Carbon Capture and Storage (CCS) Technologies for Electric Generation

Colorado Public Utilities Commission

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MIT Coal Study Overview

- Follow-on to *The Future of Nuclear Power*
  - On web at mit.edu/nuclearpower
- Full report released March 14
  - On web at mit.edu/coal
- Authors
  - John Deutch, Ernie Moniz (PIs)
  - Jim Katzer (Executive Director)
  - Stephen Ansolabehere, Janos Beer, Denny Ellerman, Julio Friedmann, Howard Herzog, Jake Jacoby, Paul Joskow, Lester Richard, Greg McRae, Edward Steinfeld

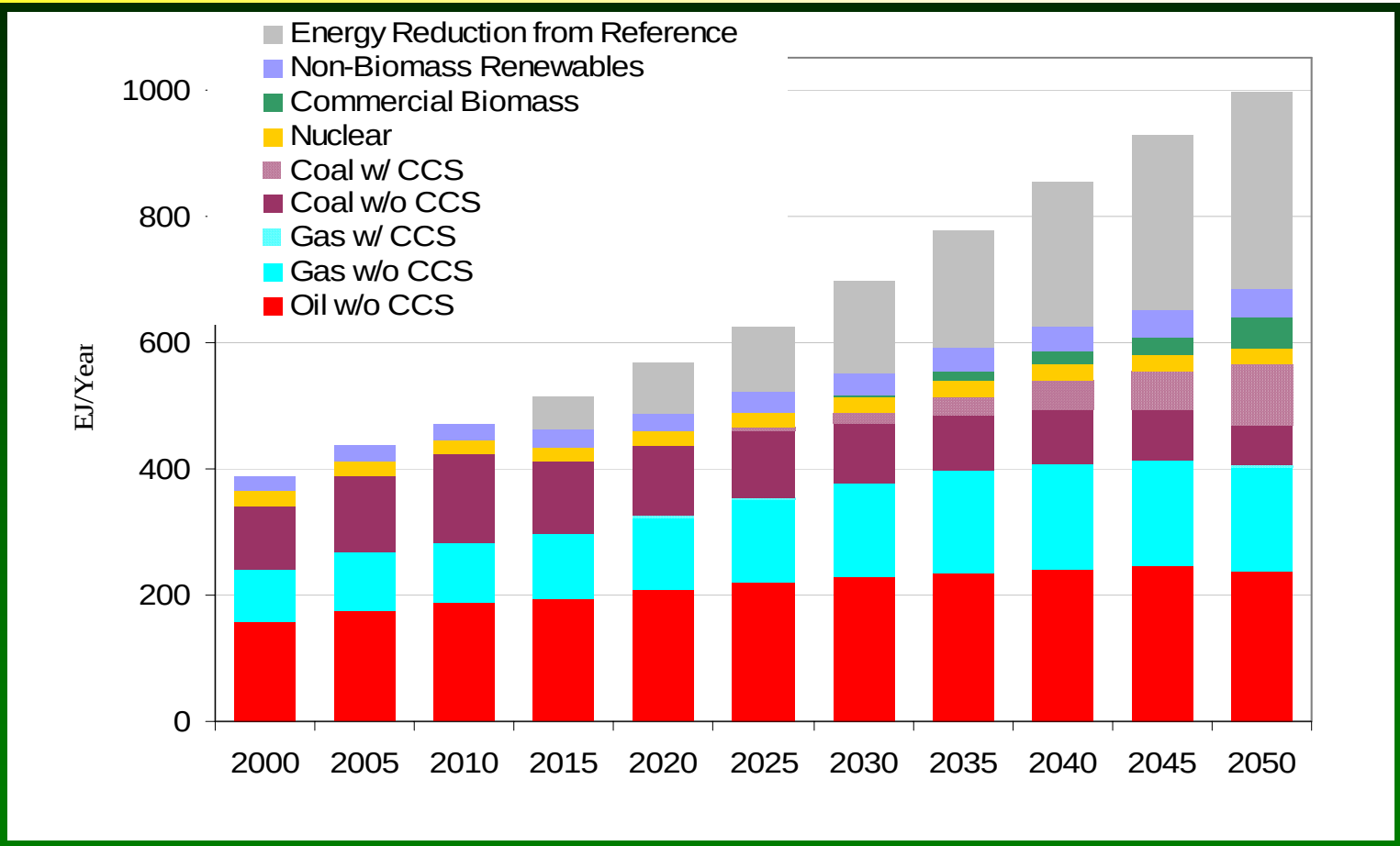
Key question:

What actions regarding technology do we take now to impact GHG emissions on a Gigaton scale in 2050?

MIT Coal Study
Key Takeaways

- Technology readiness is critical – there are myriad of options to pursue
- Don't preclude options by anointing technology 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 gigaton (Gt) scale by 2050. Large scale demonstration projects are key
- No showstoppers, but moving from the megaton (Mt) scale to the Gt scale is a major challenge

Global Primary Energy Consumption under High CO_2 Prices
Limited Nuclear Generation Case



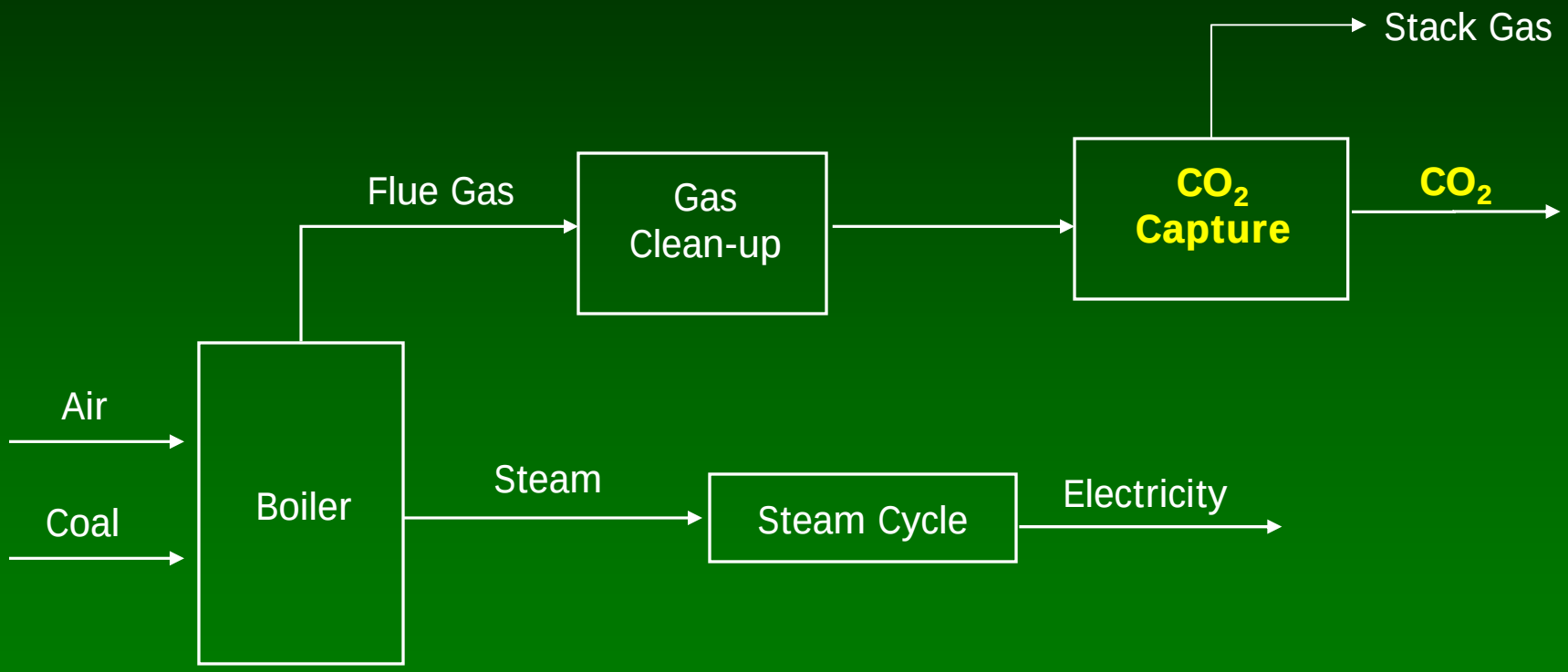
MIT Coal Study Figure 2.4

Initial CO_2 Price of \$25/tCO_2 in 2015 with 4%/yr increase

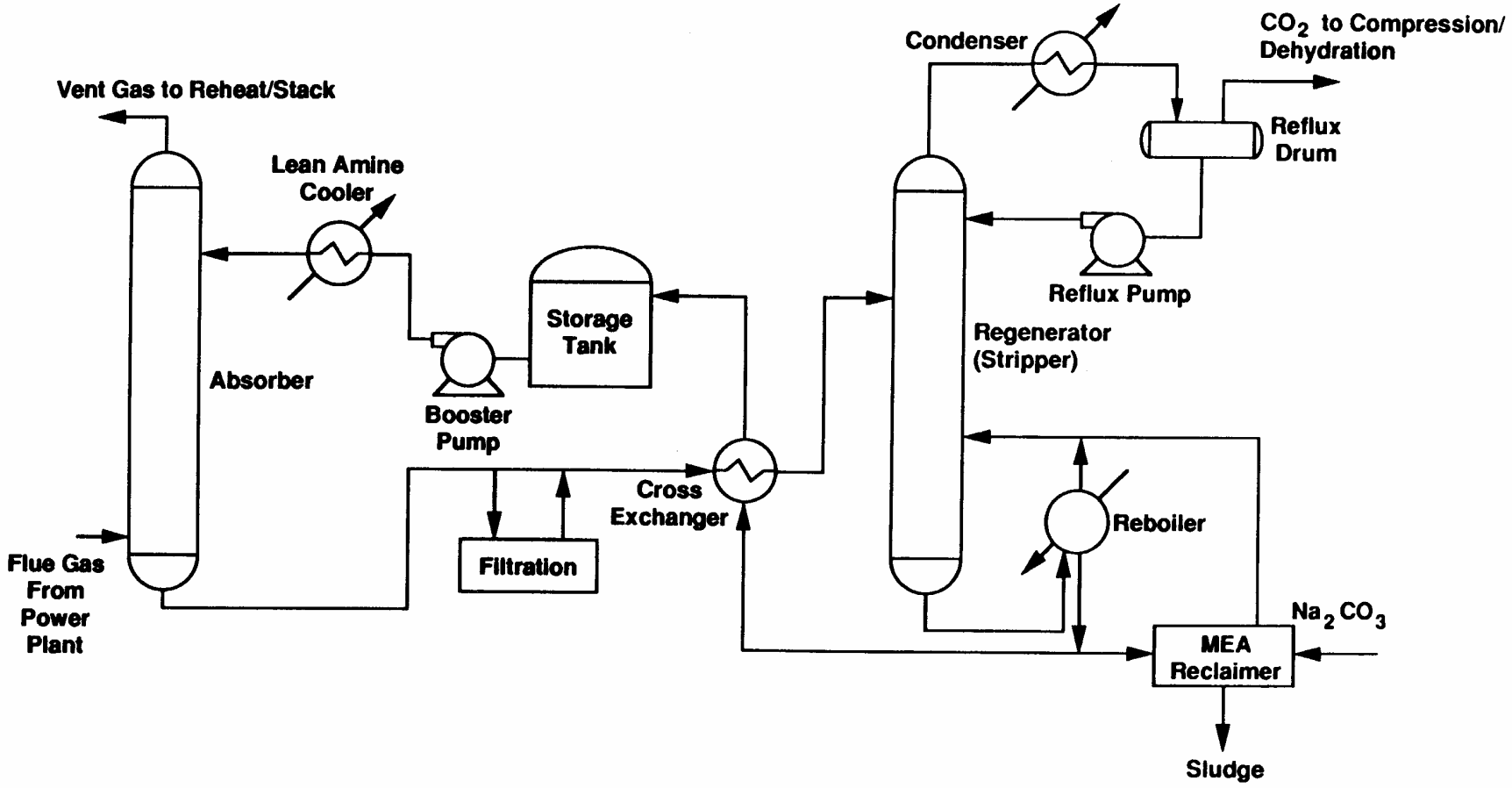
Approaches to CO_2 Capture from Coal-Fired Power Plants

- Post-combustion
- Pre-combustion
- Oxyfuel Combustion

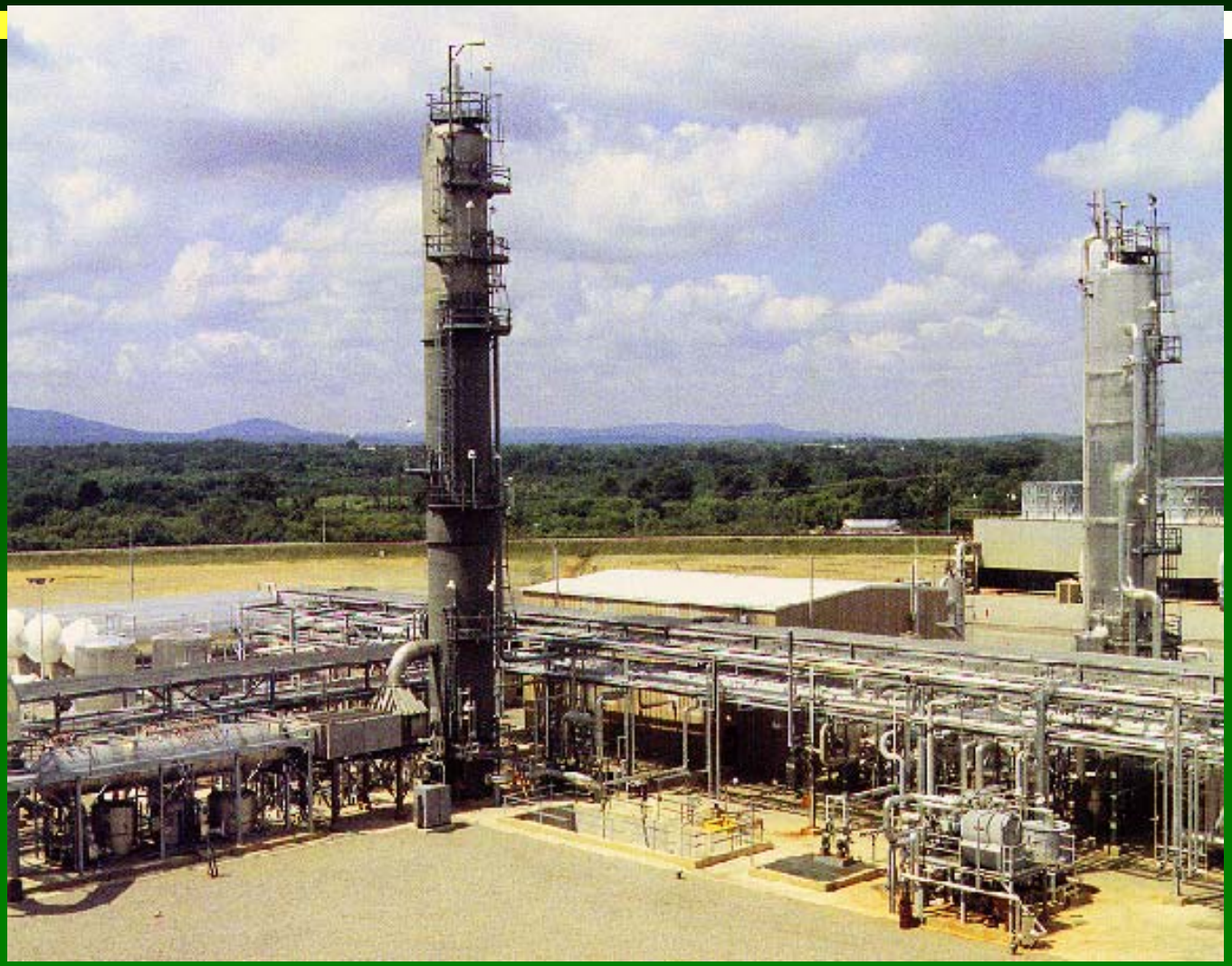
Pulverized Coal (PC) Power Plant



Schematic of Amine Process for CO_2 Capture

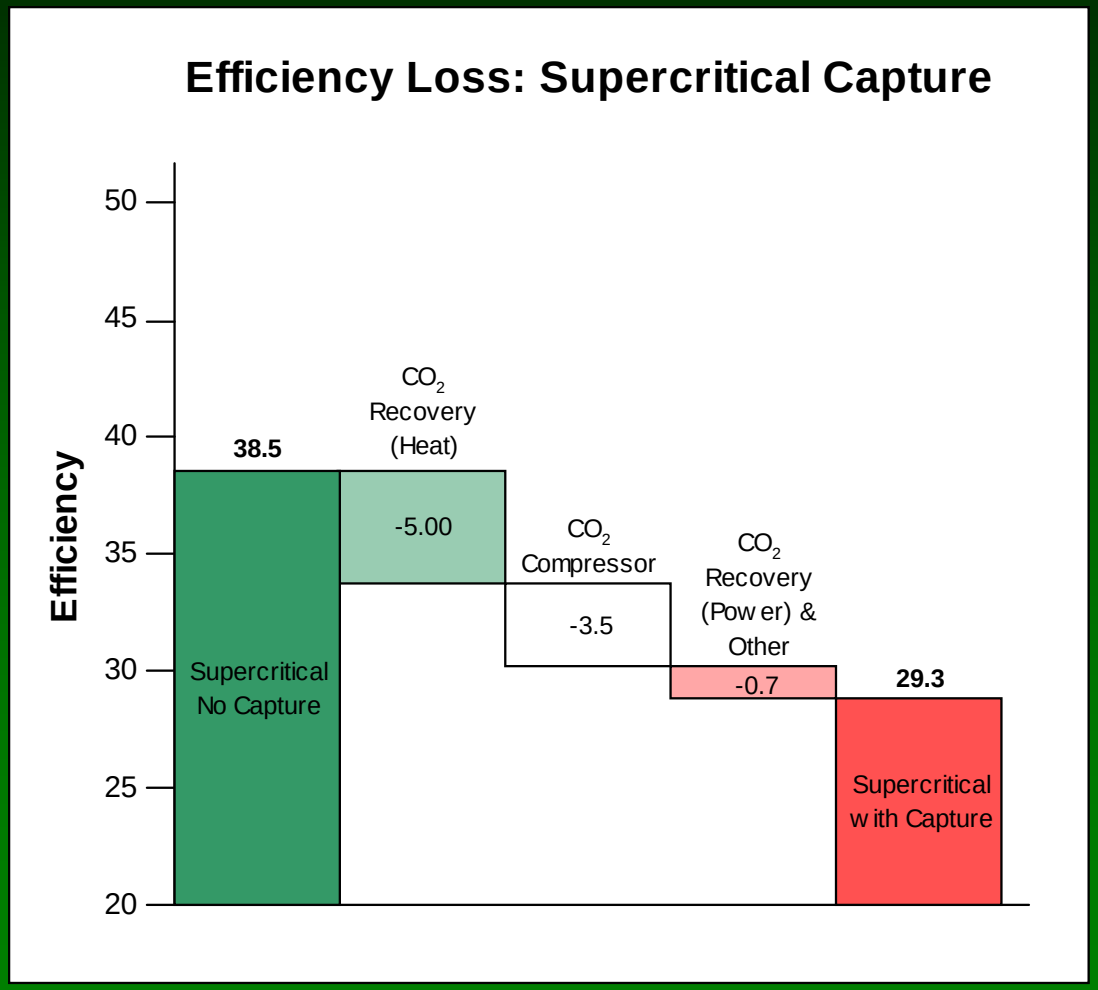


CO_2 Capture at a Coal-Fired Power Plant



Source: ABB Lummus

Parasitic Energy Requirements for PC Plant with Amine Capture

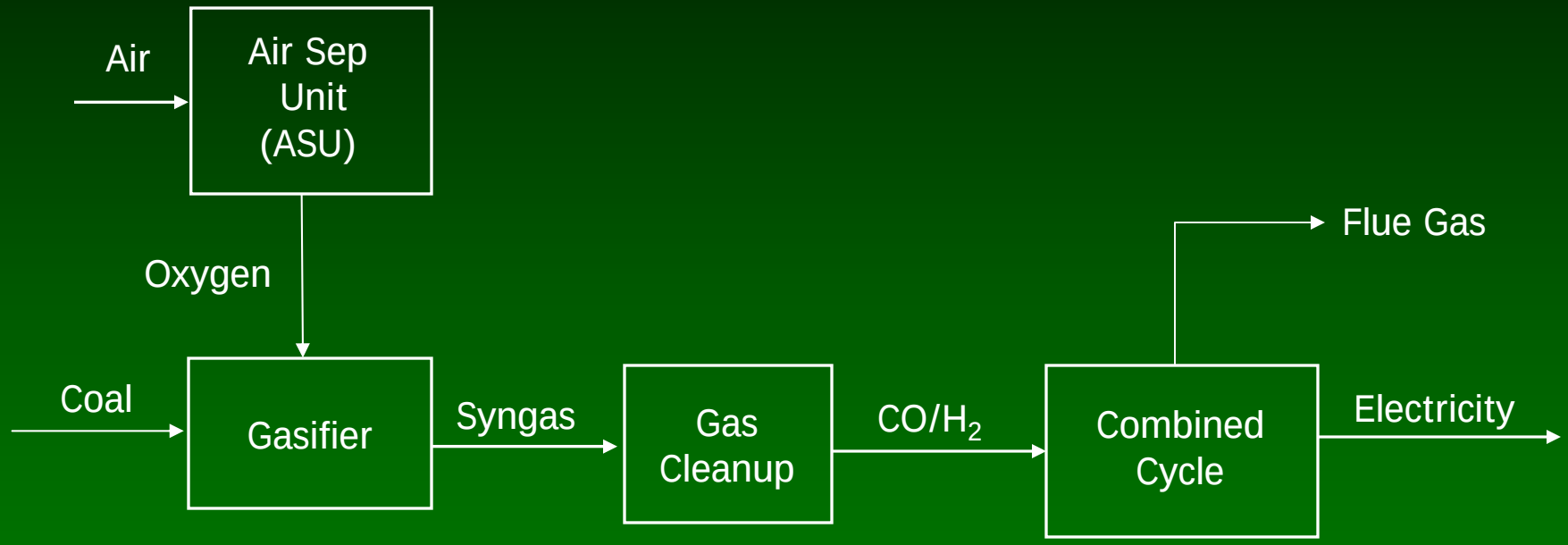


Change Power Generation Process to Facilitate CO_2 Capture

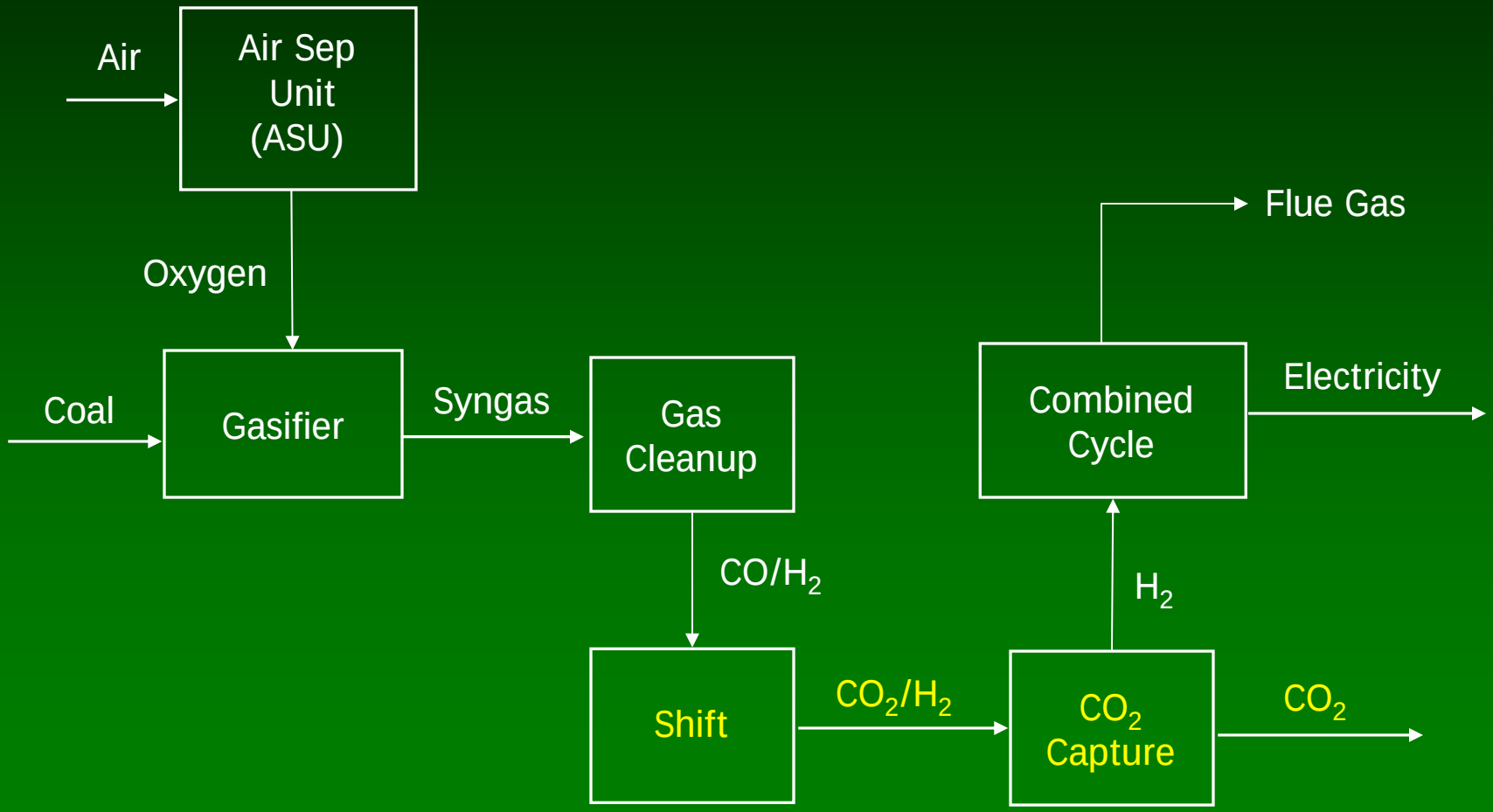
Power Plant	PC	IGCC	PC/Oxy
P (atm)	1	40	1
Fract CO_2	0.15	0.40	0.9
Capture Process	Chemical Absorption	Physical Absorption	Distillation

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

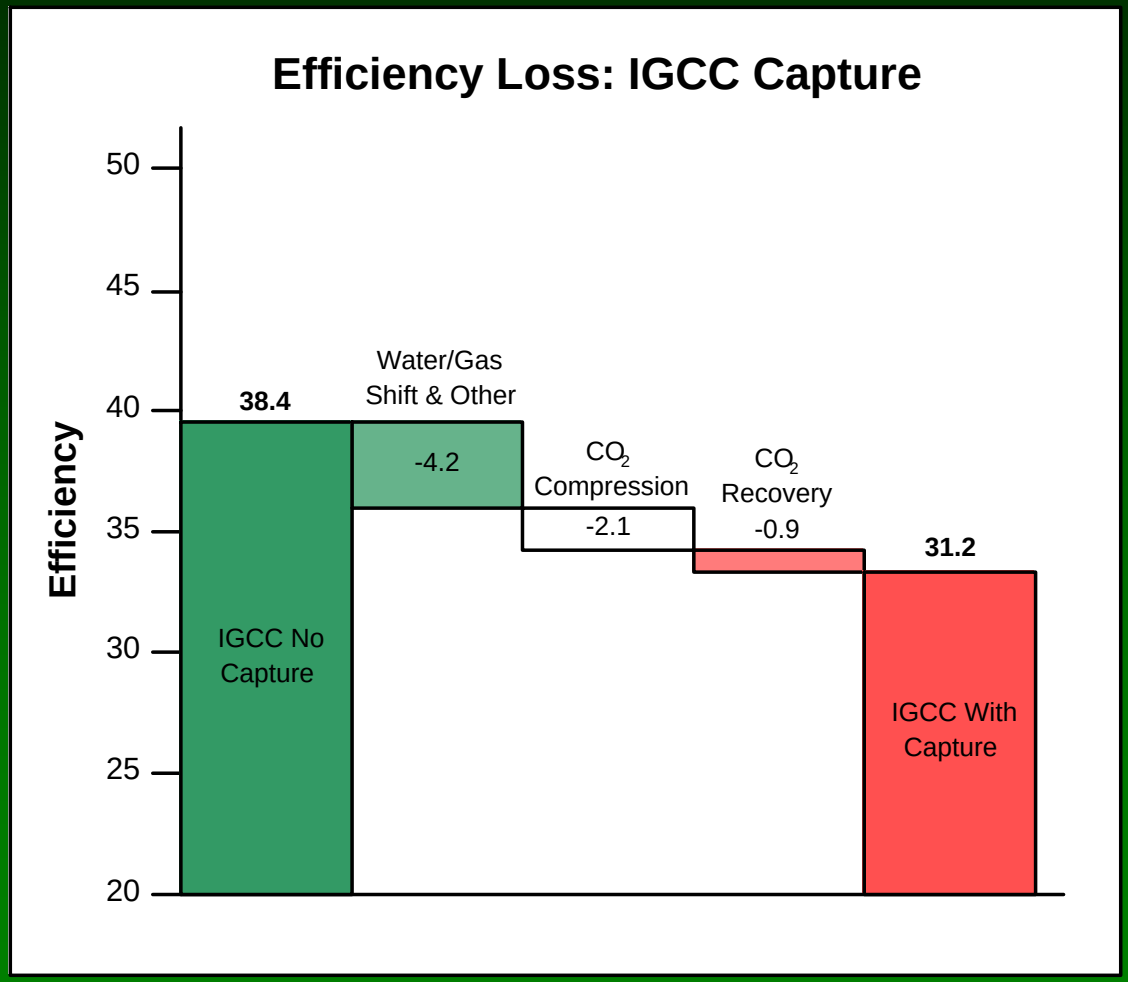
IGCC Power Plant



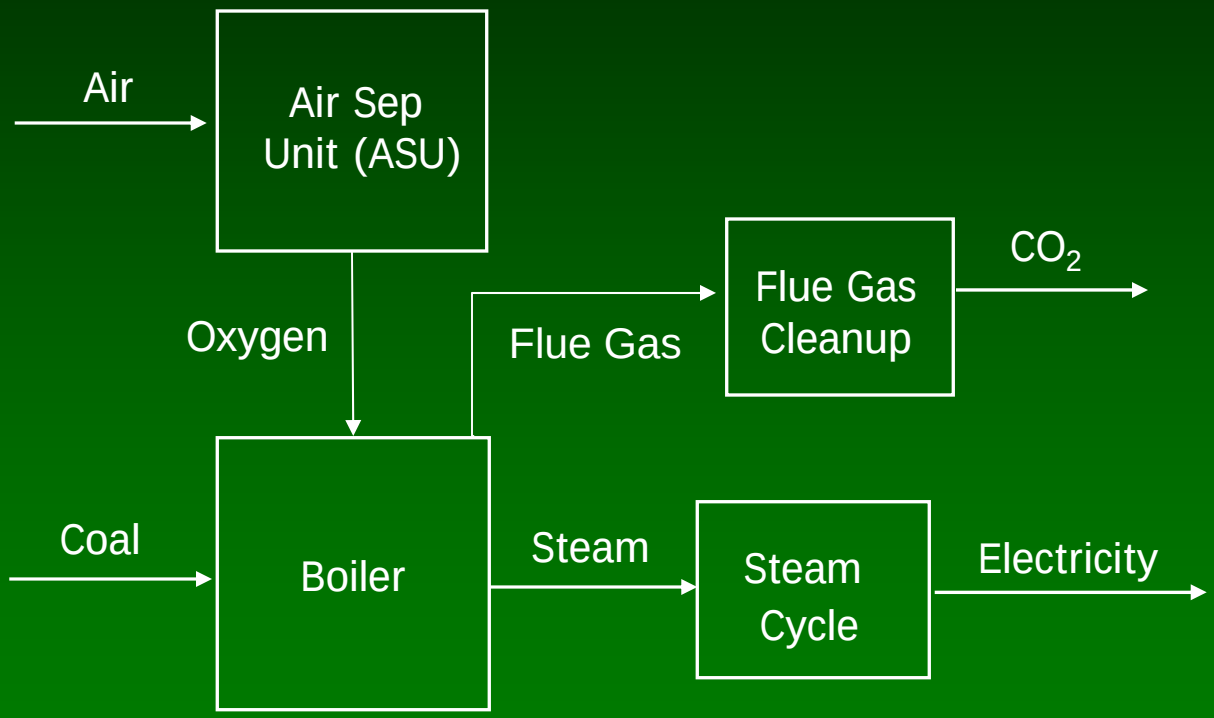
IGCC with Capture



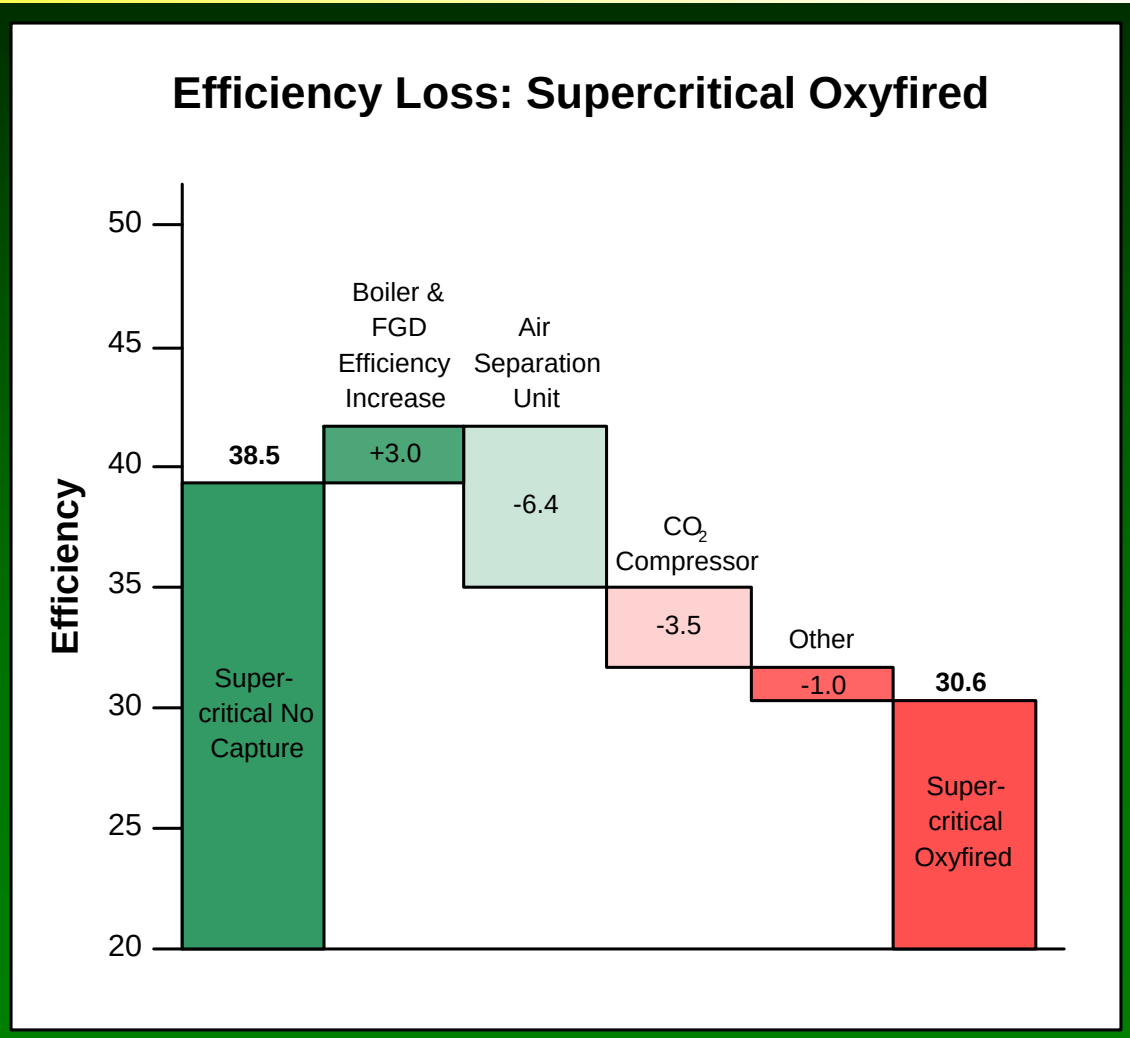
Parasitic Energy Requirements for IGCC with Capture



Oxyfuel Combustion Power Plant



Parasitic Energy Requirements for Oxyfuel Capture



Capture and Compression Costs

- Output – high purity supercritical CO_2
- The numbers that follow are representative and are used to simply compare approaches
- There is much variability in the cost
  - Process Variability – plant location, coal type, criteria emission levels, process integration, etc.
  - Economic Variability – fuel costs, cost of capital, material and labor costs, capacity factor, etc.

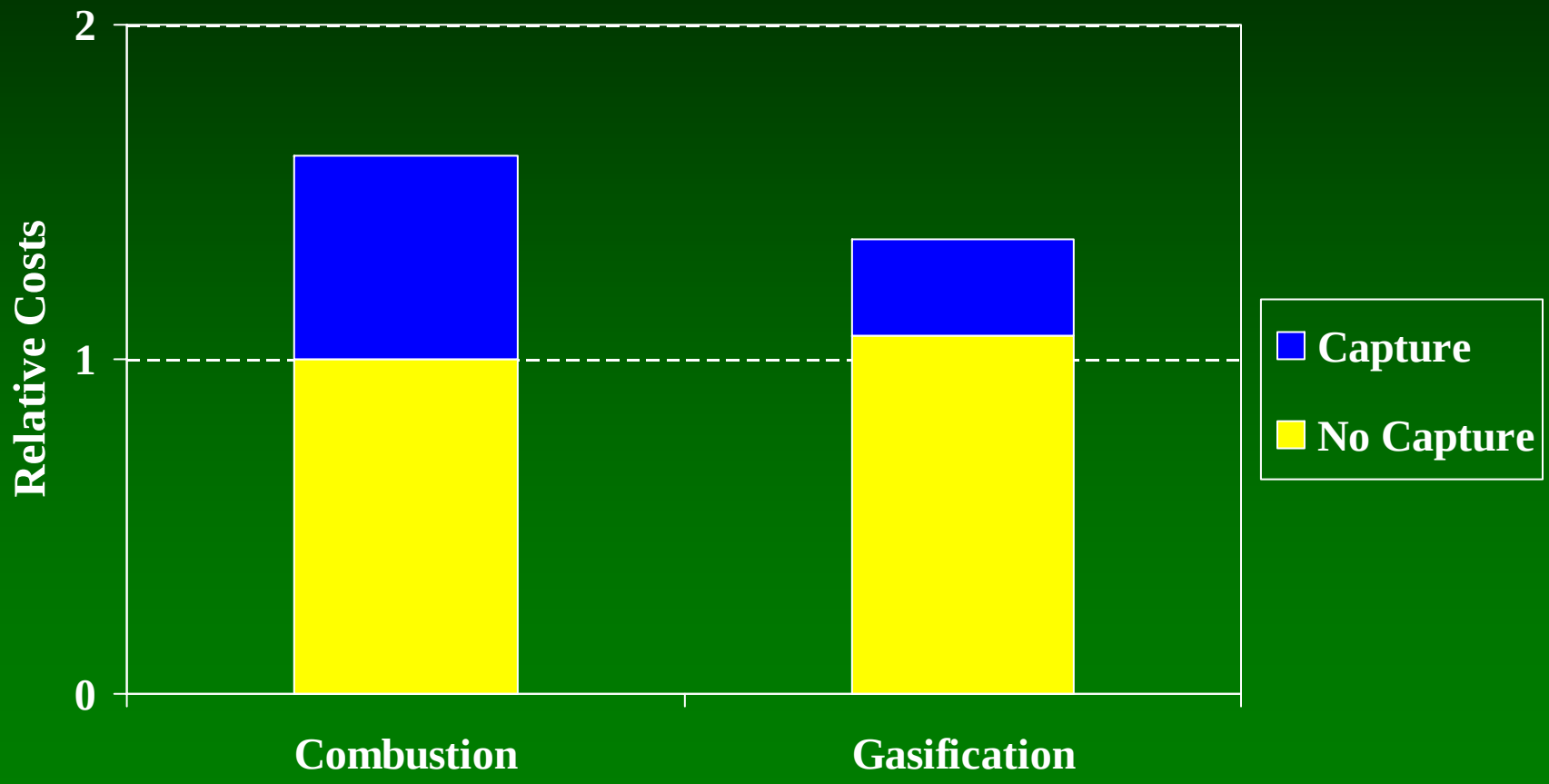
Capture and Compression Capital Costs

Power Plant	Capture Technology	Capital Investment	Power Output	$/kW
SCPC	Post-Combustion	+23%	-24%	+62%
SCPC	Oxyfuel-Combustion	+14%	-20%	+42%
IGCC	Pre-Combustion	+7%	-19%	+32%

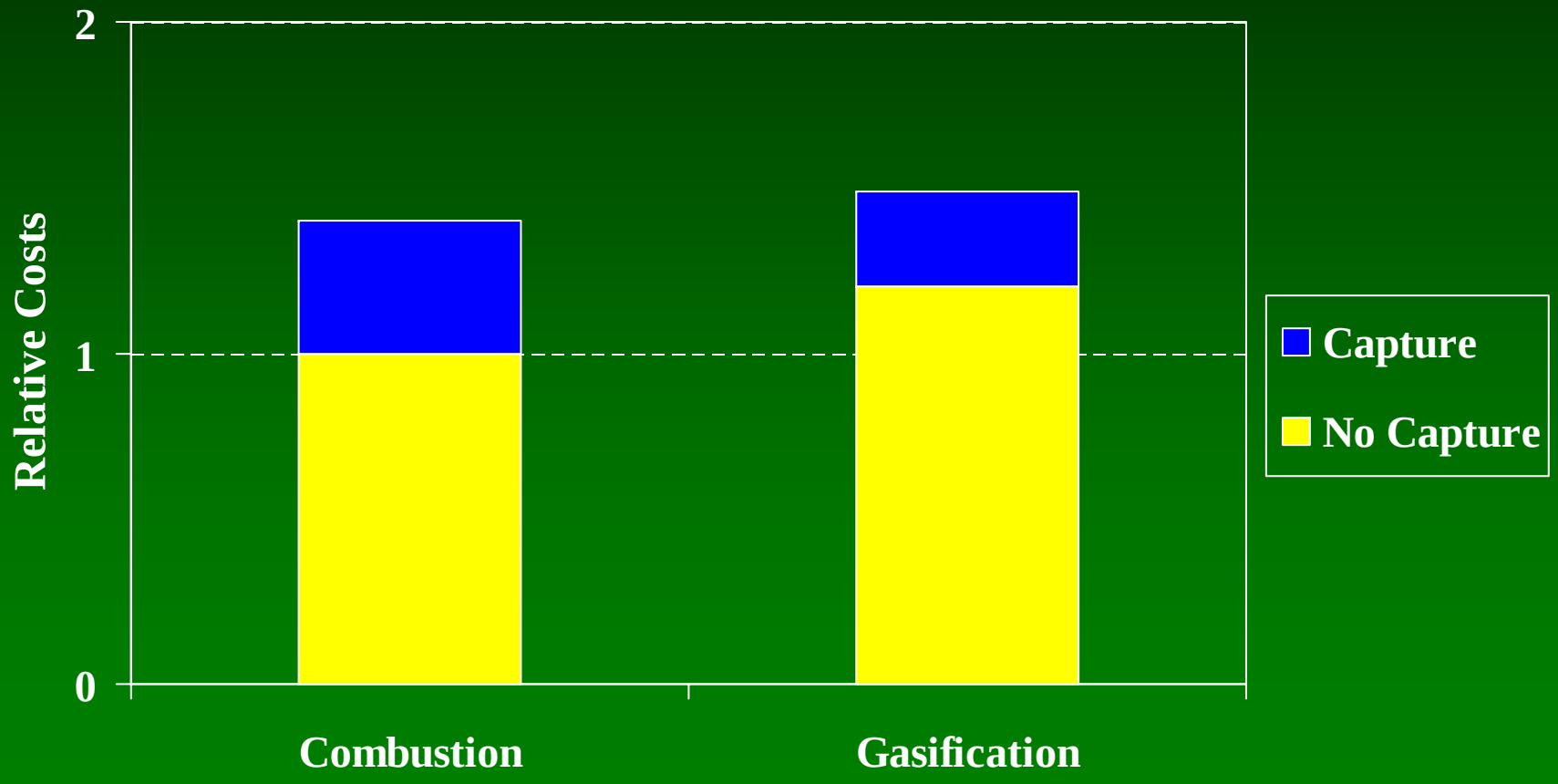
Relative Cost of Electricity

	Without Capture	With Capture
Post-Combustion	1	1.61
Oxyfuel-Combustion		1.46
Pre-Combustion	1.07	1.36

Relative Cost of Electricity



Relative Cost of Electricity



PC vs. IGCC Comparison

- Without capture
  - Efficiencies similar (~38.5% HHV)
  - Both handle criteria pollutant requirements
  - IGCC costs more (+20% today, +7% n^{th} plant)
  - Limited IGCC operating experience (availability)
- With capture
  - Incremental cost less for IGCC (32% vs. 62%)
  - Energy penalty less for IGCC (19% vs. 24%)
  - IGCC more complex
  - PC more fuel flexible

MIT Coal Study
Finding #6

- It is premature to select one coal conversion technology as the preferred route for cost-effective electricity generation combined with CCS.
  - Variability in location, coal type, etc.
  - Uncertainty in technological progress

Retrofits

- MIT Coal Study – "Coal plants will not be cheap to retrofit for CO_2 capture."
- Limitations at existing plants
  - Space
  - Storage site access
  - Efficiency
- Design of optimal "capture" plant differs from that of a "no capture" plant

Design considerations
Capture vs. no capture

- PC capture
  - Capture process
  - Compressor
  - Tighter SO_2 specs
  - Integration with LP turbine
  - High parasitic power requirement
- IGCC capture
  - Shift reactors
  - Capture process
  - Compressor
  - Quench design
  - Turbine design
  - Gasifier pressure
  - ASU/gasifier vs. turbine size
  - AGR sizing
  - ASU/Turbine integration
  - Moderate parasitic power requirement

MIT Coal Study
Capture-Ready

- Other than a few low-cost measures such as providing for extra space on the plant site and considering the potential for geologic CO_2 storage in site selection, the opportunity to reduce the uncertain eventual cost of CCS retrofit by making preparatory investment in plants without CO_2 capture does not look promising.

Building a Coal Plant Today

- Push efficiency as high as economically justifiable
  - Minimizes CO_2 produced per kWh
  - Lessens cost of possible retrofit for CCS
- Space for capture process
- Access to storage site

Cost Summary

- CCS (all components) will add $20-30 per MWh to cost of electricity. This cost assumes:
  - 2005$
  - n^{th} plant
  - Today's technology (i.e., no technological breakthroughs required)
  - Regulatory issues resolved without imposing significant new burdens
  - Operations at scale (i.e., transition costs not included)

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