Carbon Capture & Sequestration Economics

Public Workshops on Carbon Capture and Sequestration

Howard Herzog
MIT
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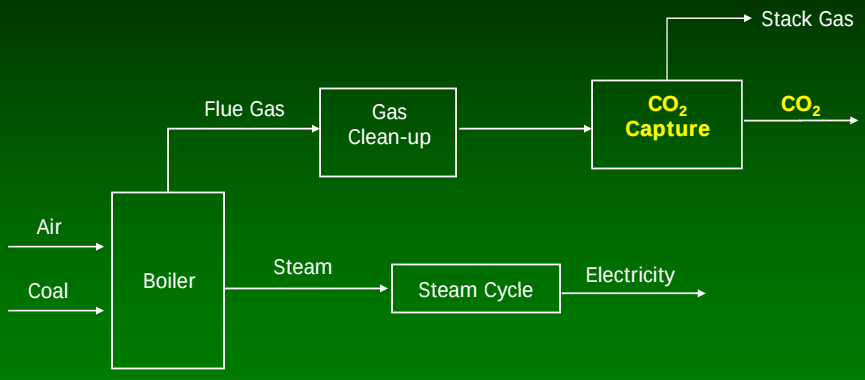
Overview

- Capture primer
- Costs
- CCS as part of a mitigation portfolio

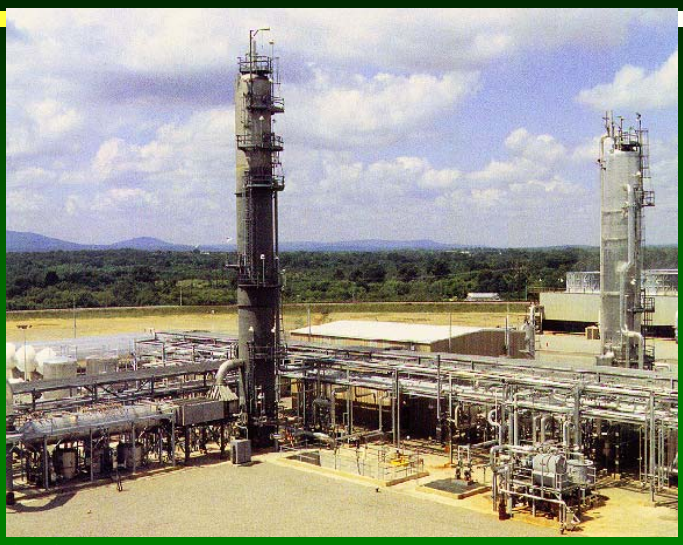
CO_2 Capture

- Majority of costs associated with CO_2 capture
- CO_2 capture refers to the separation of CO_2 from the flue gas its subsequent compression to a "supercritical" or liquid state.
- Why capture? – CO_2 is too dilute in flue gas of power plants to economically transport and inject underground.
- Some industrial processes produce a relatively pure CO_2 stream resulting in low capture costs – these are high priority targets for CCS

Post-Combustion Capture



CO_2 Capture at a Power Plant



Source: ABB Lummus

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Capture and Compression Capital Costs

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

Two approaches to lower cost of capture:
(1) Improved capture processes
(2) Modify power plant to facilitate capture

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Change Power Generation Process to Facilitate CO_2 Capture

Power Plant	PC	NGCC	IGCC
P (atm)	1	1	40
Fract CO_2	0.15	0.05	0.40
PCO_2 (atm)	0.15	0.05	16
Capture Process	Chemical Absorption	Chemical Absorption	Physical Absorption

PCO_2 indicates the difficulty of capture.

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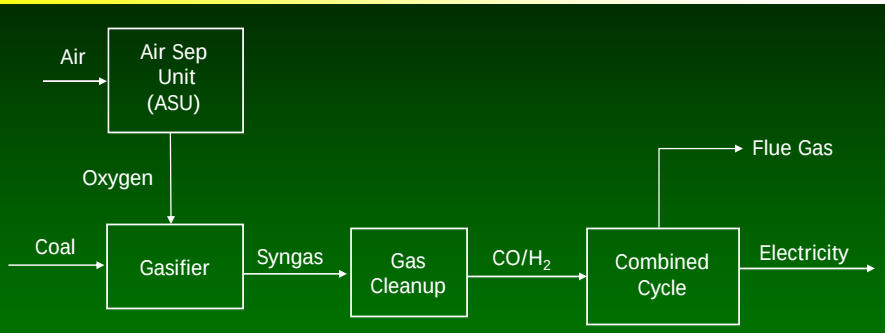
IGCC Power Plant



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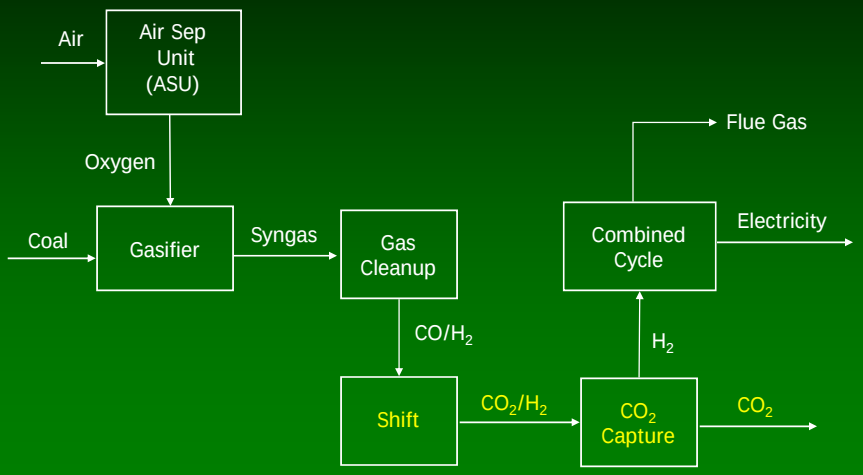
Pre-Combustion Capture



CCS Costs

- Current cost estimates are significantly higher than 2 years ago due to recent run-up in commodity prices
- Considerable uncertainty in cost estimates
  - Volatility in markets
  - Recent data sparse
  - Dealing with “first-of-a-kind” technology

Estimated CCS Costs for Coal

- Estimated CCS Costs for coal
  - additional $35-45 per MWh to cost of generation
  - $50-65/tonne CO_2 avoided
- This cost assumes:
  - 2007$
  - 90% capture
  - CA conditions
  - includes transport and storage ($10/tonne CO_2 avoided)
  - Today's technology (i.e., no technological breakthroughs required)
  - Regulatory issues resolved without imposing significant new burdens
  - Operations at scale

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CO_2 Sources in California

	# of Facilities	Capacity	2004 CO_2 Emissions (Mt/yr)
Gas Power	221	39,000 MW	58
Oil Power	3	32 MW	0
Coal Power	8	440 MW	3
Cement	11	15 Mt/yr	12*
Ethanol	4	68×10^6 gal/yr	0.4*
Gas Processing	31	1×10^9 CFD	?
Refineries	15	2×10^6 bbl/d	18*
Total	**293**	**-**	**~90**

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*Estimated

Estimated CCS Costs

- Estimated CCS Costs for coal
  - additional $35-45 per MWh to cost of generation
  - $50-65/tonne CO_2 avoided
- Estimated CCS Costs for gas
  - additional $30 per MWh to cost of generation
  - $85/tonne CO_2 avoided
- Estimated CCS Costs for processes with a pure CO_2 stream
  - $20-30/tonne CO_2 avoided
- EOR credit can offset about $20/tonne CO_2

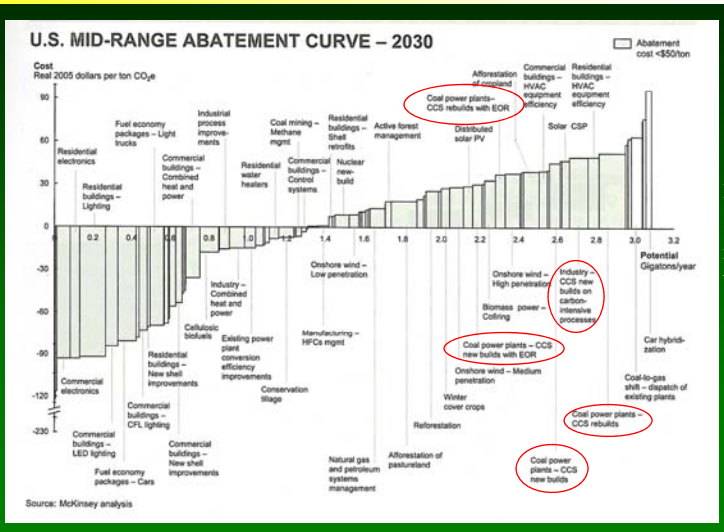
Important Issues for Economics

- Quality and Quantity of the CO_2 Source
- Proximity of Sources to Sinks
- Boundary Issues - Regional vs. In-state
- Existing vs. New Sources

Existing vs. New Sources

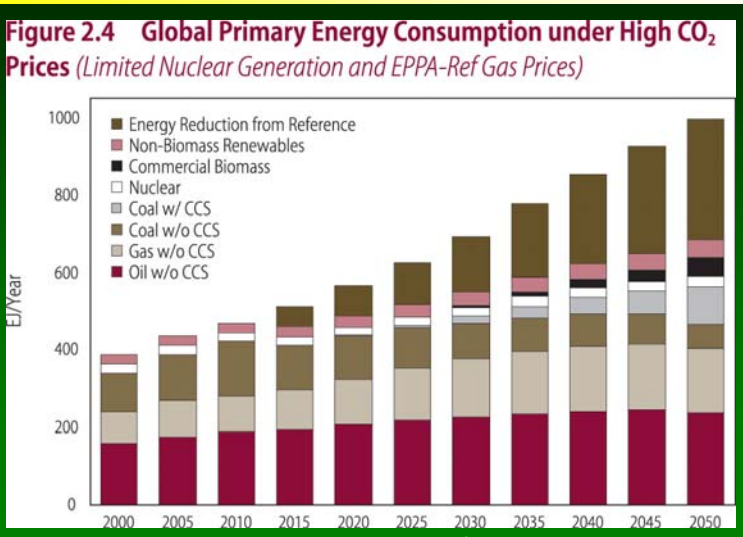
- In general, applying CCS to a new source has advantages over retrofits
  - Lower costs
    - » Optimized designs
    - » Higher efficiencies
    - » Fewer constraints
  - Siting flexibility
  - Adding capacity vs. subtracting capacity
- Exception: Existing facilities that produce a concentrated CO_2 stream are best near-term prospects

McKinsey& Company December 2007



Estimate 3.5-5.2 Gt/yr required by 2030.

Carbon-Constrained Scenario
High CO_2 Prices - Limited Nuclear



from MIT Coal Study

Closing Thoughts

- Almost universal agreement of top-down and bottom-up economic models that CCS is potentially a cost-effective mitigation technology
- Investments and learning need to start immediately to get desired results by mid-century
- CCS varies regionally – each state/region has its unique set of sources and geological reservoirs
  - An interesting analogy for California is Norway
  - Partial capture from coal may be interesting to meet SB1368 standard of 1100 lb/MWh

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