The Economics of Technologies to Combat Global Warming Workshop

Howard Herzog

Snowmass, CO

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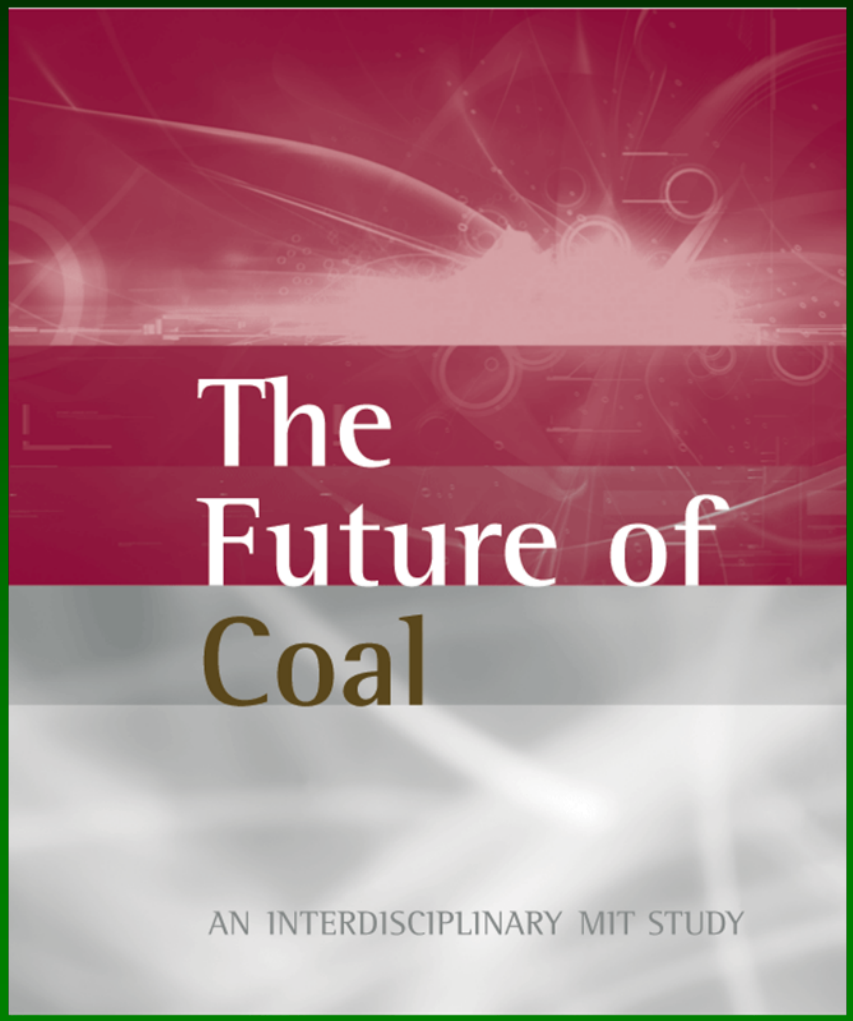
Overview

- CCS can be applied in different situations
  - Electric power plants
  - Non-power facilities
    - Gas processing
    - Refineries
    - Chemicals
    - Etc
  - Fuel conversion plants (e.g., coal-to-liquids)
- The biggest single class of emitters (by far) are coal-fired power plants

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.

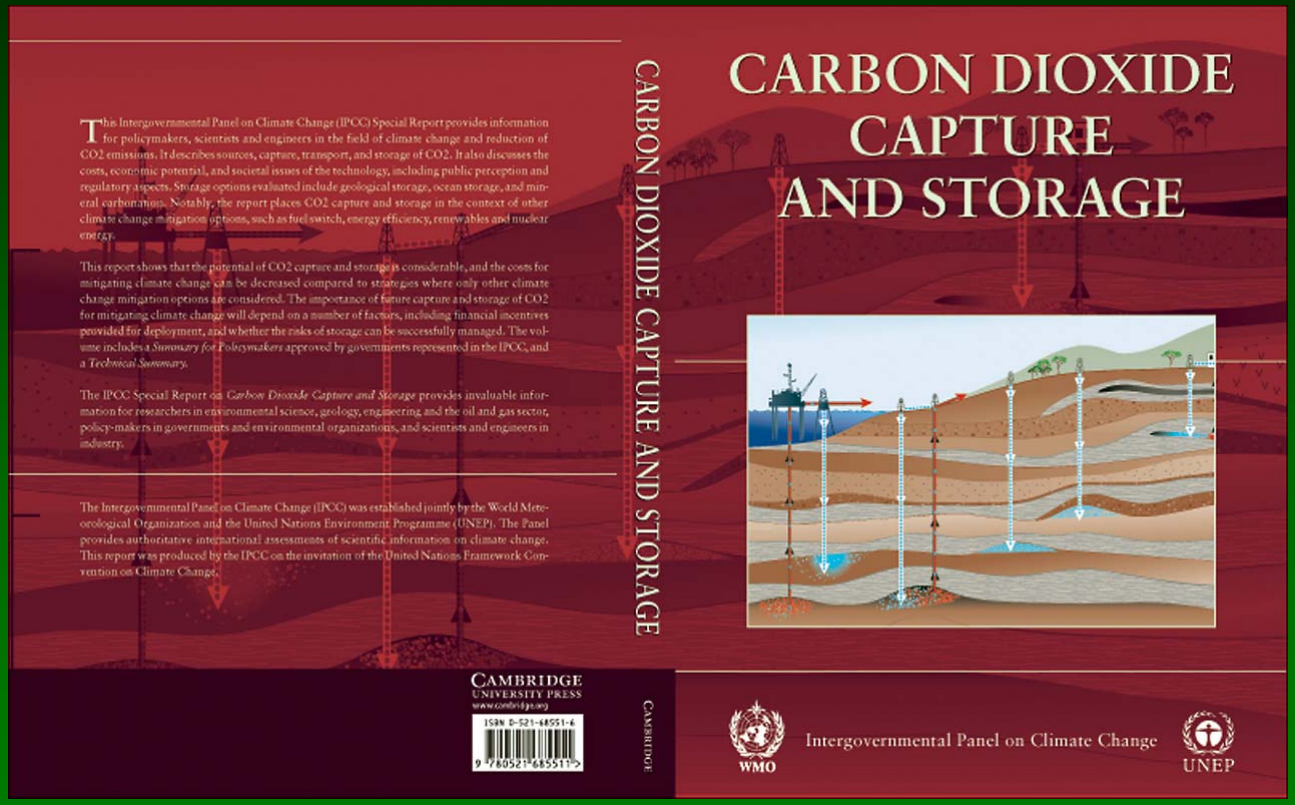
MIT Coal Study
Summary of Key Takeaways

- Technology readiness is critical – there are myriad options to pursue.
- Don't preclude options by anointing winners prematurely.
- We need to drastically increase R&D to bring CO_2 capture technologies to fruition. There is urgency to move ahead now if we are to reach Gt scale by 2050. Large scale demonstration projects are key.
- No showstoppers, but moving from the Mt scale to the Gt scale is a major challenge.

Two biggest challenges for CCS

- Reducing costs primarily associated with capture
- Reducing uncertainties primarily associated with storage at scale

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



Accepted September 26, 2005 -- www.ipcc.ch

Simple guide -- www.unep.org/dec/docs/CCS_guide.pdf

Howard Herzog / MIT Laboratory for Energy and the Environment

What's New Since the IPCC report?

- CCS is becoming more central in the policy debate worldwide

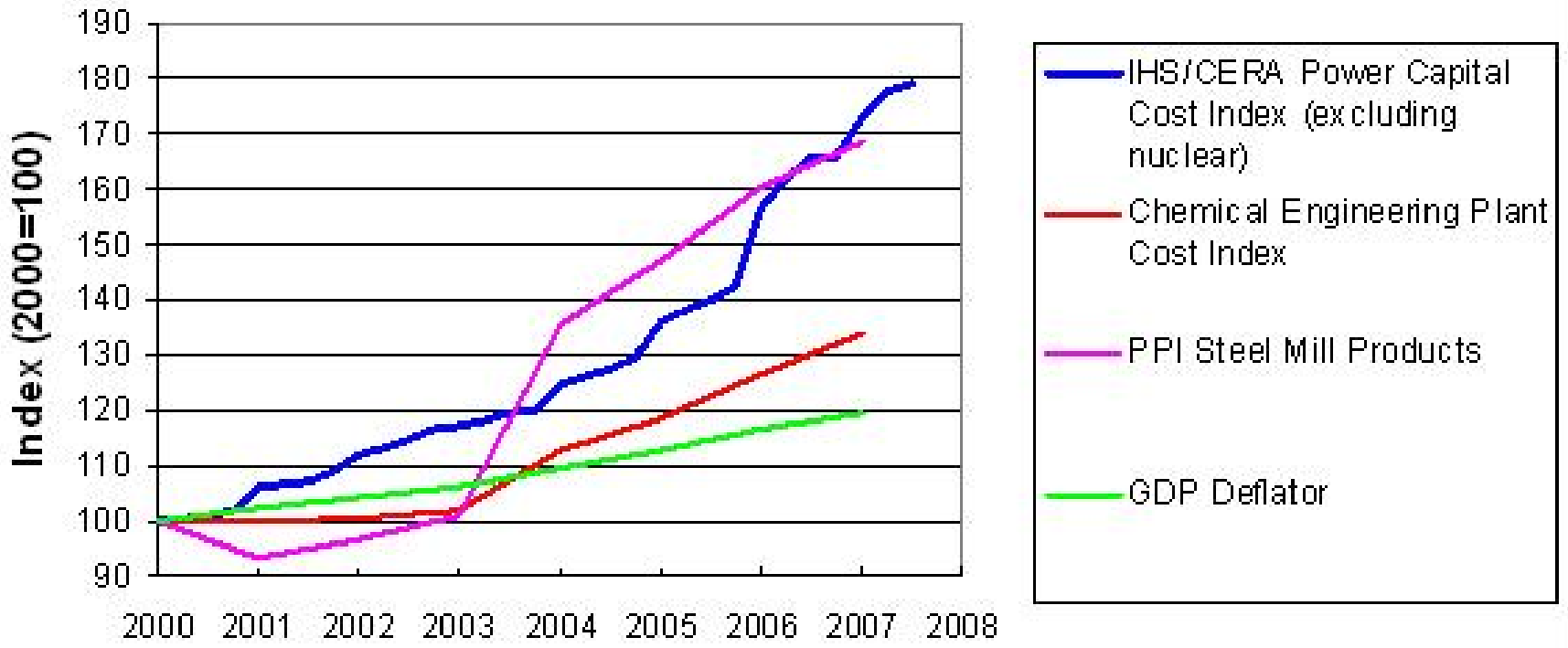
CCS in Policy Debate Examples

- Introduced in March 2008 by Waxman (D-CA) and Markey (D-MA)
  - Would prevent permitting of coal-fired power plants that cannot capture and sequester 85% of their CO_2 emissions
- Calls for moratorium on coal without CCS by Gore and Hansen
- Air permits denied in Kansas and Georgia
- Emissions performance standards in CA, WA

What's New Since the IPCC report?

- Costs have gone through the roof and are still rising – I trust no costs estimates (including/especially my own)

Cost Indices



SCPC Cost Estimates

Coal Type	Study Name	Capital Cost ($/kW) No CCS	Capital Cost ($/kW) With CCS
Bituminous	MIT	1,913	3,079
Bituminous	CERA	2,500	4,500
Bituminous	NETL	1,575	2,870
Bituminous	S&P	2,438	3,378
Bituminous	Duke - Cliffside, NC	3,000	
Bituminous	AMP Ohio	2,900	
Sub-Bituminous	EPRI	1,950	3,440
Sub-Bituminous	BERR/CPCC	2,618	4,445
Sub-Bituminous	AEP/Swepco -AK	2,800	
Sub-Bituminous	Sunflower - KS	2,572	
Sub-Bituminous	AMP Ohio	3,300	
Sub-Bituminous	Tenaska - TX		5,000

What's New Since the IPCC report?

- Good progress on improving fundamental knowledge (where only modest investments are required), especially in geologic storage
- Serious efforts to develop regulatory frameworks

Regulatory Efforts Examples

- IOGCC - A Regulatory Framework for Carbon Capture and Geological Storage (January 2005)
- WRI - CCS Guidelines: CO2 Capture, Transport and Storage (draft available)
- EPA - Proposed rule for Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO2) Geologic Sequestration (GS) Wells (July 2008)

What's New Since the IPCC report?

- CCS means more than IGCC

Post-Combustion Capture: More than an Afterthought

- Compatible with existing coal infrastructure
  - No change in basic combustion technology
  - Offers good retrofit opportunities
- Leading candidate today for gas-fired power plants
- Slow progress of IGCC in power sector
- Offers flexibility – e.g., can operate without capture as a peaking unit

What's New Since the IPCC report?

- More technology options being identified

Beyond Solvents: Stimulus-Responsive Sorbents

- Definition: materials that undergo dramatic changes in ordering (resulting in a large change in capacity for solutes like CO_2) with small changes in energy input
- Example: water hydrates (problem is restricted range of operating conditions)
- Other Materials: liquid crystals, ionic liquids, metal organic frameworks
- Stimuli: electric fields, magnetic fields, light irradiation (solvents use temperature and/or pressure)

What's New Since the IPCC report?

- Moved from being too pessimistic (CCS-are you crazy?) to too optimistic (CCS is the silver bullet)

What's the Same Since the IPCC Report?

- Not enough funding to move toward "technological readiness"
- Estimates of storage capacities are highly uncertain
- Long-term stewardship (and associated liability) of geologic reservoirs still a major issue
- Snake oil salesman are still out there (or more politely, lots of hammers looking for nails)

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