The Carbon Capture and Storage (CCS) Challenge: From Megatonnes to Gigatonnes

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Coal is the cheapest and dirtiest source of energy around. If we cannot get a handle on the coal problem, nothing else matters.

POWER SOURCE: Coal plant in Jilin, China

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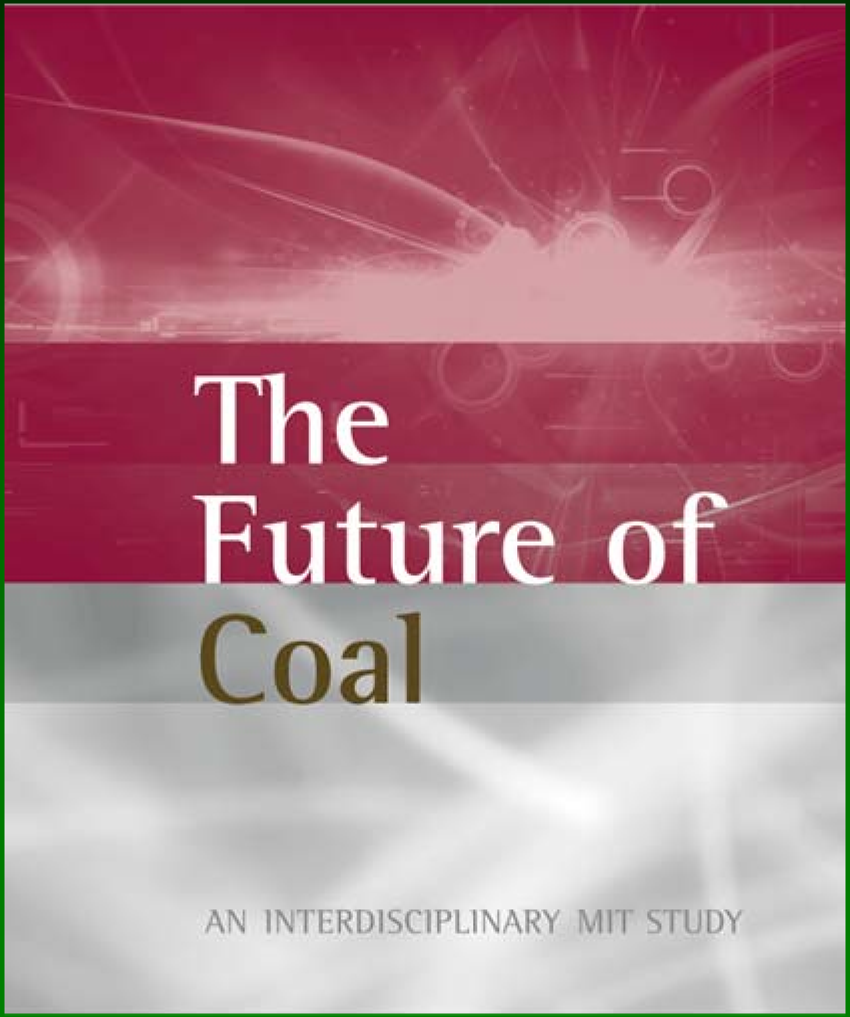
The MIT Coal Study



- Released March 14, 2007
  - On web at mit.edu/coal
- We conclude that CO_2 capture and sequestration (CCS) is the critical enabling technology that would reduce CO_2 emissions significantly while also allowing coal to meet the world’s pressing energy needs.

CCS Today

- All major components of a carbon capture and sequestration system are commercially available today.
  - Capture and compression
  - Transport
  - Injection
  - Monitoring
- However, there is no CCS industry – even though the technological components of CCS are all in use somewhere in the economy, they do not currently function together in the way imagined as a pathway for reducing carbon emissions.

CO_2 Injection Projects
Million Tonne per Year Scale

Project	Leader	Location	CO_2 Source	CO_2 Sink
Sleipner (1996)	Statoil	North Sea Norway	Gas Processing	Deep Brine Formation
Weyburn (2000)	Pan Canadian	Saskatchewan Canada	Coal Gasification	EOR
In Salah (2004)	BP	Algeria	Gas Processing	Depleted Gas Reservoir
Snovit (2008)	Statoil	Barents Sea Norway	Gas Processing	Deep Brine Formation

The Scale-up Challenge
From Megatonnes to Gigatonnes

- We have yet to build a large-scale (>1Mt CO_2/yr) power plant CCS demonstration
- In order to have a significant impact on climate change, we need to operate at the billion tonne (Gt) per year level
- This implies that 100s of power plants will need to capture and store their CO_2

Challenges for Large-Scale Deployment

- Costs
- Transportation Infrastructure
- Subsurface Uncertainty
  - Storage Capacity
  - Leakage from Storage Reservoirs
- Regulatory and Legal Issues
- Public Acceptance

CCS Costs

- Considerable uncertainty in cost estimates
  - Volatility in markets
  - Recent data sparse
  - Dealing with “first-of-a-kind” technology
- Significant factor in CCS costs is the high parasitic energy load – about 25% of power plant output for coal-fired plants

Capture and Compression Capital Costs

Power Plant	Capture Technology	Capital Investment	Power Output	$/kW
SCPC	Post-Combustion	+23%	-24%	+62%

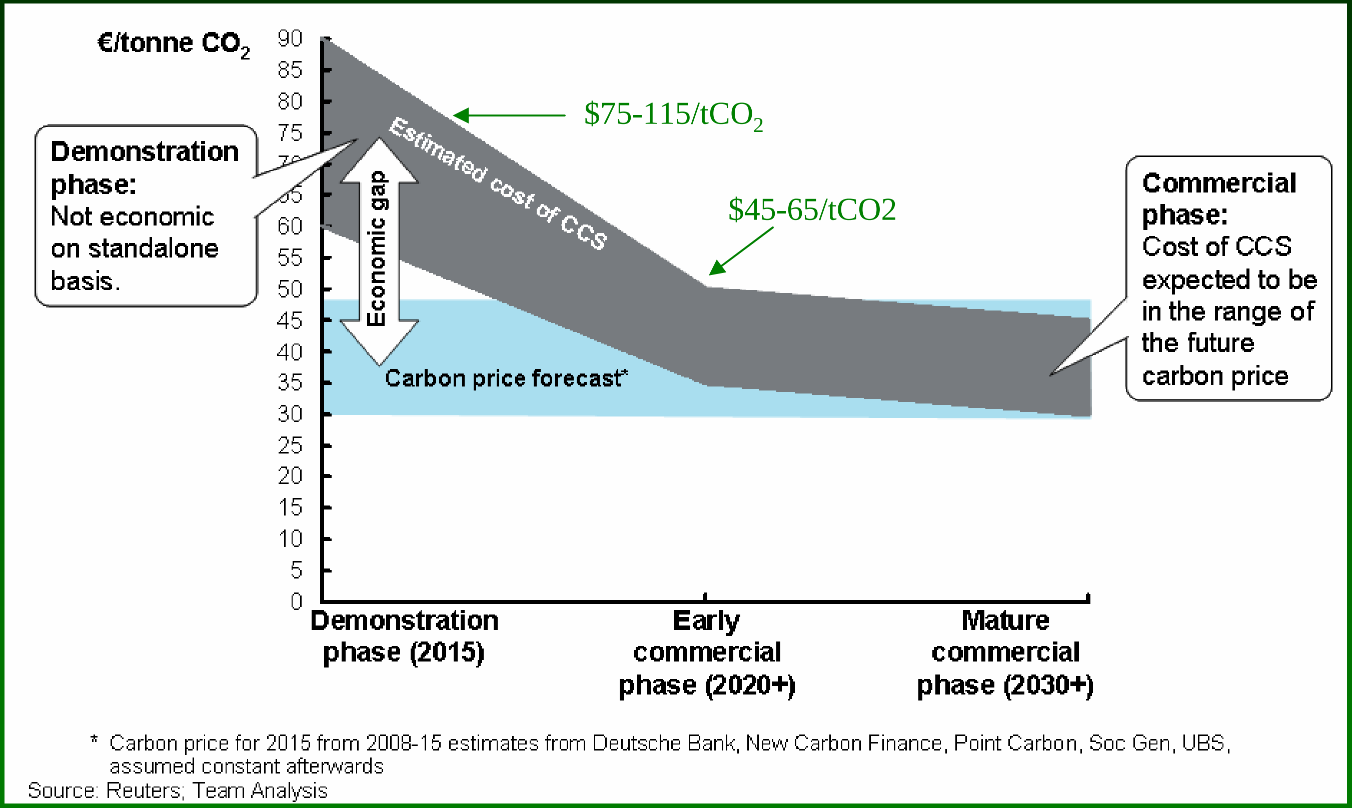
Comparison of Capture Technology Pathways

	Plusses	Minuses
Post-Combustion	Compatible with existing infrastructure; retrofits; flexibility	Current methods have high energy penalties
Oxy-Combustion	Potentially less expensive than post-combustion; retrofits	Cost of oxygen; lack of experience
Pre-Combustion	Projected lowest incremental cost for capture	Slow progress of IGCC in power sector

Estimated CCS Costs for Coal

- Estimated CCS Costs for coal:
  - additional $40 per MWh to cost of generation
  - $60-65/tonne CO_2 avoided
- This cost assumes:
  - 2007$
  - Nth plant
  - 90% capture
  - Includes transport and storage (~$10/tonne CO_2 avoided)
  - Based on SCPC technology with post-combustion capture
  - Today's technology (i.e., no technological breakthroughs required)
  - Regulatory issues resolved without imposing significant new burdens
  - Operations at scale
- For details see:
  - http://sequestration.mit.edu/pdf/GHGT9_Hamilton_Herzog_Parsons.pdf

McKinsey and Company Report



From Carbon Capture & Storage: Assessing the Economics, McKinsey and Company report

http://www.mckinsey.com/clientservice/ccsi/pdf/ccs_assessing_the_economics.pdf

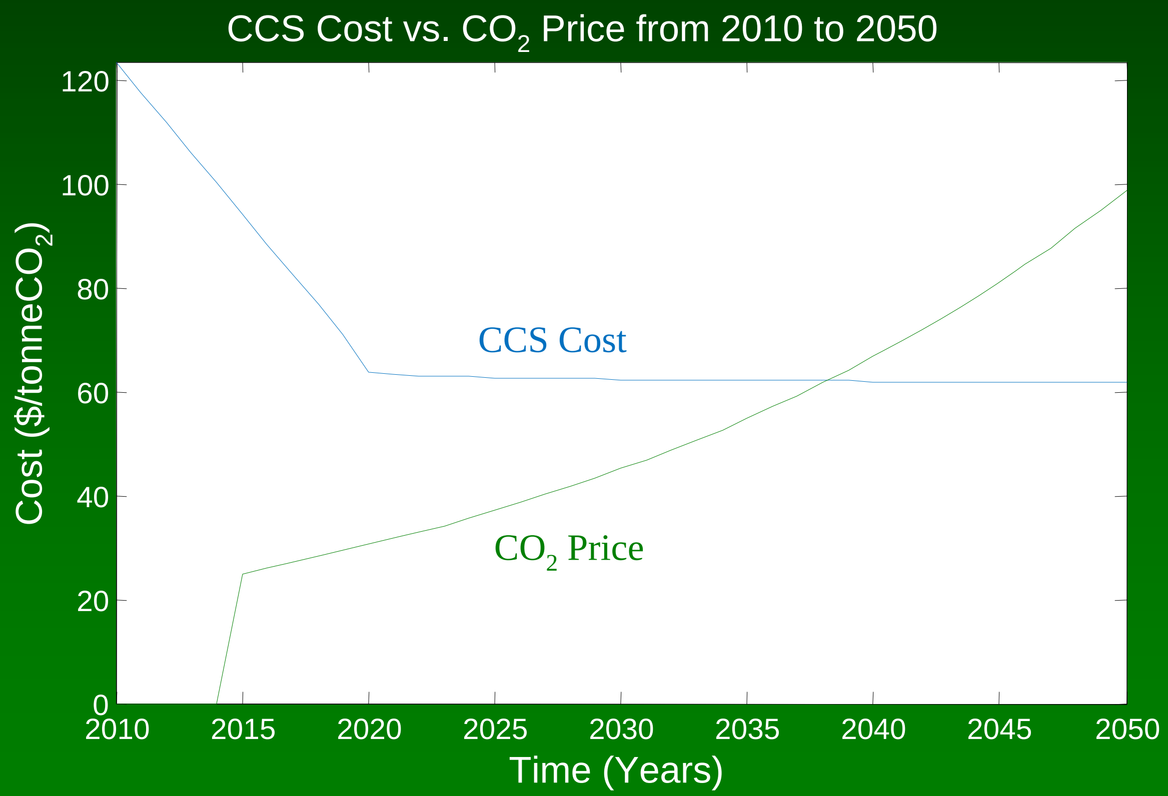
Harvard Report

- Results:
  - FOAK: $100-150/t$CO_2$ (McKinsey: $75-115)
  - NOAK: $30-50/t$CO_2$ (McKinsey: $45-65)
- Criteria:
  - Analysis of existing data (versus a bottom-up cost study)
  - Does not include transport costs
  - For 2005/2006 cost levels (assumes we come off 2008 peak)

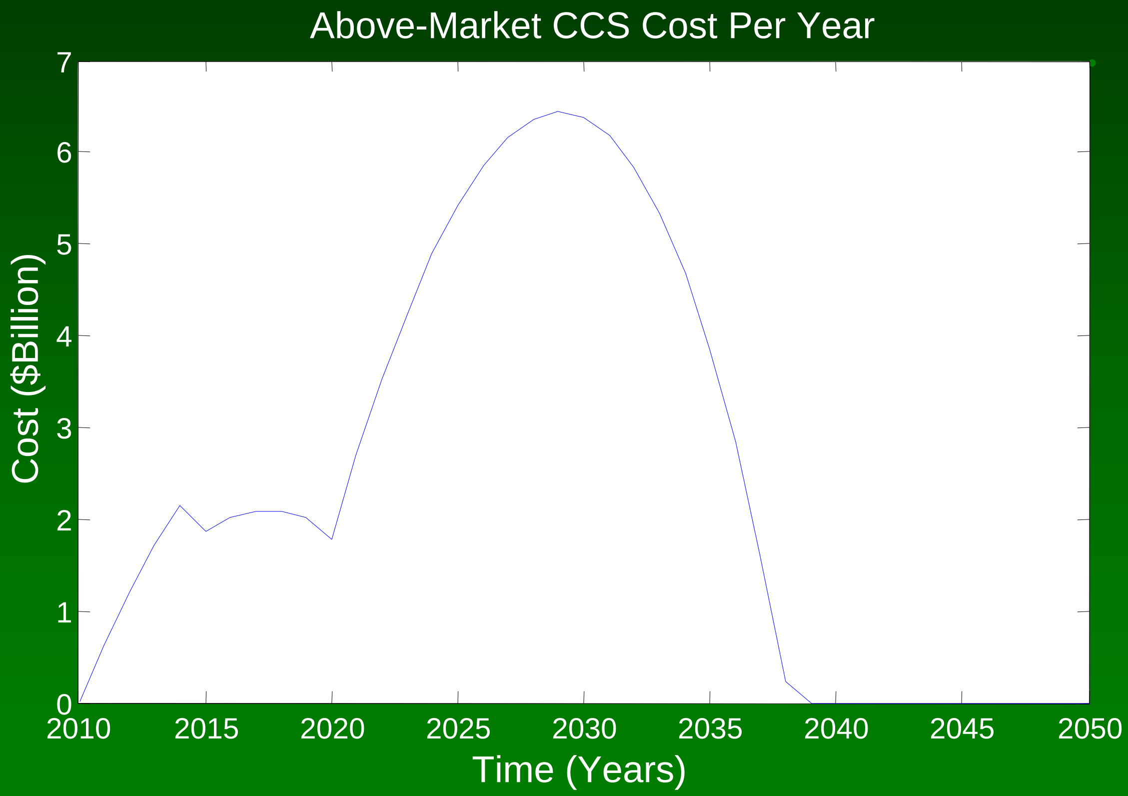
From Al-Juaied, Mohammed A and Whitmore, Adam, “Realistic Costs of Carbon Capture” Discussion Paper 2009-08, Cambridge, Mass.: Belfer Center for Science and International Affairs, July 2009.

http://belfercenter.ksg.harvard.edu/files/2009_AlJuaied_Whitmore_Realistic_Costs_of_Carbon_Capture_web.pdf

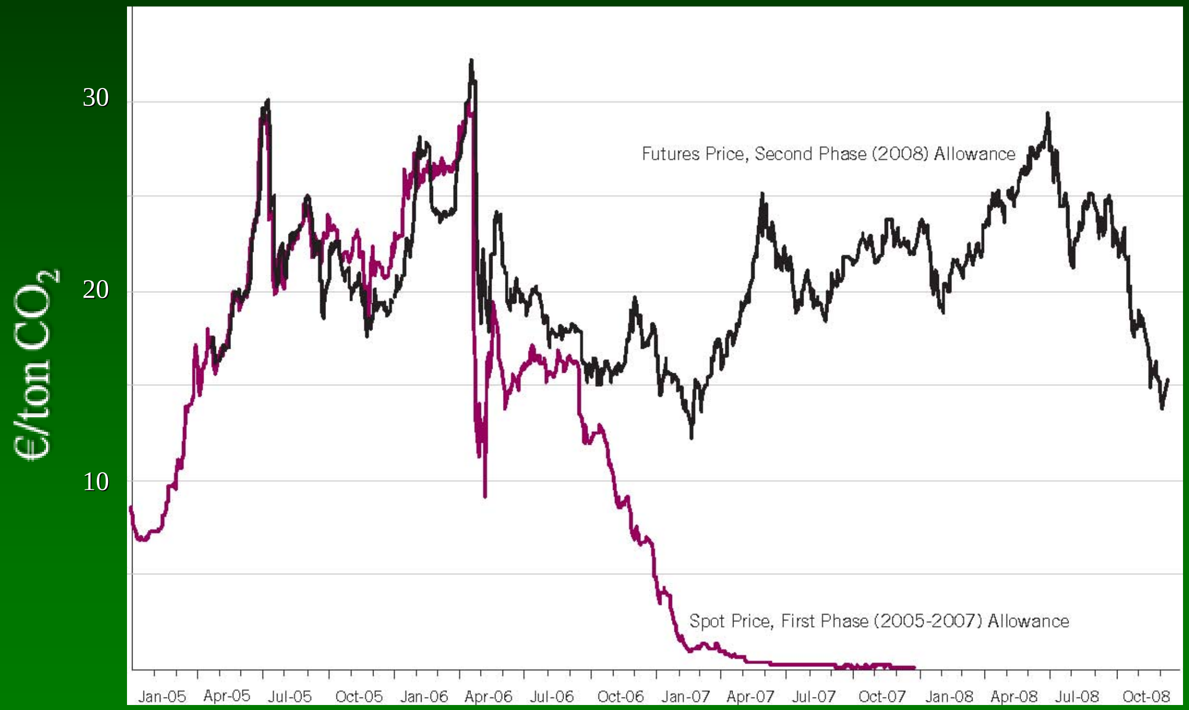
At first, a cap-and-trade system will not be sufficient for deployment



US Deployment Gap
$125 Billion



EU-ETS CO_2 Price History



Source: Point Carbon and ECX.

Transportation Infrastructure

- What will pipeline networks look like?
  - National network like natural gas?
  - Regional networks like utility grids?
- Chicken vs. Egg
  - Infrastructure in place will enable CCS, but
  - Can we afford to build infrastructure before there is a critical mass of CCS activity in an area
- How to regulate
  - *The future CCS regulatory environment will depend on the industrial organization of the sector.*
  - Issues include access, pricing, anti-trust
  - Regulation of gas pipelines very different than oil pipelines

Storage Capacity

- IPCC – *available evidence suggests that, it is likely that there is a technical potential of at least about 2000 $GtCO_2$ of storage capacity in geological formations*
- US DOE - For US saline formations, 920 – 3400 $GtCO_2$
- Reports from field – we just do not know

Leakage from Storage Reservoirs

- IPCC - *Observations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1,000 years.*
- CO_2 Storage represents a minimal health and safety risk
- Reports from field – Confidence in these predictions

Regulating Geologic Storage of CO_2

- Key issues
  - Legal access to the geologic formation
  - CO_2 injection (today under UIC Program)
  - Long-term stewardship
  - Credit under climate regulation
- Issues
  - Federal vs. state
  - Multiple regulations vs. unified regulation
  - Regulatory requirements (e.g. monitoring and verification) commensurate with the risks
  - Private vs. public role

Public Acceptance

- All technologies must deal with this issue (includes NIMBY)
- Hydrogen Energy's Carson Project
  - Opposition led by Environmental Justice movement
  - Relocated from LA area to Bakersfield area
- Shell project in Barendrecht, Netherlands
  - 400,000 tons per year
  - Source: Pernis refinery
  - Opposition major issue – technology "unproven"

MIT Coal Study
Central Message

- Demonstration of technical, economic, and institutional features of carbon capture and sequestration at coal conversion plants will
  - give policymakers and the public greater confidence that a practical carbon emission control option exists
  - shorten the deployment time and reduce the cost for carbon capture and sequestration should a carbon emission control policy be adopted, and
  - maintain opportunities for the lowest cost and most widely available energy form to be used to meet the world’s pressing energy needs

Large-scale Demos

- Characteristics (from MIT Coal Study)
  - On order of 10 worldwide
  - Scale of a million tons per year
  - In a variety of geologies
- G8 called for 20 worldwide by 2020
- Recent Activity
  - EU: 300 million permits from ETS
  - US: Support in stimulus bill
  - Australia: Global Carbon Capture and Storage Institute

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