *Coal-fired power generation*
- *Domestic oil production*

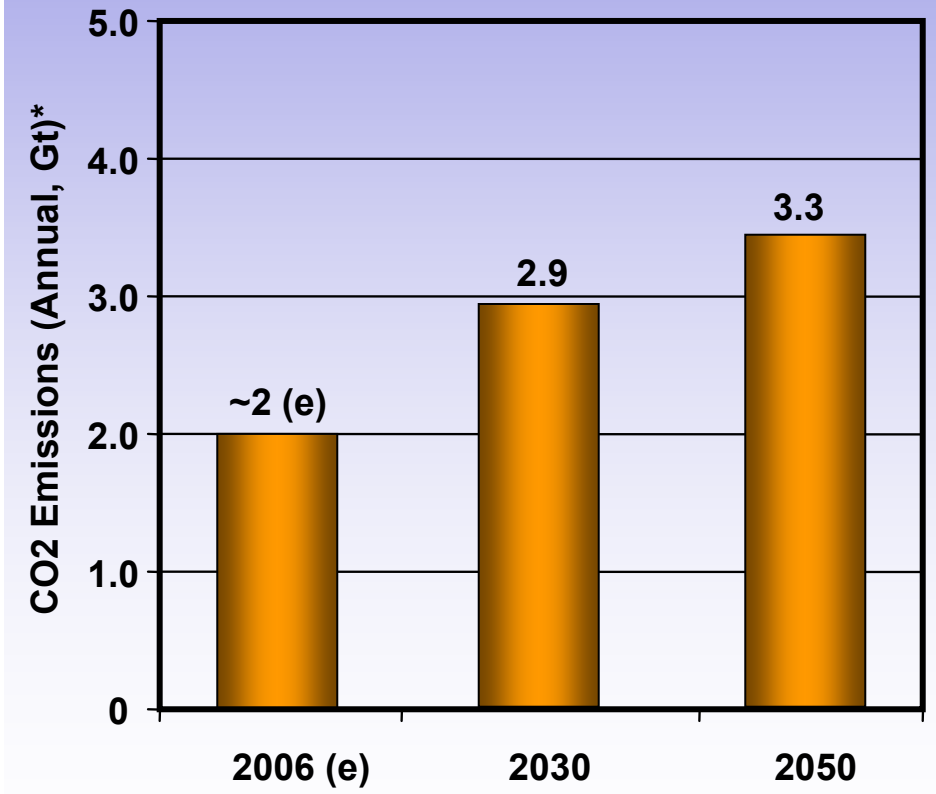
These are two sectors that lend themselves to using or benefiting from CO_2 capture and storage (CCS) for reducing CO_2 emissions.

- *Coal-fired power plants w/CCS can capture 90% of CO2 emissions otherwise emitted to the atmosphere*
- *CO2 enhanced oil recovery can provide significant volumes of incremental domestic oil production*

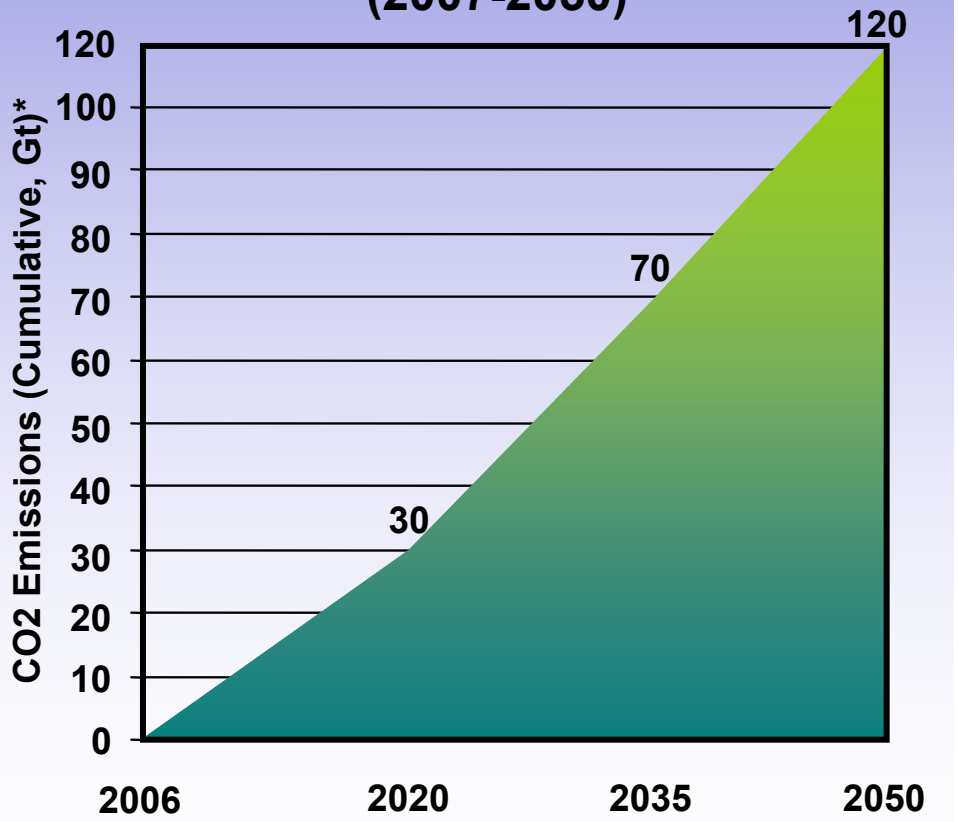
Background

CO2 emissions from U.S. coal-fired power plants are expected to increase significantly (EIA Reference Case).

Annual CO2 Emissions from Coal (2006-2050)



Cumulative CO2 Emissions From Coal (2007-2050)



*1 Gt (gigatonne) = 1 billion metric tons (in 2005, the U.S. emitted a total of 6 Gt of CO2).

Source: EIA/AEO 2007 and CarBen 2007.

Background

The EIA has examined a variety of legislative proposals that would significantly reduce CO2 emissions in the power sector:

1. Assessment of Proposed Cap and Trade Legislation (March, 2006)[1]
2. Assessment of Proposed Cap and Trade Legislation (January, 2007)[2]
3. Assessment of Clean Fuel Energy Portfolio Standard (February, 2007)[3]

A common feature of these EIA studies is that CCS is not part of the solution, except in one extreme cap and trade case.

The reason according to the EIA, is that using CCS with coal- or gas-fired power is not economically competitive with other options for reducing CO2 emissions in the power sector.

(1) Energy Market and Economic Impacts of a Proposal to Reduce Greenhouse Gas Intensity with a Cap and Trade Systems, U.S. DOE, Energy Information Administration, January, 2007.
(2) Energy Market Impacts of Alternative Greenhouse Gas Intensity Reduction Goals, U.S. DOE, Energy Information Administration, March, 2006.
(3) Energy Market Impacts of a Clean Energy Portfolio Standard - Follow-up, U.S. DOE, Energy Information Administration, February, 2007.

How Will Texas Replace TXU's Cancellation Of 8 Traditional Super Critical Coal-fired Power Plants?

The decision of how Texas will replace its cancelled 6 GW (10% capacity) of traditional coal-fired power is important:

- Size of the state's economy
- Role as a national trendsetter

Based on public announcements, the options being considered are:

1. Significantly increasing renewables
2. Considering new nuclear plants
3. Increasing the use of natural gas
4. Examining IGCC with CO2-EOR

Essential Question

What will it take to make CCS affordable and a major part of the solution?

Question #1:

How much domestic coal-fired power generation capacity (GW) will need to be equipped with CCS?

The Stern Report: ***"The global power sector will have to be at least 60% de-carbonized by 2050 to stabilize greenhouse gases."***

CarBen's "Atmospheric Stabilization Case" (550 ppm) for U.S. Electric Power Sector (Year 2050):

- CO2 Emissions of < 1 Gt (70+% de-carbonized)
- Increased efficiency, no/low carbon fuels, and capital stock turnover
- 275 GW of coal-fired power w/CCS

*Source: DiPietro, J.P., Kuuskraa, V.A., and Forbes, S., "Examining Technology Scenarios for Achieving Atmospheric Stabilization of GHG Concentrations: A U.S. Pathway" presented at 8th International Conference on Greenhouse Gas Technologies (GHGT-8), 19th-22nd June 2006, Trondheim, Norway (Updated to 2007).

Two Pathways To Atmospheric Stabilization: U.S. Electric Power Sector

Two pathways for reaching the atmospheric stabilization goal for U.S electric power of **less than 1 Gt of CO2 emissions in 2050.**

- ***Hard Pathway:***
  - High CO2 and electricity prices ($50/mt and 7.5¢/kWh)
  - Late introduction of high cost CCS
  - High nuclear (250 GW) replacing coal (200 GW)

- ***Smart Pathway:***
  - Moderate CO2 and electricity prices ($15/mt and 6.2¢/kWh)
  - Early introduction of affordable CCS
  - Moderate nuclear (150 GW) as complement to coal (350 GW)

Both pathways entail significant increases in efficiency and non-hydro renewables.

Taking The Right Pathway

The Smart and Hard Pathways represent a near-term "fork in the road".

- ***Power plants*** are long life, "locked-in" assets. If we wait on investing in CCS and efficiency technologies, we will be stuck with low efficiency, high costs plants and technology with which to address CO2 emissions.
- ***Oil fields*** and ***CO2-EOR*** can similarly be "locked-in" to either an old recovery technology/low CO2 storage option or be developed to maximize oil recovery and storage capacity.

Question #2: *Are significant cost reductions in CCS technology achievable, if we use time and investments wisely?*

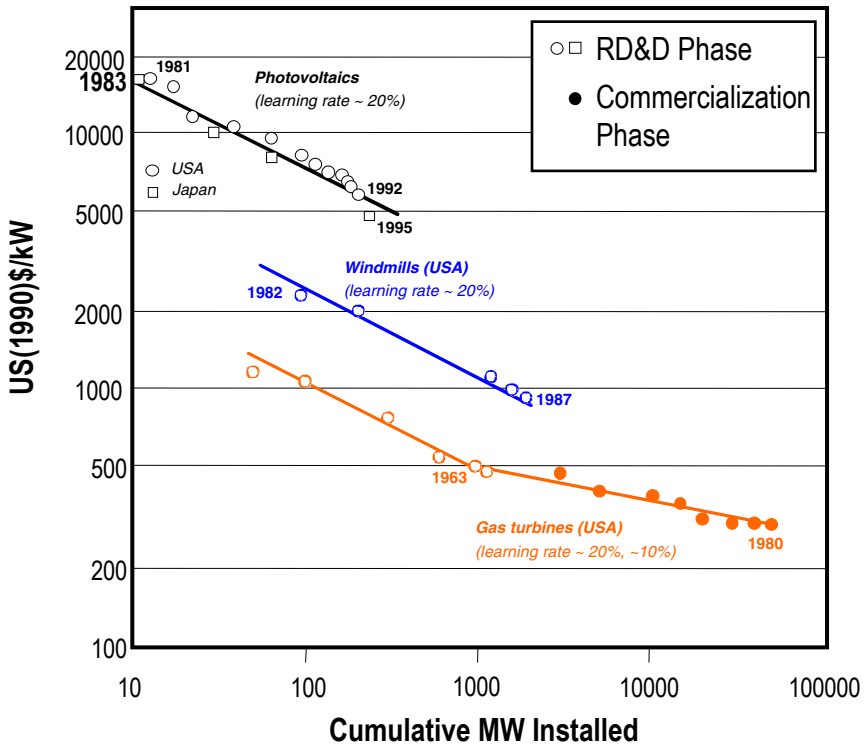
Today's costs of CCS are high ($35 to $40/mt) and uncompetitive with other CO2 reduction options for the power industry.

- ***U.S. Gas Turbine Experience.*** Significant "learning-based" cost savings have occurred for gas turbines and other new energy technologies:
  - 20% cost reduction for every doubling of installed capacity during the RD&D Phase
  - 10% additional cost reduction for every subsequent doubling of installed capacity during the Commercialization Phase.
- ***CO_2 Capture Project.*** Goal is to reduce the costs of CO_2 capture by at least 50%.
- ***EIA NEMS Electricity Market Module**.* The "technology learning" function for CCS in EIA's National Energy Modeling System is consistent with the U.S. gas turbine experience and is used in this analysis.

*U.S. Department of Energy, Energy Information Administration, "Assumptions to the Annual Energy Outlook 2006" Report # DOE/EIA-0445(2006), March 2006

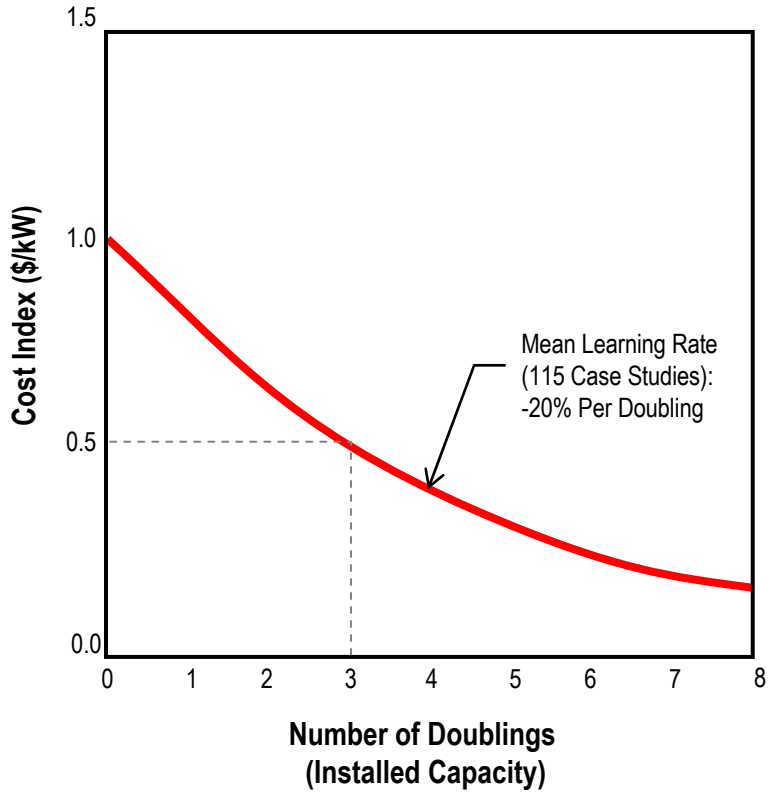
Costs of New CCS Technology Will Decline Due to "Learning"

Learning Curves for Energy Technologies



Source: Nakicenovic, N., Grubler, A., and MacDonald, A., "Global Energy Perspectives", ISBN-10: 0521645697, Cambridge University Press (1998).

Historical Cost Reductions Rates from Learning Curves



Modified from Nakicenovic (1998).

Question #3:

How much might integration of CCS with CO_2–EOR reduce costs and facilitate early action?

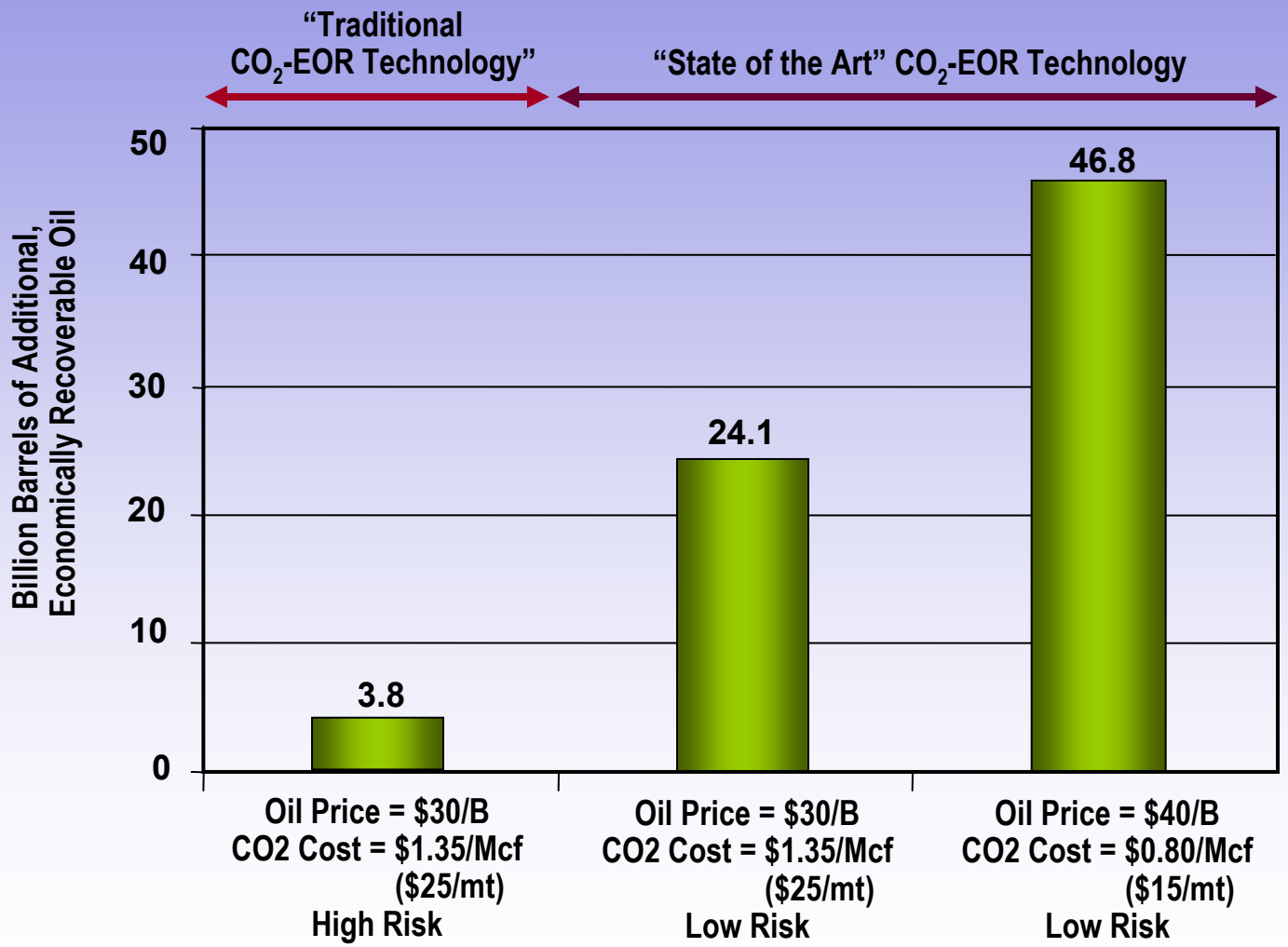
- ***Productive Use of CO2 is Already Underway.*** CO_2-EOR already uses 40 million metric tons of CO_2 per year, with 10 million metric tons of this from industrial sources.
- ***The U.S. has Numerous Mature Domestic Fields Holding 400 Billion Barrels of "Stranded" Oil In-Place***. CO_2-EOR could economically recover 24 to 47 billion barrels, depending on oil prices and availability of CO_2.[1] "Next Generation" CO2-EOR technology would significantly increase these oil volumes.[2]
- ***Sufficient CO_2 Supply is a Major Constraint.*** CO_2-EOR could readily use 8 to 12 billion metric tons of affordable, "EOR-Ready" CO_2.

* Source:

[1] Advanced Resources International, Ten Basin-Oriented CO2-EOR Assessments Examine Strategies for Increasing Domestic Oil Production, Alaska, California, Onshore Gulf Coast, Mid-Continent, Illinois and Michigan, Permian Basin, Rocky Mountains, East and Central Texas, Offshore Louisiana, and Williston Basin, February 2006, U.S. Department of Energy, Office of Fossil Energy. http://www.fe.doe.gov/programs/oilgas/eor/Ten_Basin-Oriented_CO2-EOR_Assessments.html

[2] Advanced Resources International, Evaluating the Potential for "Game Changer" Improvements in Oil Recovery Efficiency from CO2 Enhanced Oil Recovery, U.S. Department of Energy, Office of Oil and Natural Gas, Office of Fossil Energy, August 2005. http://www.fe.doe.gov/programs/oilgas/eor/Game_Changer_Oil_Recovery_Efficiency.html

A Large Market For CO_2 Is Offered By Enhanced Oil Recovery



Source: Advanced Resources International (2006)

Combining the Benefits: A "Win-Win" Solution for Affordable CCS

Coal-Fired Power Sector (2020-2050)

Develop Lower Cost, Publicly Accepted CCS Technology

- 30+ Commercial-Size Demos of CO2 Capture Plus RD&D Investment
- Numerous Large-Scale Demos of CO2 Storage Options

Sell Captured CO_2 for Oil Recovery

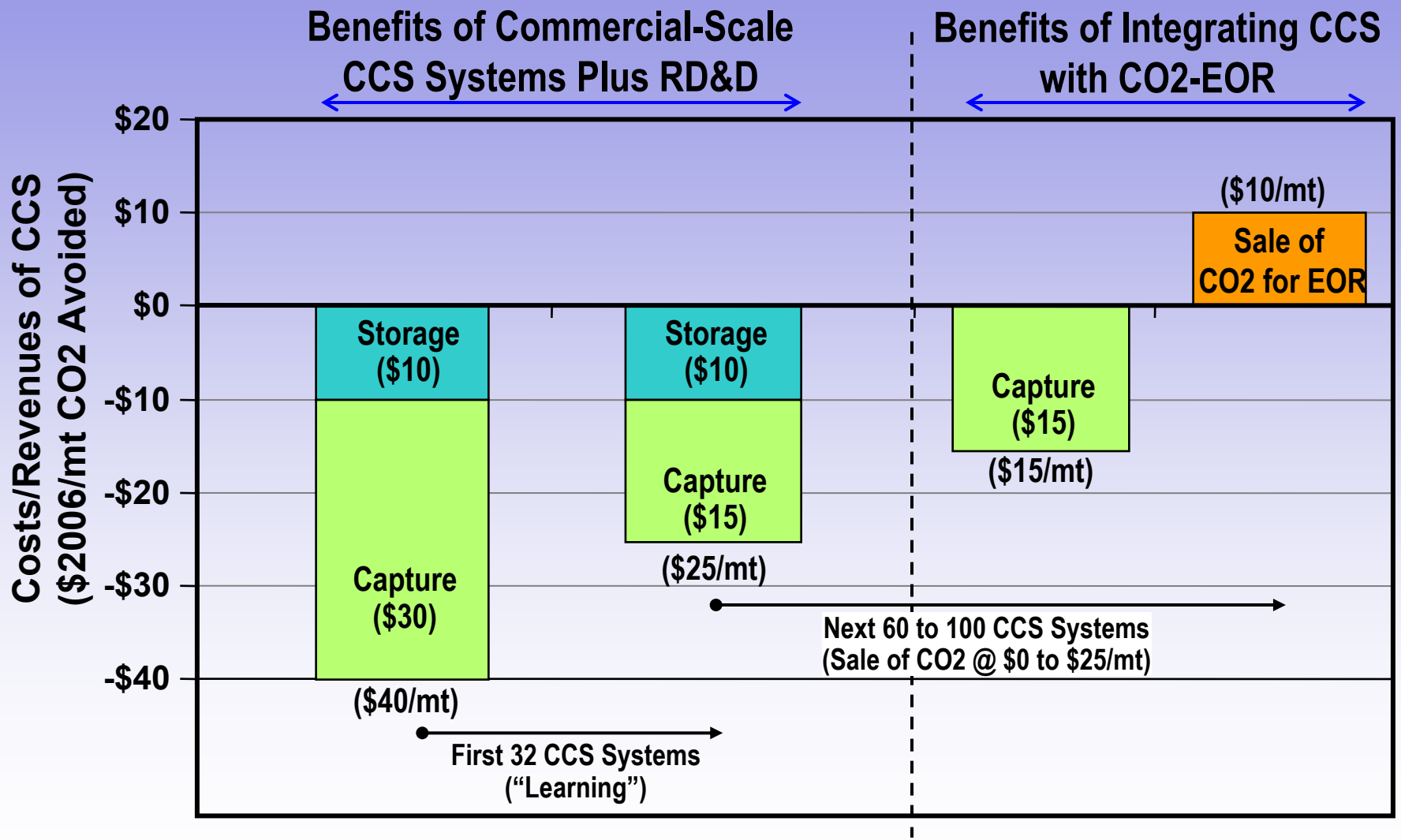
- 8 to 12 Gt of CO2 for CO2-EOR
- Avoid Cost of Storage ($10/mt CO2)
- Gain Additional Revenues ($300 billion @ $25/mt for CO2)

U.S. Petroleum Sector (2020-2050)

Purchase CO_2 for CO2-EOR

- Purchase 8 to 12 Gt of CO_2 (@ price of $0 to $25/mt)
- Produce an Extra 40 Billion Barrels of Domestic Oil
- Provide up to $300 Billion for Captured CO2 Emissions

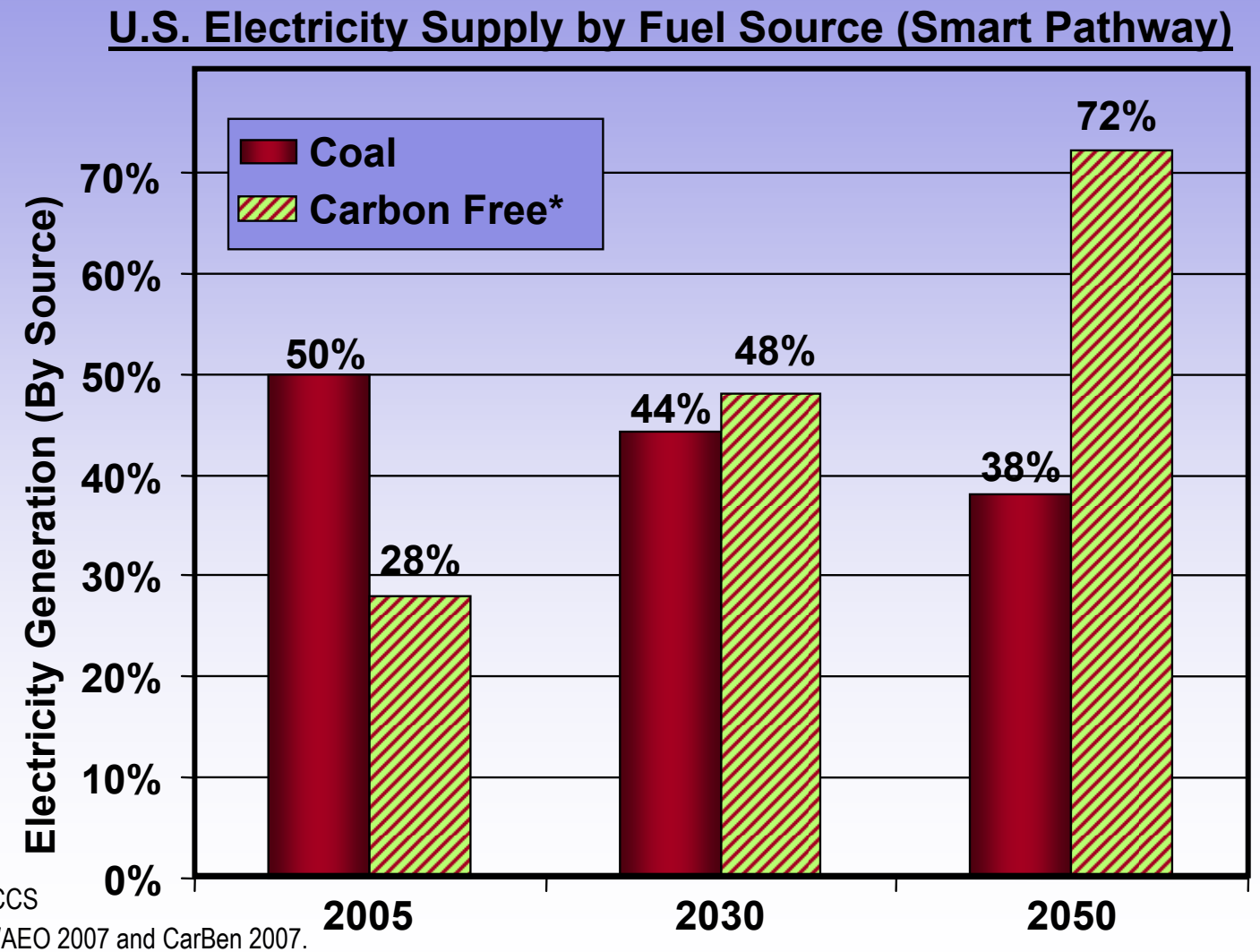
"Learning By Doing" And CO2-EOR Can Make CCS "Affordable": SCPC Example*



*Based on *Feasibility Study for an Integrated Gasification Combined Cycle Facility at a Texas Site.* EPRI, Palo Alto, CA: 2006. 1014510.

"Smart Pathway" For Coal-fired Power Generation

In the "Smart Pathway" and with CCS, the U.S. electric power sector becomes greater than 70% de-carbonized.



*Renewables
*Nuclear
*Coal/NG w/CCS

Source: EIA/AEO 2007 and CarBen 2007.

Three Key Issues

1. ***How to stimulate carbon management responses in the electric power sector?***
   - Create value for reducing carbon emissions
2. ***How to achieve the deep cost reduction for CCS technology?***
   - Launch 30+ commercial-scale (400 MW, net output w/CCS) deployments of CCS for deep "learning-based" cost reductions
   - Assure a robust foundation of RD&D that links field experience with scientific advances
   - Pursue synergies between CCS and improved power plant efficiency
3. ***How to make integration of CCS and CO_2-EOR attractive to industry?***
   - Initiate "advanced technology" CO2-EOR field projects that provide a step-change in CO2 storage capacity
   - Provide a robust foundation of RD&D on integrated CO2-EOR and storage, particularly on monitoring and diagnostic technology.

Final Question:

Is production of domestic oil "more valuable" than using imported oil?

Producing 40 billion barrels of otherwise unrecoverable domestic oil with CO2-EOR offers benefits beyond just a market for captured CO2:

- Improved domestic energy security and somewhat lower world oil prices,
- An improved trade balance of $2 trillion, and
- Additional revenues to states for funding education (other services) of $160 billion (from production taxes and royalties), plus $340 billion to state/Federal treasury from income taxes.

But, this is another story for another day and for another audience.

Closing Comments

The combination of "technology learning" for CO_2 capture and sale of CO_2 to enhanced oil recovery can make CCS "affordable" in the near-term:

1. Sponsor 30+ commercial-scale demonstrations of CO2 capture to reduce costs by 50%.
2. Create "value" for reducing CO2 emissions.
3. Assure a robust program of RD&D in both CO2 capture and storage.
4. Expand the market for using power plant CO2 for domestic oil recovery
    - Incentives plus robust RD&D
    - "Next generation" CO2-EOR technology

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