CO_2 Capture and EOR: Can Both Be Profitable Together

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Agenda

- **Present Situation**
- **Carbon Capture Utilization and Storage Challenge**
- **Where the Economics Don't Work**
- **Where the Economics Do Work**
- **Conclusions**

CCUS is Happening Now

- CO_2 flooding began with anthropogenic sources
- Val Verde Basin, Enid Fertilizer Plant, La Barge, Dakota Gasification Plant
- No power plants

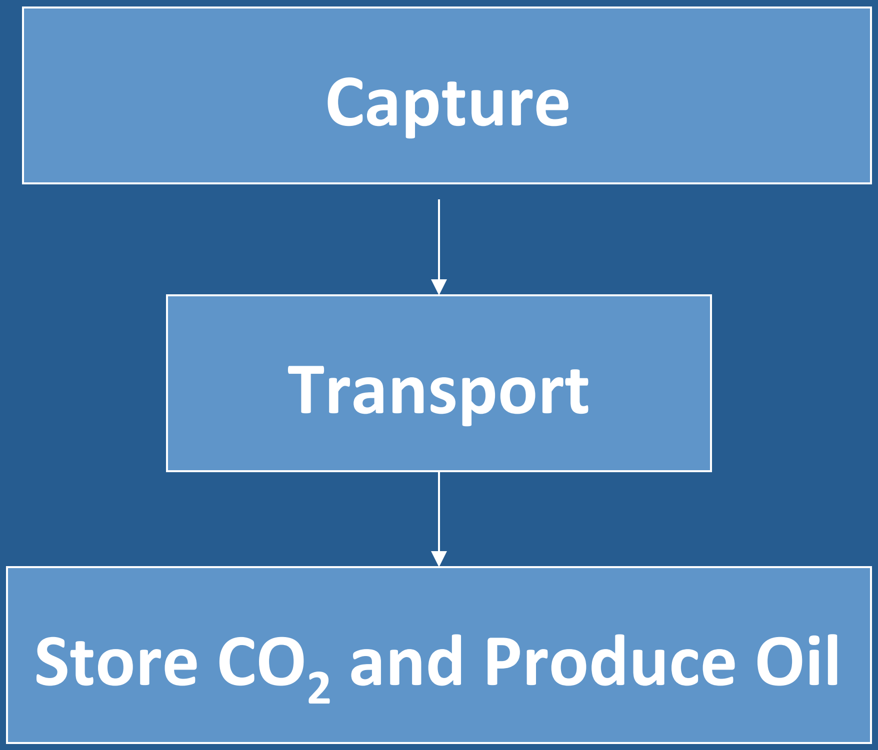
U.S. Pipeline Systems

Source: Kinder Morgan

50 Million TPY (1% US Emission)

Mostly Non-Anthropogenic

CCUS



To capture CO_2, transport it to an oil field, use it for EOR, securely store it

The CCUS Challenge

To capture CO_2, transport it to an oil field, use it for EOR, securely store it <u>and do so at a profit.</u>

Kemper Project


THE WALL STREET JOURNAL. BUSINESS

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BUSINESS

Mississippi Plant Shows the Cost of 'Clean Coal'

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By REBECCA SMITH and CAMERON MCWHIRTER CONNECT

Oct. 13, 2013 7:23 p.m. ET

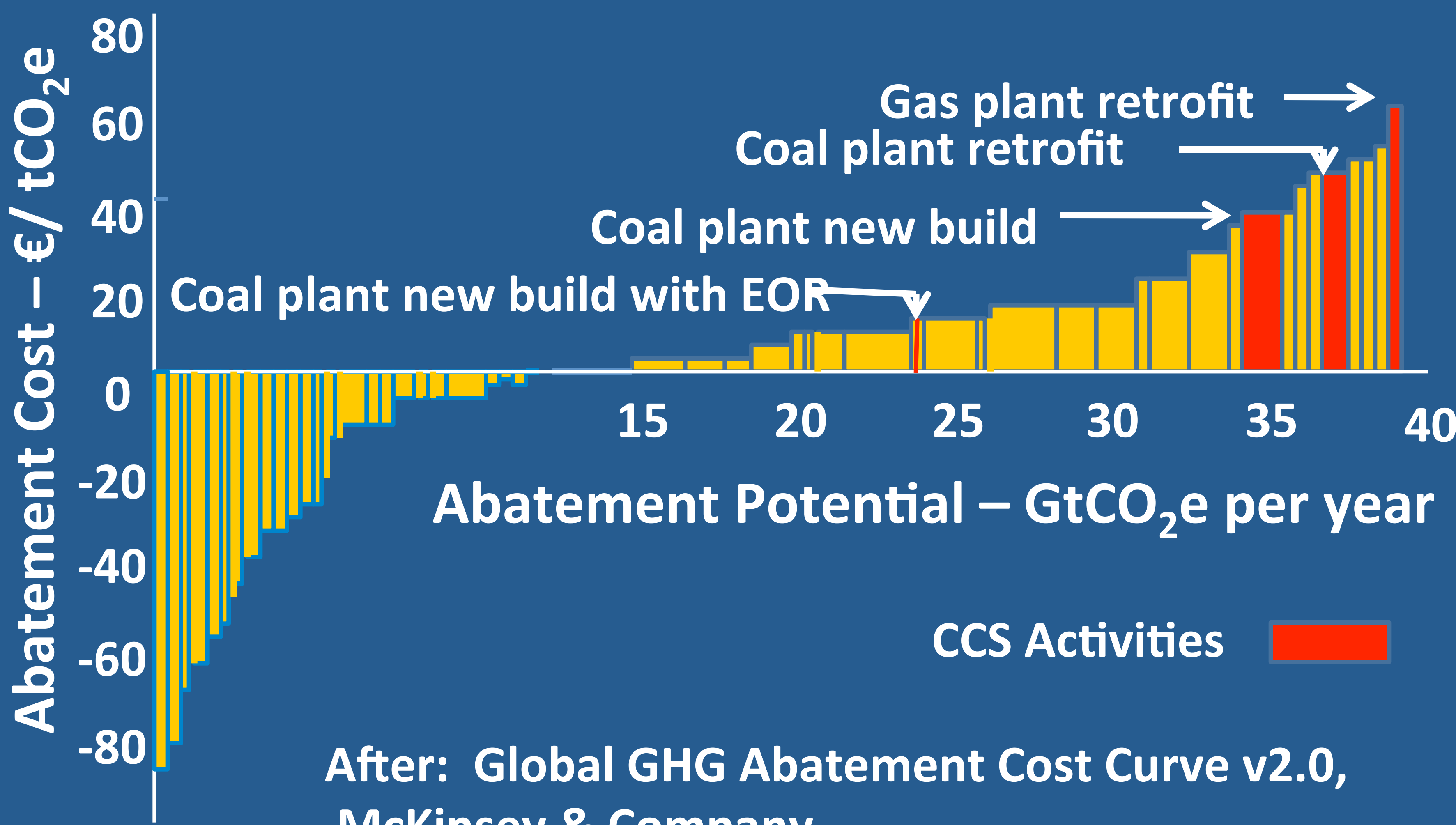
DE KALB, Miss.—For decades, the federal government has touted a bright future for nonpolluting power plants fueled by coal. But in this rural corner of eastern Mississippi, the reality of so-called clean coal isn't pretty.

Mississippi Power Co.'s Kemper County plant here, meant to showcase technology for generating clean electricity from low-quality coal, ranks as one of the most-expensive U.S. fossil-fuel projects ever—at $4.7 billion and rising. Mississippi Power's 186,000 customers, who live in one of the poorest regions of the country, are reeling at double-digit rate increases. And even Mississippi Power's parent, Atlanta-based Southern Co. SO +1.35% , has said Kemper shouldn't be used as a nationwide model.

- “one of the most-expensive”
- “$4.7 billion and rising”
- “scaring people away”
- “calamity”

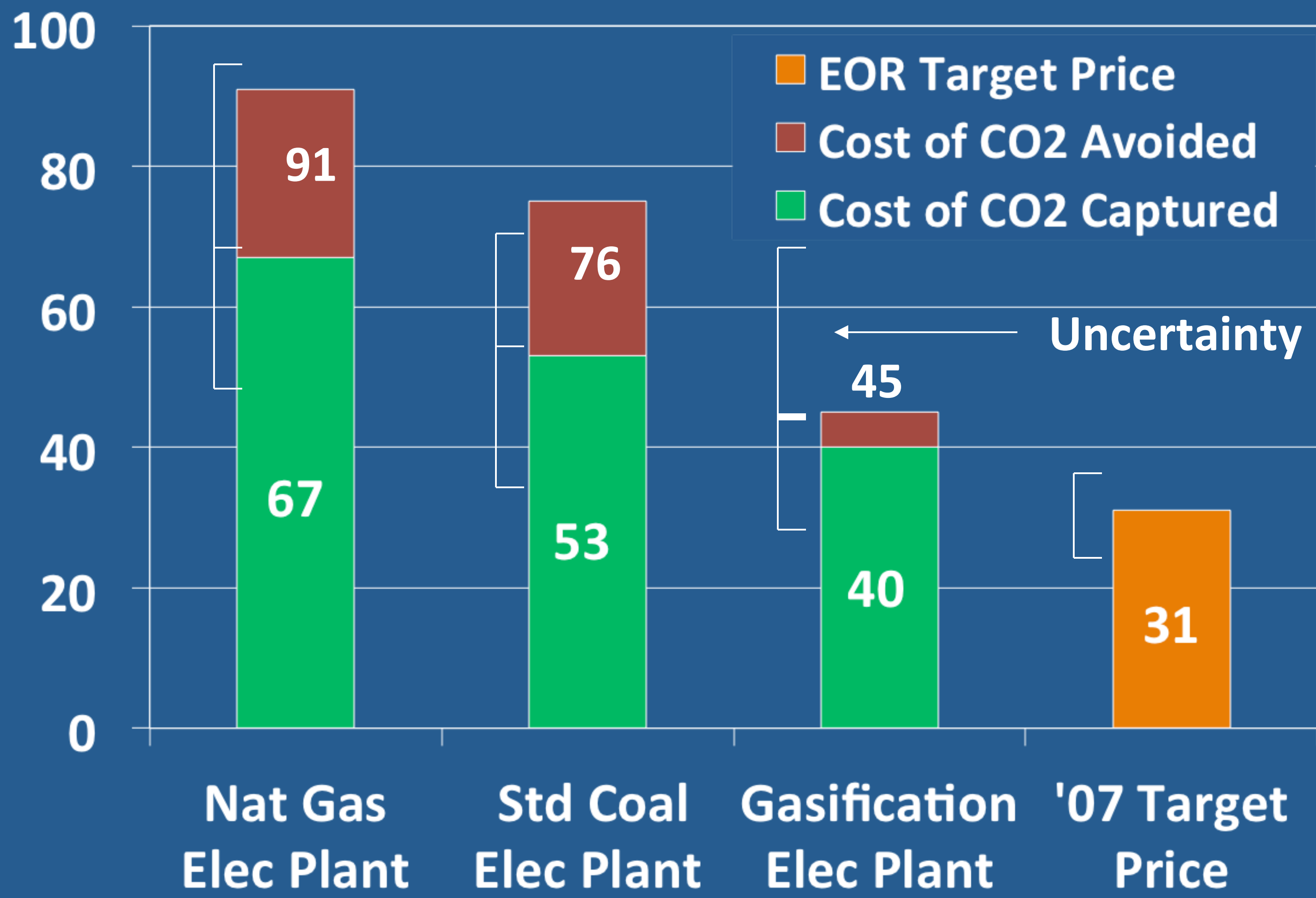
Source: WSJ, Oct 13, 2013

CCUS Often Has Unfavorable Economics



After: Global GHG Abatement Cost Curve v2.0, McKinsey & Company

2007 CO_2 Mitigation Costs ($/tonne)



Sources: NETL, IPCC, Personal Knowledge

When Do the Economics Work?

Example Project

- 50 MMCFD
- 90 miles
- Vented Pure CO_2 (wet)
- Oil field needs CO_2 for 10 years (182.5 BCF)
- Oil field needs CO_2 at a price <= 2% of oil price

1 tonne CO_2 ~ 19.3 MCF CO_2

50 MMCFD ~ 946,000 TPY

Dehydration and Compression Cost Equations

- Plant capital = \$3,000 (HP)
- Plant operating costs (excl. power) = \$0.08/MCF
- Plant Power Cost/Day =

$$0.75 \, (HP/1000) \, (24) \, (\$/MW\text{-}hr)$$

CO_2 Dehydration Equipment
Colorado, U.S.A.
Source: Kinder Morgan

Power Price Equation

- **Power Price = Wires + (Heat Rate) (Gas Price) + Adder**

\$/MW-hr = \$10 + 8 (\$/MMBTU gas price) + \$10

Assume natural gas price = \$4/MMBTU

Power Price = 10 + (8) (4) + 10 = \$52/MW-hr

Currant Creek Power Plant
Source: Wikipedia

Horsepower Calculation

- HP = 22 (Rs) (s) (Q) (F)

Assume: Ps = 0 PSIG (15 PSIA)

Pd = 2200 PSIG (2215 PSIA)

s = no. stages = 5 (5 Stage unit)

Rs = comp ratio/stage < 3.0 to 4.0

Rs = (2215/15) ^ (1/5) = 2.7

Q = 50 MMCFD

F = 1 for s = 1; 1.07 for s = 2; 1.1 for s > 2

- HP = 22 (2.7) (5) (50) (1.1) = 16,300 HP

Dehydration and Compression Cost Calculation

- Plant Cost = $48.9 million
- Equivalent Uniform Annual Cost (15%) = $9.7 Million
- Unit Capital Cost = $0.53/MCF
- Plant Operating Cost = $0.08/MCF
- Plant Power Cost/Day = $15,300
- Plant Power Cost /MCF = $0.31/MCF
- Total Cost = 0.53 + 0.08 + 0.31 = $0.92/MCF

Transportation Costs

- Pipeline Cost = \$50,000 / in-mile
- 10 inch pipe needed for the 90 mile pipeline
- Cost = (90) (10) (\$50,000) = \$45 million
- Equivalent Uniform Annual Cost (15%) = \$8.9 million
- Pipeline Tariff = \$0.49/MCF

Katz CO_2 Pipeline
Source: Kinder Morgan

Delivered Price vs. Maximum Price

- **Dehydration and Compression Cost = $0.92/MCF**
- **Pipeline Tariff = $0.49/MCF**
- **Delivered Price (at 15%) = $1.41/MCF**

  (at 20%) = $1.62/MCF

- **Maximum CO_2 price is about 2% of oil price**

  1.35/0.02 = $71 per barrel

  1.55/0.02 = $81 per barrel

- **<u>Therefore CCUS is economically feasible</u>**

Sources of Pure CO_2

- Fertilizer Plants
- Natural Gas/CO_2 Separation Plants
- Coal Gasification Plants (not economic to build)
- IGCC Plants (not economic to build)
- Underground CO_2 Source Fields

CO_2 Compressor

Source: Kinder Morgan

Conclusions

- Capture at pulverized coal power plants is too expensive to combine with EOR
- Capture at coal gasification plants including IGCC plants is economically attractive if the plant is already built
- Capture of pure CO_2 is economically attractive depending on the location