Carbon Capture & Sequestration Economics

Public Workshops on Carbon Capture and Sequestration

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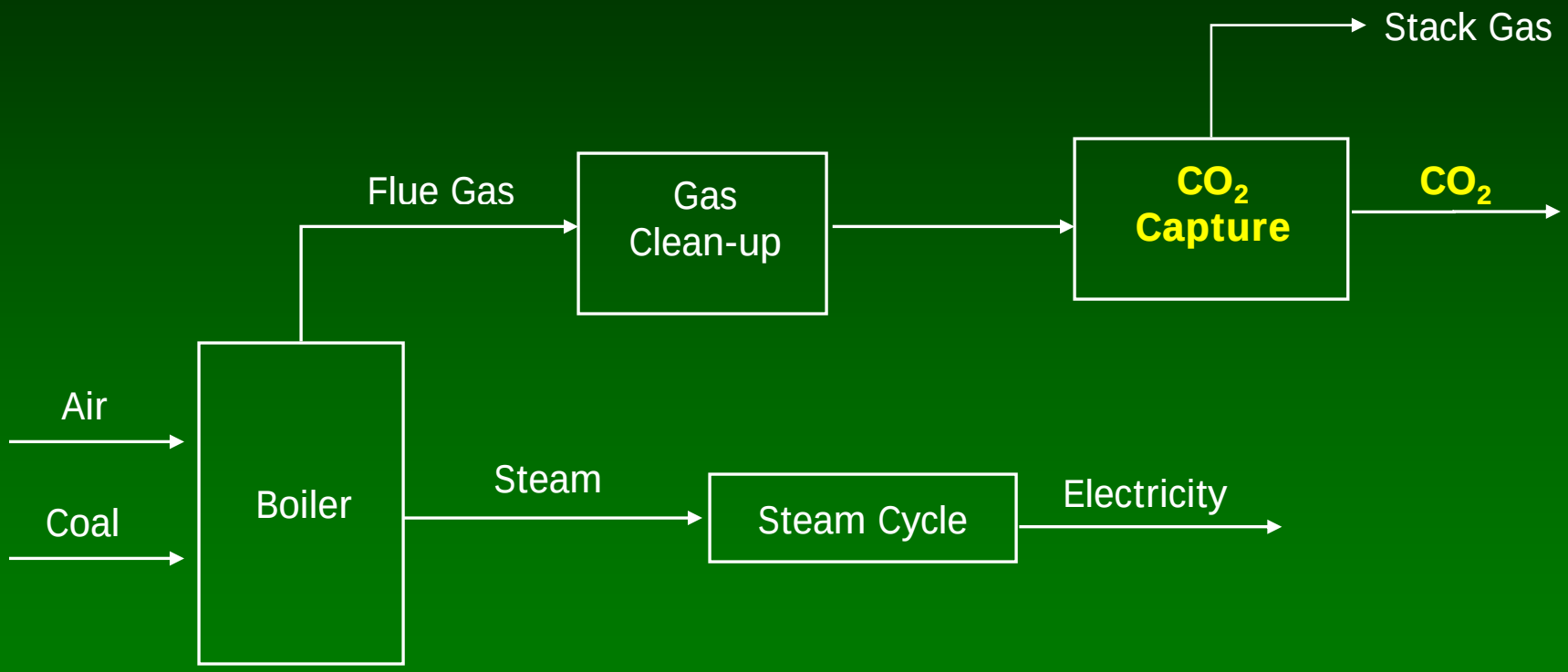
Overview

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

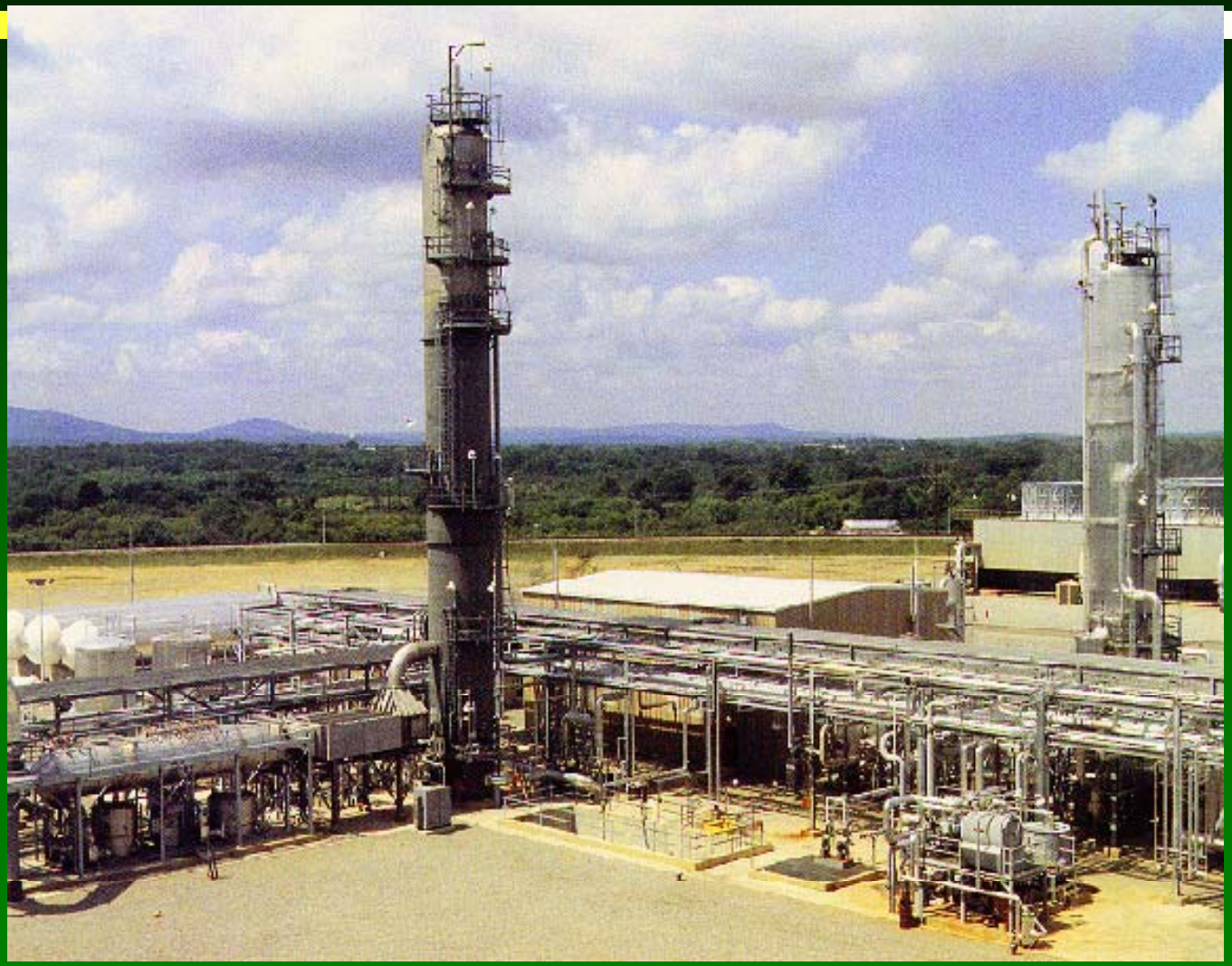
CO_2 Capture

- 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

Capture and Compression Capital Costs

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

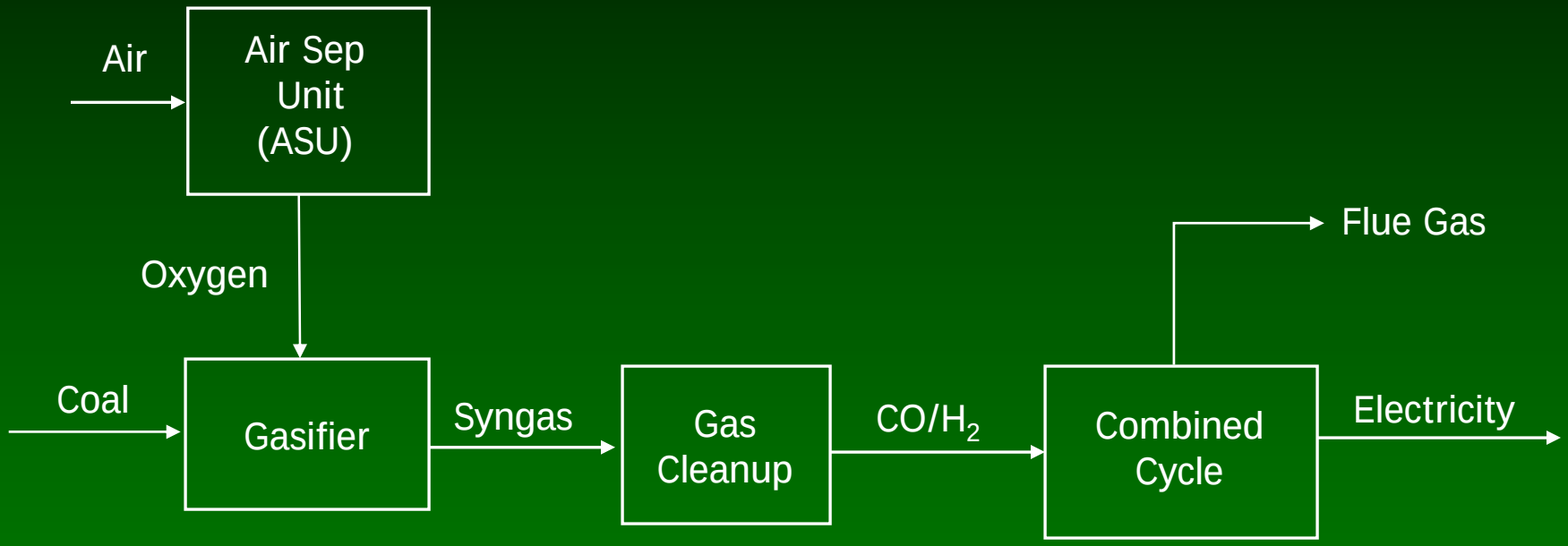
Two approaches to lower cost of capture:
(1) Improved capture processes
(2) Modify power plant to facilitate capture

Change Power Generation Process to Facilitate CO_2 Capture

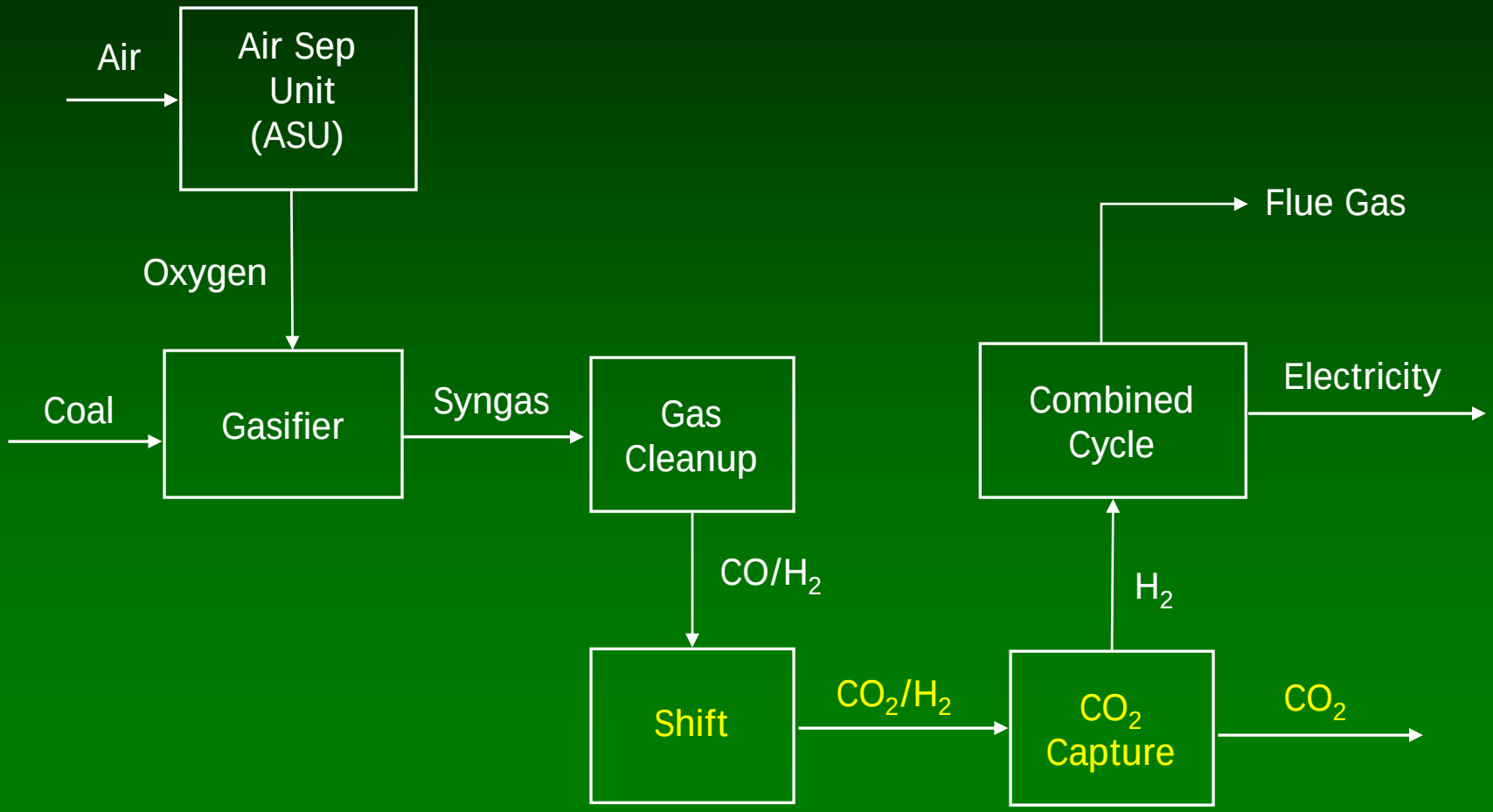
Power Plant	**PC**	**NGCC**	**IGCC**
P (atm)	1	1	40
Fract CO_2	0.15	0.05	0.40
PCO_2 (atm)	0.15	0.05	16
Capture Process	Chemical Absorption	Chemical Absorption	Physical Absorption

PCO_2 indicates the difficulty of capture.

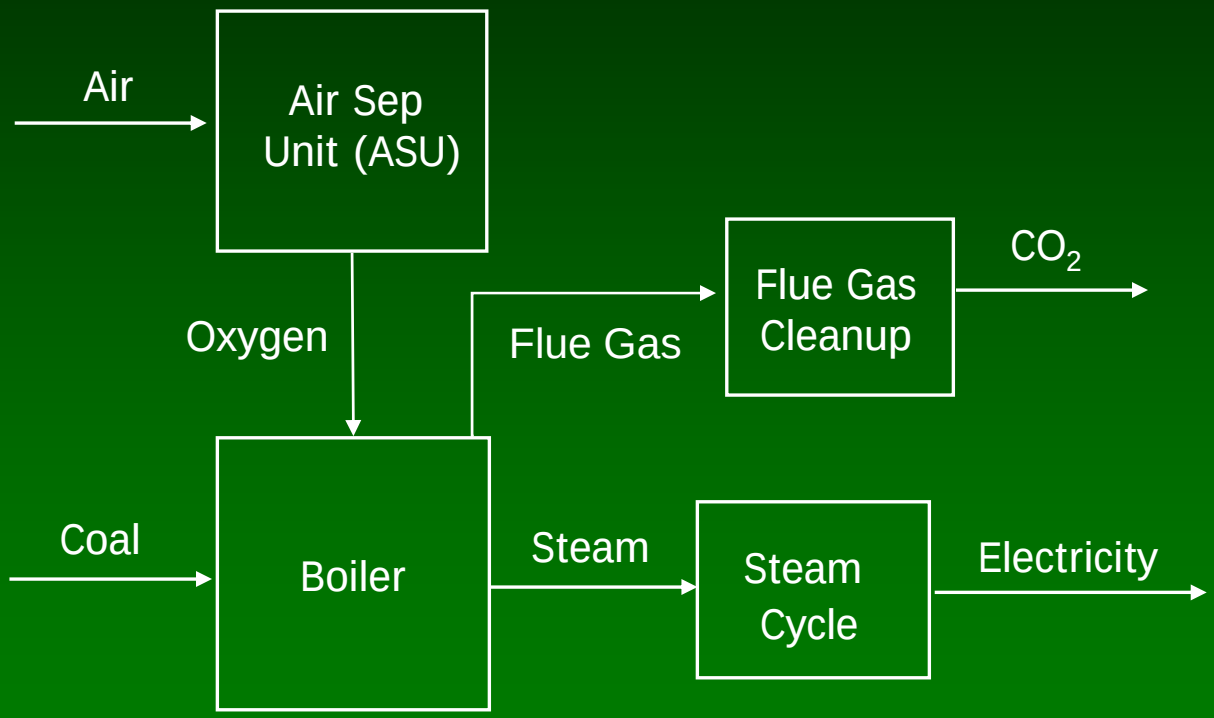
IGCC Power Plant



Pre-Combustion Capture

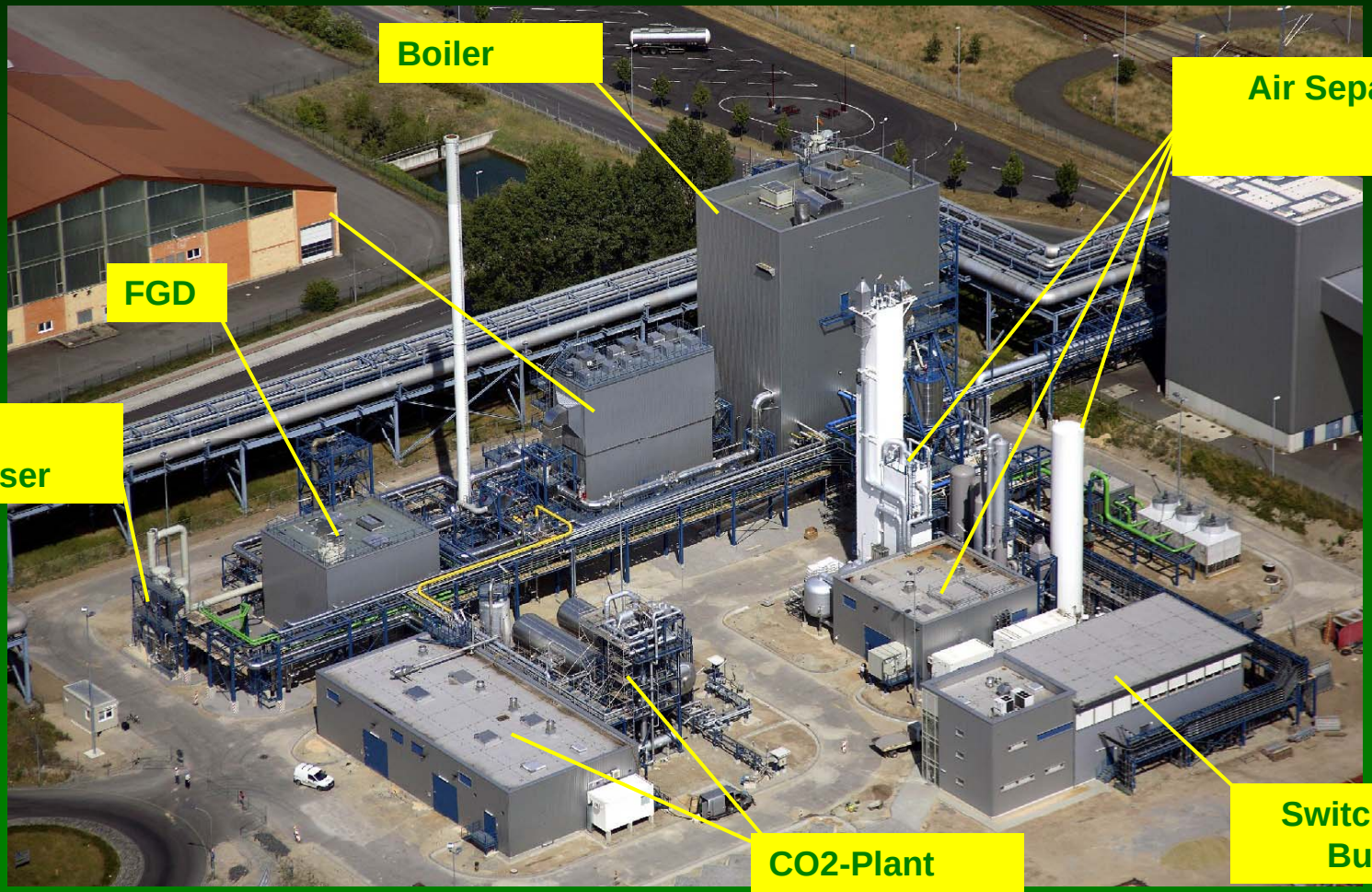


Oxy-Combustion Capture



Vattenfall Schwarze Pumpe Plant

Oxy-combustion 30 MW_{th} Pilot Plant



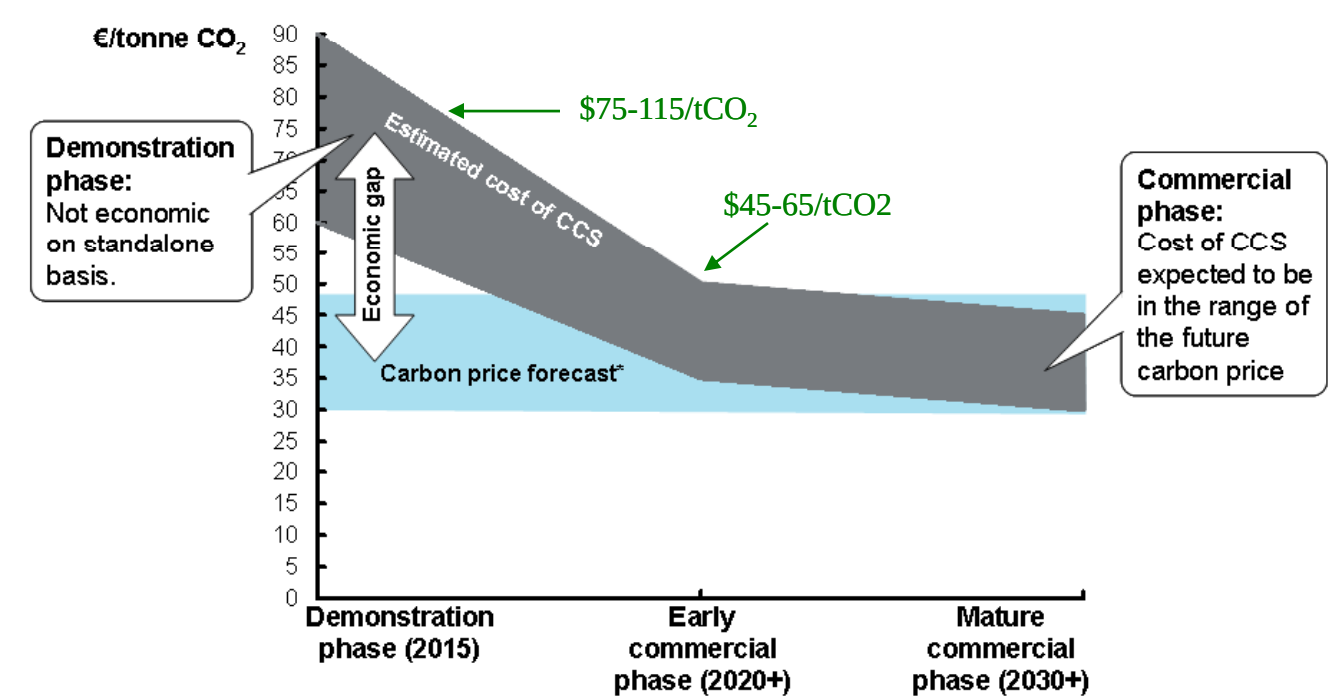
CCS Costs

- 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 $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)
  - 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

Estimated CCS Costs

- Estimated CCS Costs for coal
  - additional $40 per MWh to cost of generation
  - $60-65/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

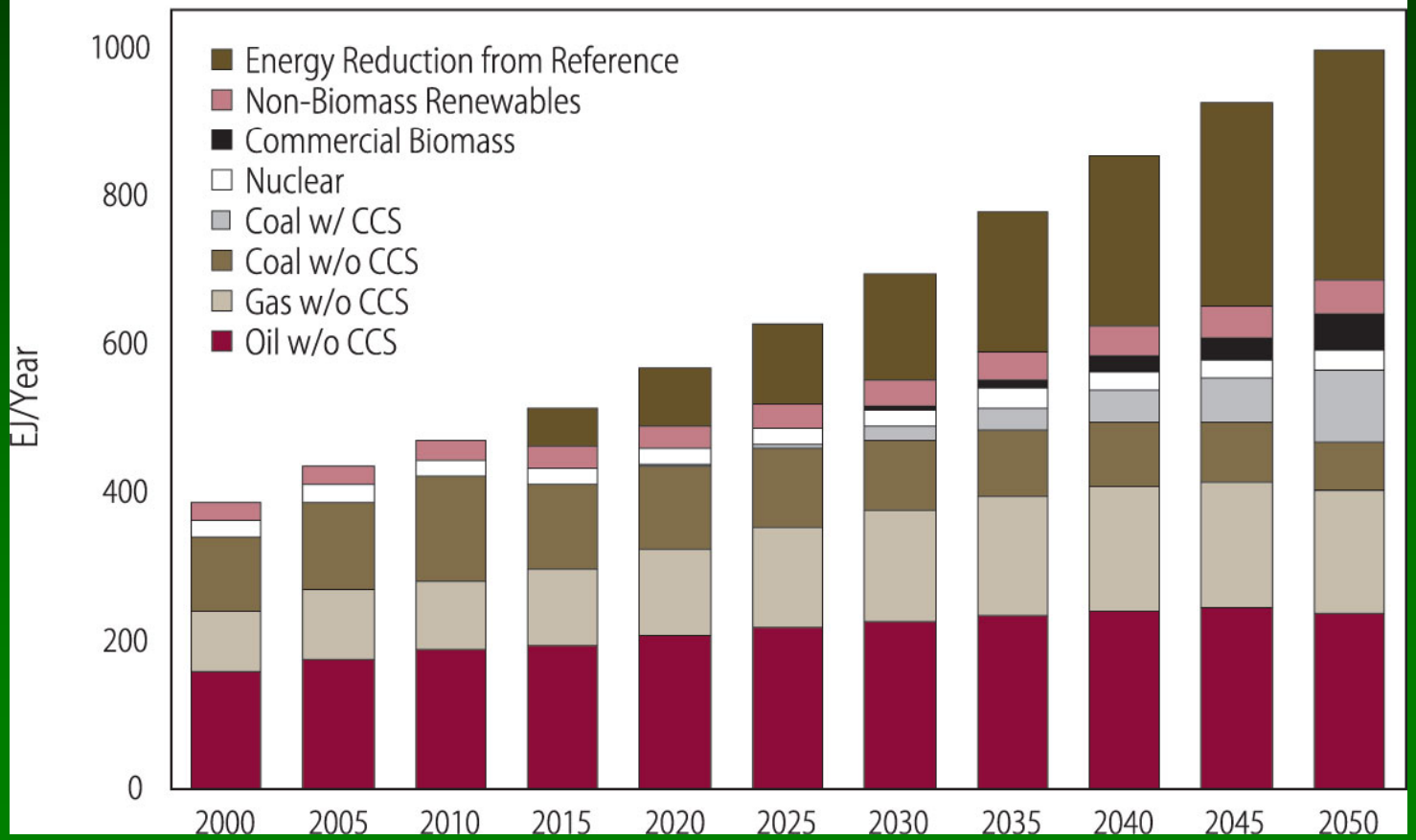
- Quality and Quantity of the CO_2 Source
- Proximity of Sources to Sinks
- Existing vs. New Sources

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

Carbon-Constrained Scenario
High CO_2 Prices - Limited Nuclear

Figure 2.4 Global Primary Energy Consumption under High CO_2 Prices *(Limited Nuclear Generation and EPPA-Ref Gas Prices)*



from MIT Coal Study

Effect of Carbon Price
CCS Available

	2000	BAU 2050	Low CO_2 Price 2050	High CO_2 Price 2050
Coal CO_2 emissions ($GtCO_2$/yr)	9	32	15	5
Coal Consumption (EJ/yr)	100	448	200	161
% Coal with CCS	0	0	4	60

From MIT Coal Study

- Despite carbon price, coal consumption increases from today's use
- Coal use does decrease from a BAU case
- The higher the carbon price, the more coal consumption decreases
- Low carbon prices do not induce CCS
- High carbon prices – coal consumption increases, but emissions decrease (compared to today) thanks to CCS
- Price Scenarios
  - Low - $7/tonne CO2 in 2010 with 5% annual increase
  - High - $25/tonne CO2 in 2015 with 4% annual increase

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

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