

Rethinking CCS

Moving Forward in Times of Uncertainty

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Not So Flattering Assessments of CCS

- *“The past five years have shown CCS to be a failure,” said Christian von Hirschhausen, DIW’s [German Institute for Economic Research] research director for industrial economics.*
 - From: <http://www.dw.de/carbon-capture-technology-loses-out-in-germany/a-16999567>
- *The technology is currently mired in an existential crisis that cannot be explained purely by technoeconomic arguments.*
 - From: Heleen de Coninck, *Climate Policy*, Vol. 13, No. 4, 530–532

CCS and Climate Policy

- Of all the major mitigation options, only CCS has climate change mitigation as it's sole reason for being developed.
- As goes climate policy, so goes CCS
 - *The past five years have shown climate policy to be a failure*
 - *Climate policy is currently mired in an existential crisis*

Outline

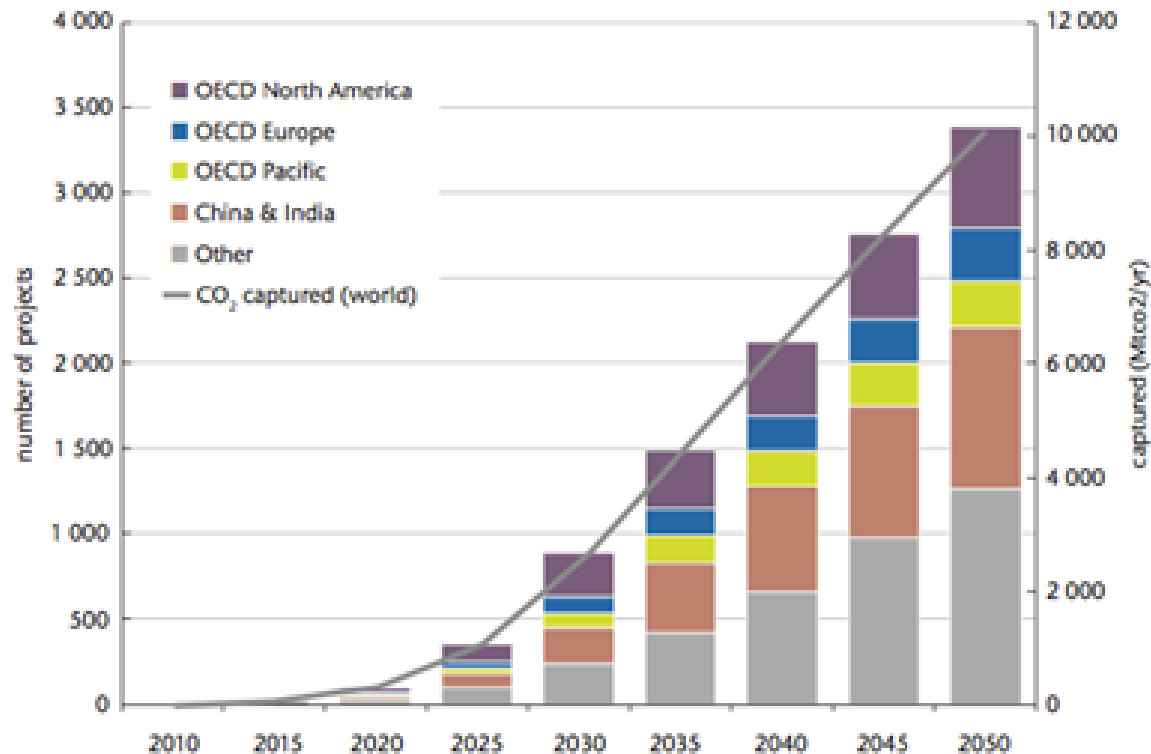
- The New Reality
- What is Happening in the US?
- Rethinking CCS

Most CCS Roadmaps are Obsolete

The Vision

- Over the next 10 years, there will be about 20 large-scale CCS demonstrations worldwide
- CCS commercial projects will be feasible by 2020 and we will see 100s of commercial CCS projects built by 2050
- R&D will develop new generations of CCS technologies and CCS costs will drop significantly

IEA CCS roadmap (2009)



Most CCS Roadmaps are Obsolete

The Reality

- Large-scale CCS demonstrations are extremely difficult to build and we are seeing many cancellations worldwide. There are still no large-scale CCS demonstrations at power plants (two are under construction).
- CCS will not be commercial by 2020 – the cost will be higher than the market can bear
- New generation technologies are still in the lab. Cost reductions will be primarily from removing first mover costs.

All CCS Roadmaps are Obsolete

The Reasons

- Primary Reason
 - Weak or non-existent climate policy
- Contributing factors
 - Weak economic growth, budget deficits
 - Low natural gas prices
 - Escalating capital costs

What is Happening in the US?

- Gas vs. Coal
- Demonstration Projects
- CCUS (i.e., EOR)
- Climate Policy

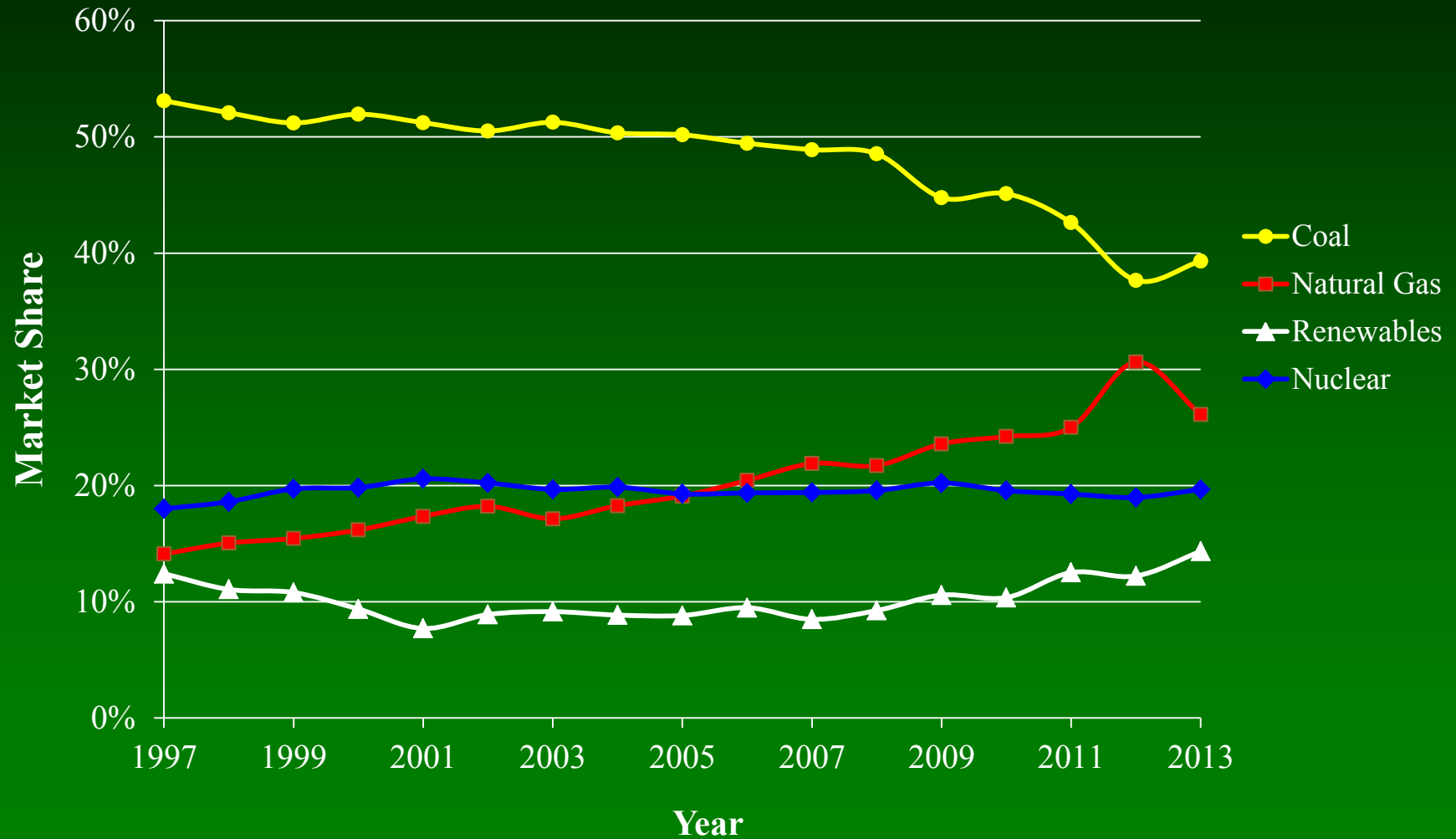
What are Target Sources for CCS?

Source	Share (%)
Coal-Fired Power Plants	60
Other Power Plants (primarily gas)	19
Cement	7
Refineries	6
Iron and Steel	5
Petrochemical	3

Intergovernmental Panel on Climate Change (IPCC)
Special Report on Carbon Dioxide Capture and Storage
(2005)

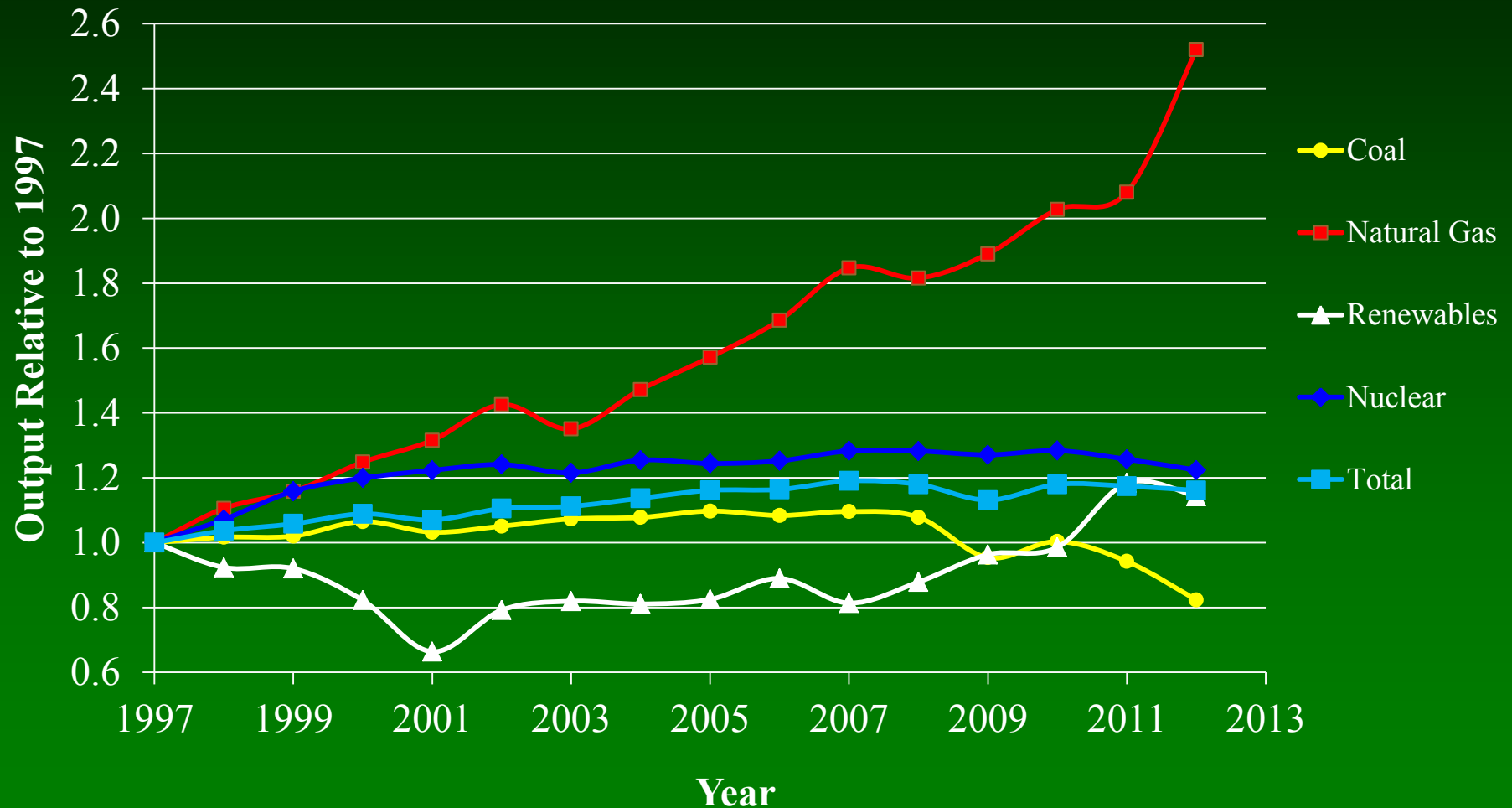
Electricity Generation by Fuel

Market Shares



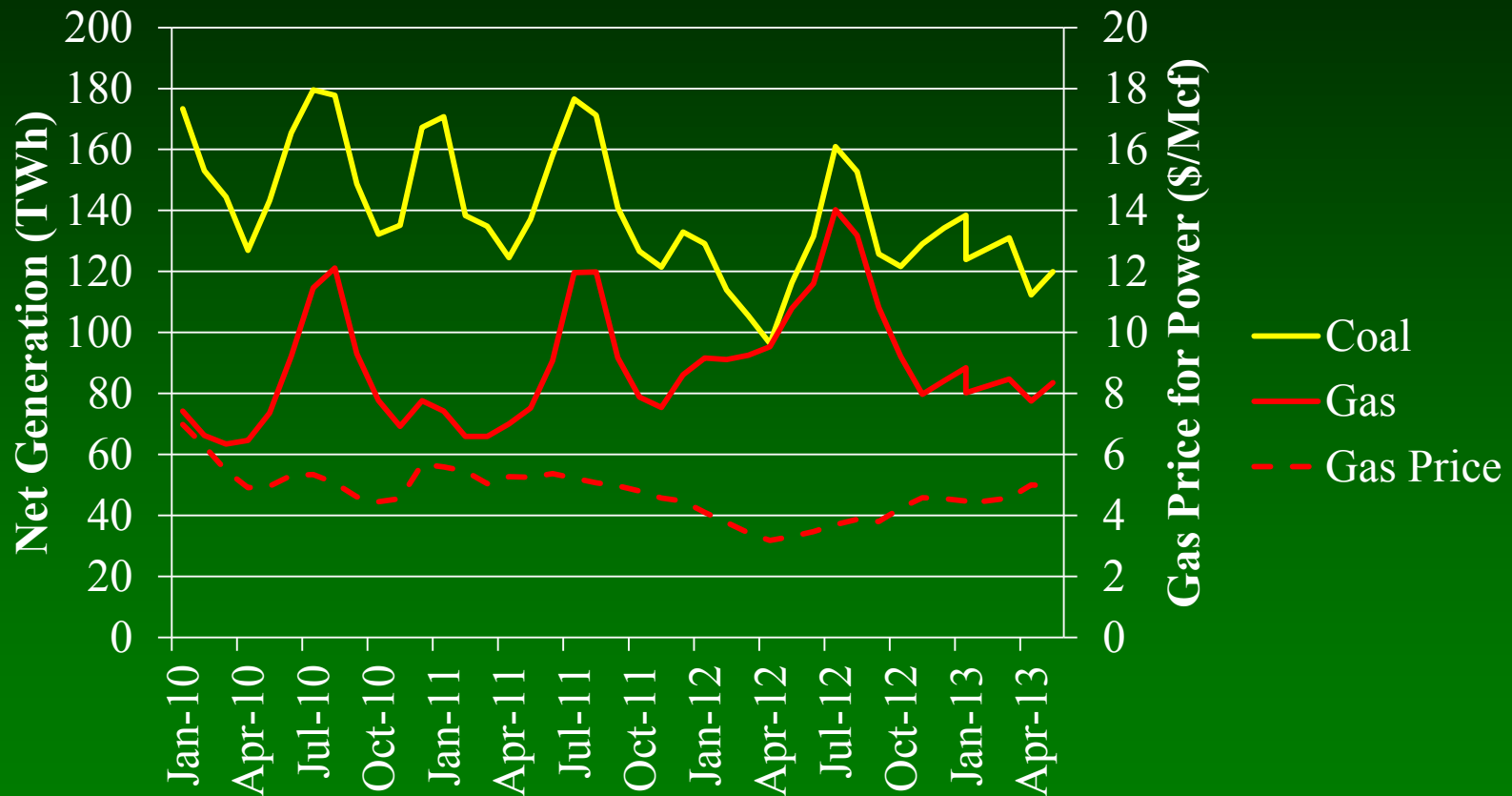
Electricity Generation by Fuel

Output Relative to 1997

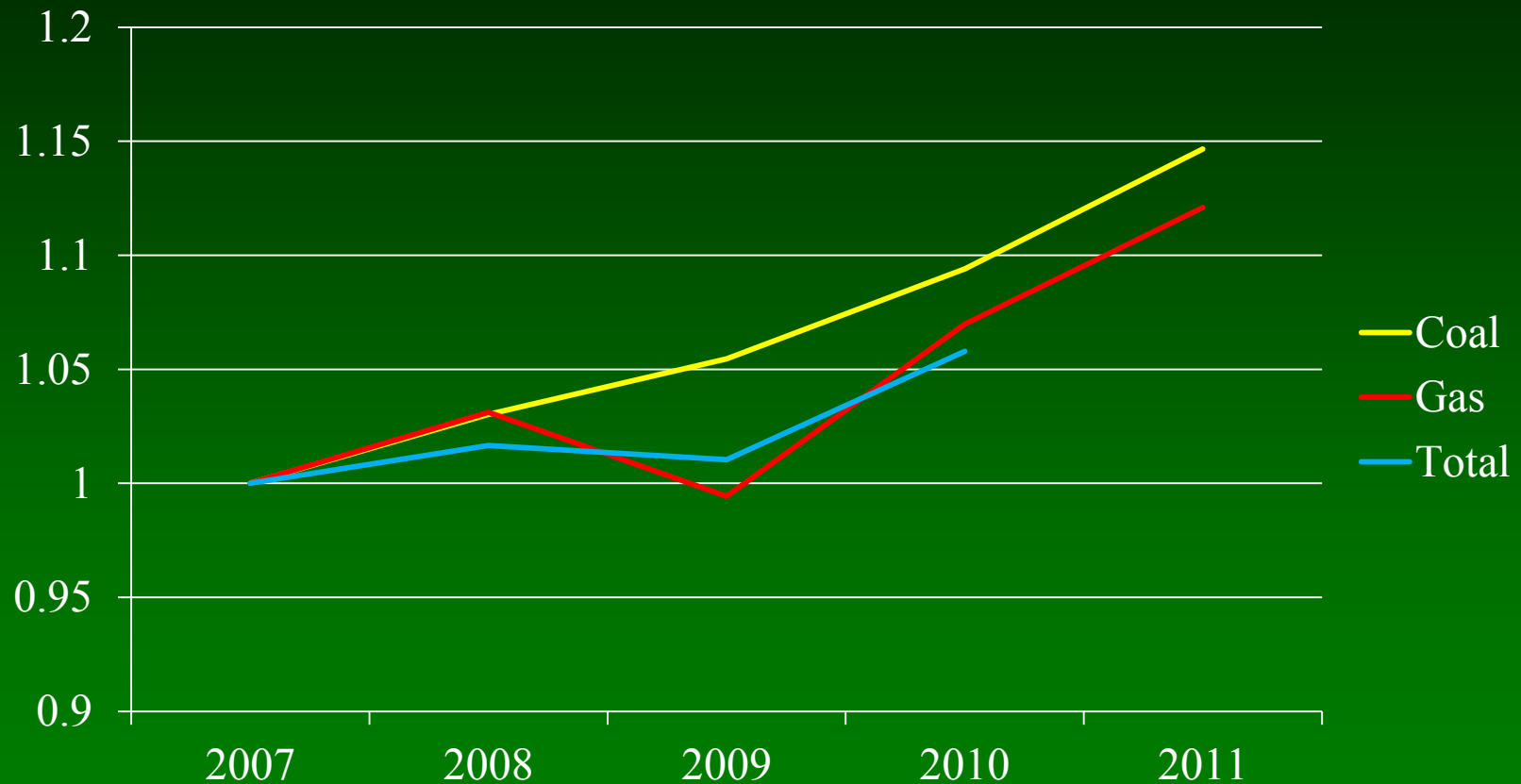


Electricity Generation 2010-present

Coal vs. Gas



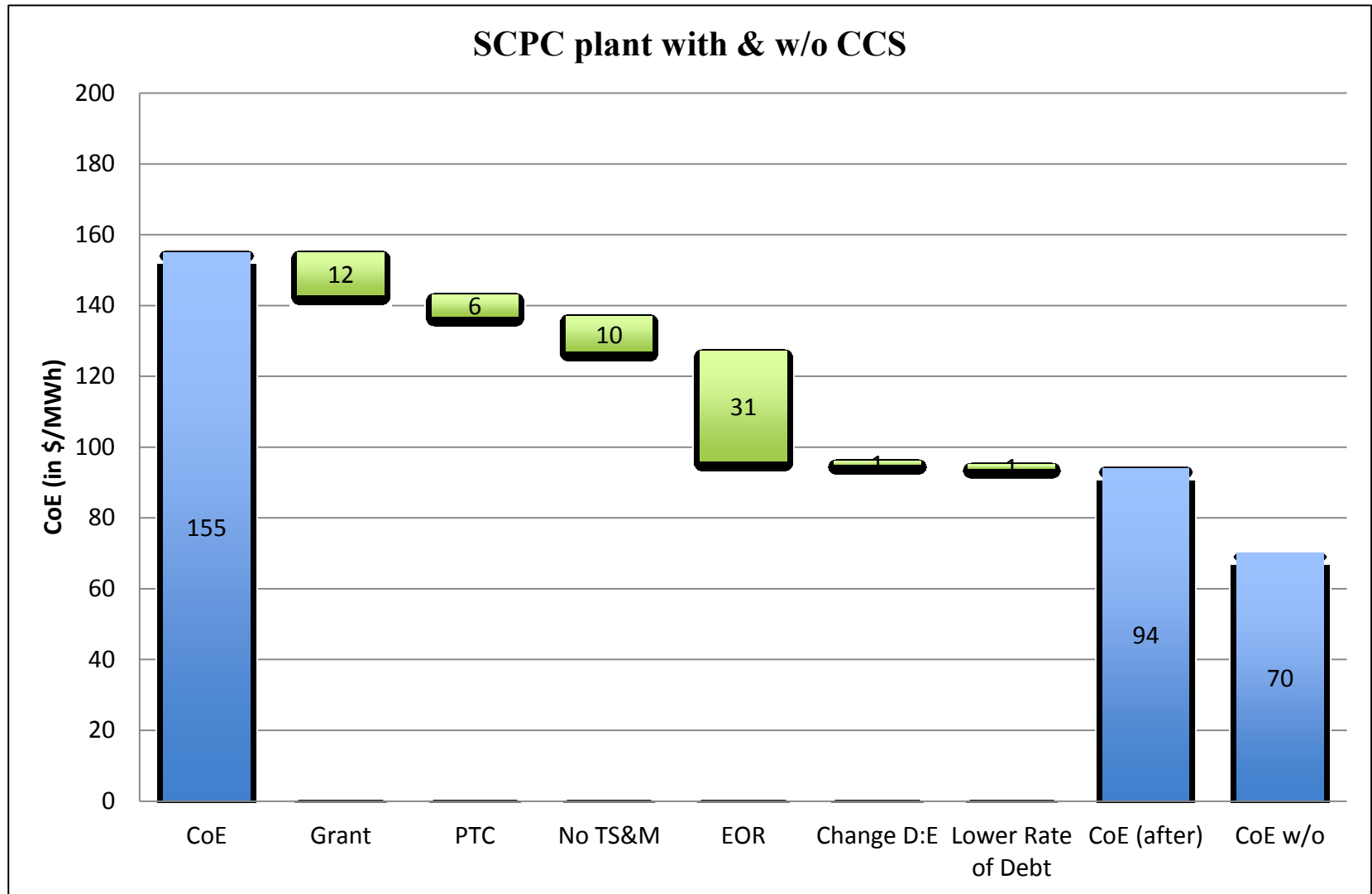
World Energy Consumption Relative to 2007



Paying for CCS Projects

- Markets
 - Carbon markets
 - Electricity markets
 - EOR
 - Others (e.g., polygeneration)
- Incentives (e.g., Government cost-sharing, Tax credits)
 - Encourage early action (before markets develop)
 - Help defray first-mover costs

Project Economics - SCPC



From: Raveendran, S.P., "The Role of CCS as a Mitigation Technology and Challenges to its Commercialization," M.I.T. Masters Thesis, May (2013).

US CCS Power Projects

CCPI and/or Stimulus Funds

Project	Company	Size	Capture	CO ₂ Fate	Notes
TCEP (TX)	Summit Power	400 MW	Pre-C (Linde acid gas)	EOR	Finalizing Finances
Kemper County (MS)	Southern	582 MW	Pre-C (KBR)	EOR	Under Construction
WA Parish (TX)	NRG	240 MW	Post-C (Fluor)	EOR	
HECA (CA)	SCS	400 MW	Pre-C (Fluor)	EOR	Poly-gen
FutureGen 2.0 (IL)	FutureGen Alliance	200MW	Oxyfuel	Saline	Phase 2 - Feb 2013

US CCS Industrial Projects

Stimulus Funds

Project	Company	Size (Mt/yr)	CO ₂ Source	CO ₂ Fate	Start
Decatur (IL)	Arthur Daniels Midland	1	Ethanol Production	Saline	Nov, 2011
Port Arthur (TX)	Air Products	1	Hydrogen Production	EOR	Jan, 2013
Lake Charles (LA)	Leucadia Energy	4.5	Methanol Production	EOR	Est. 2014

CCUS

- CCUS = Carbon Capture, Utilization, and Storage
- Much more emphasis now being placed on finding markets for CCS that are not climate change driven
- Primary form of utilization EOR

CCUS - Rough Costs

- Value of CCS for EOR ~\$20/ton
- Cost of producing CO₂ from a power plant (not avoided cost) ~\$50/ton
- Some CO₂ sources are much lower costs, like gas processing, ammonia production, ethanol plants

Potential Roles for EOR in CCS Development

- Can Do
 - Help project economics (positive value on CO₂)
 - Build out infrastructure
 - Develop capacity along the supply chain
 - Help shape regulatory environment (including liability issue)
- Cannot Do
 - Avoid need for subsidies for capturing CO₂ from coal-fired power plants (and many other industrial sources)
 - » Will new gas turbines (e.g., Net Power) be competitive????
 - Replace climate change as the primary driver for CCS technology

EPA's Carbon Pollution Standards New Power Plants

- March 27, 2012, EPA proposed that new fossil-fuel-fired power plants meet an output-based standard of 1,000 lb CO₂/MWh gross
 - New natural gas combined cycle (NGCC) power plant units should be able to meet the proposed standard without add-on controls
 - New power plants that are designed to use coal or petroleum coke would need to incorporate technology to reduce carbon dioxide emissions to meet the standard, such as carbon capture and storage (CCS)
- EPA has received over 2 million comments on the proposal

From: EPA FACT SHEET: Proposed Carbon Pollution Standard for New Power Plants

EPA's Carbon Pollution Standards Power Plants

- June 25, 2013 - Presidential Memorandum - Power Sector Carbon Pollution Standards
 - <http://www.whitehouse.gov/the-press-office/2013/06/25/presidential-memorandum-power-sector-carbon-pollution-standards>
- New Plants – Issue a new proposal by September 20, 2013
- Existing Plants
 - Rules proposed by June 1, 2014
 - Rules finalized June 1, 2015

EPA's 1000 lb/MWH New Source Performance Standard

At what gas price would you build coal with CCS to meet the emission standard rather than build natural gas combined cycle (NGCC) plants?

NGCC capacity factor	CO ₂ Storage Option	Gas Price (\$/MMBtu)	Range for gas price
0.45+/-0.05	EOR	8.2	4.1-12.5
0.75+/-0.05	EOR	10.1	7.4-13.1
0.75+/-0.05	Saline	13.2	10.5-16.2

Cost assumptions for PC capture plant w/ 52.4% capture, based on NETL (2011) "*Cost and Performance of PC and IGCC Plants for a Range of Carbon Dioxide Capture*":

Capital cost:

CCS plant: Lognormal distribution w/ mean 2875 \$/kW, range [2700,3300]

NGCC plant: Normal distribution w/ mean 892 \$/kW, stdev 25 \$/kW

Fixed operating cost: 80.72 \$/kW

Variable operating cost: 0.0064 \$/kWh

Heat rate: 10,662 Btu/kWh

Cost of capital: 12.4% (Capture plant), 11.6% (NGCC)

Coal price: 2.3 \$/MMBtu

Net capacity: 550 MW

Capacity factor coal plant: Normal distribution w/ mean 0.75, standard deviation 0.05

EOR: CO₂ produced is bought for \$20/ton

Saline: Injection and storage cost \$20/ton

From: Eide, J. "Rethinking CCS - Strategies for Technology Development in Times of Uncertainty," M.I.T. Masters Thesis, May (2013).

Rethinking CCS

- Herzog, H. and J. Eide, "Rethinking CCS - Moving Forward in Times of Uncertainty," in *Cornerstone*, the official journal of the World Coal Association, by Wiley Periodicals Inc., Vol 1:1, pp 44-50, Spring (2013).
 - http://sequestration.mit.edu/pdf/2013_Cornerstone_article.pdf
- Eide, J. "Rethinking CCS - Strategies for Technology Development in Times of Uncertainty," M.I.T. Masters Thesis, May (2013).
 - http://sequestration.mit.edu/pdf/2013_JanEide_Thesis.pdf
- Raveendran, S.P., "The Role of CCS as a Mitigation Technology and Challenges to its Commercialization," M.I.T. Masters Thesis, May (2013).
 - http://sequestration.mit.edu/pdf/2013_SadiaRaveendran_Thesis.pdf

Barriers to CCS

- Financial
 - Lack of markets
 - First mover costs
- Regulatory
- Public Acceptance/NIMBY

How many/ What type of CCS demonstration projects do we really need?

	High-purity capture	Power generation capture
EOR storage	<p>HP-CCUS</p> <p>Learning:</p> <ul style="list-style-type: none">- Less learning about capture- Less learning about storage <p>Cost</p> <ul style="list-style-type: none">- Least expensive	<p>CCUS</p> <p>Learning:</p> <ul style="list-style-type: none">- Learn about capture- Less learning about storage <p>Cost</p> <ul style="list-style-type: none">- Expensive
Non-EOR storage	<p>HP-CCS</p> <p>Learning:</p> <ul style="list-style-type: none">- Less learning about capture- Learn about storage <p>Cost</p> <ul style="list-style-type: none">- Less expensive	<p>CCS</p> <p>Learning:</p> <ul style="list-style-type: none">- Learn about capture- Learn about storage <p>Cost</p> <ul style="list-style-type: none">- Most expensive

Moving Forward

1. Demonstration programs incorporating EOR should be viewed as a steppingstone. The focus on long-term, large-scale CO₂ storage projects in saline formations needs to be strengthened.
2. More efforts are needed to demonstrate the feasibility of CCS on natural gas-fired power plants.
3. A stronger focus is needed on pilot-scale projects (vs. large-scale demonstrations) of novel capture technologies that hold the promise of significant cost reductions.
4. Current emission standards proposed for coal-fired power plants will not incentivize CCS projects.
5. There is a need for much stronger international coordination of demonstration efforts.

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