CO_2 CONTROL TECHNOLOGY EFFECTS ON IGCC PLANT PERFORMANCE AND COST

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Motivation

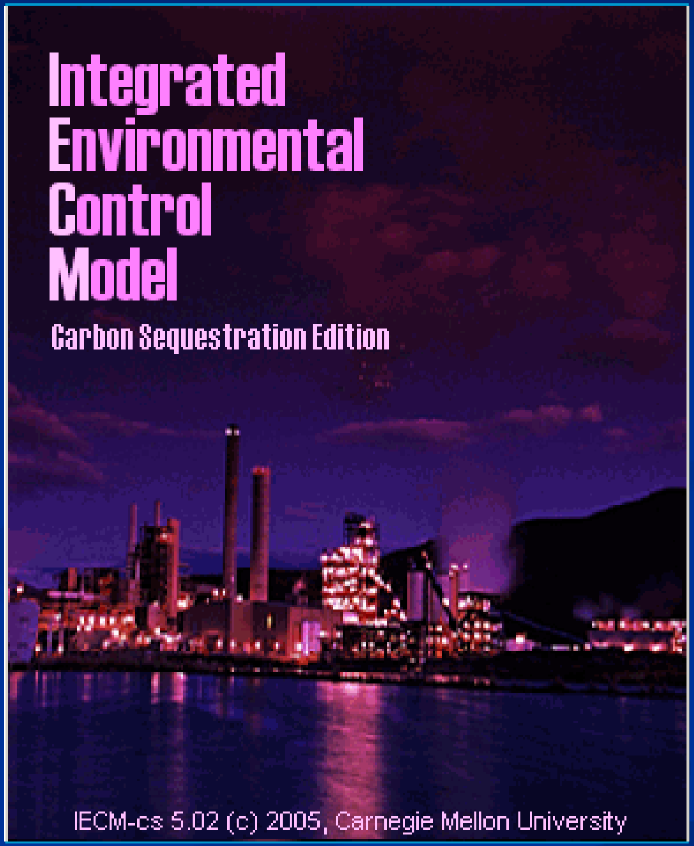
- No generally available process models that can be easily used or modified to study IGCC with CO_2 capture for different assumptions and technology selections
- Uncertainties in performance and cost are also seldom considered

Research Objectives

- Provide a method and tools for systematic comparison of IGCC system with and without CO_2 capture
- Investigate factors influencing IGCC systems with CO_2 capture
- Describe key uncertainties in performances and costs of IGCC systems with CO_2 capture

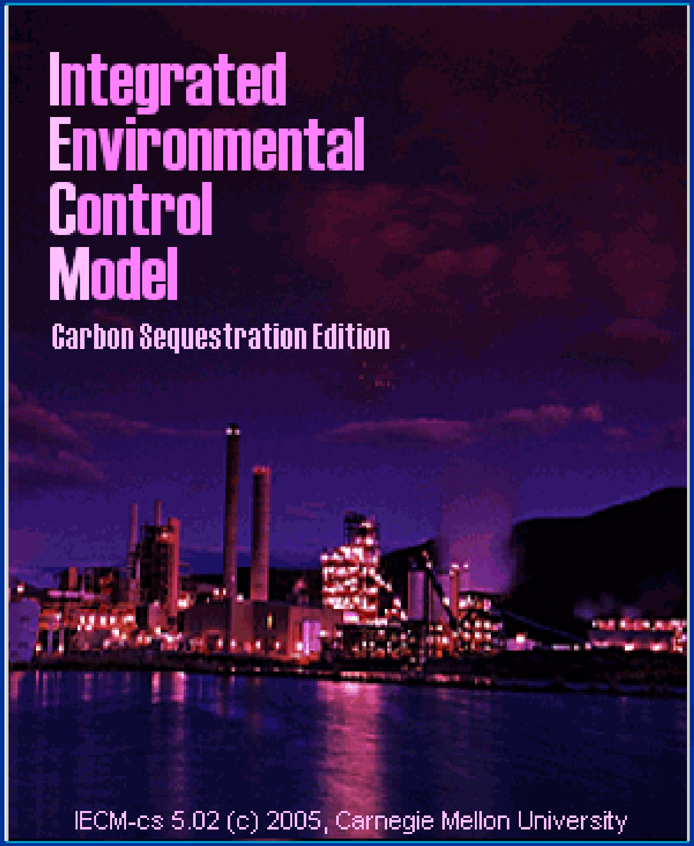
The IECM

- A desktop computer model developed for DOE/NETL
- Provides preliminary design estimates of performance, emissions, costs and uncertainties:
  - PC, NGCC and IGCC plants
  - Emission control systems
  - CO_2 capture and storage options (pre- and post-combustion, oxy-combustion, transport, storage)
- Roughly 1000 users worldwide

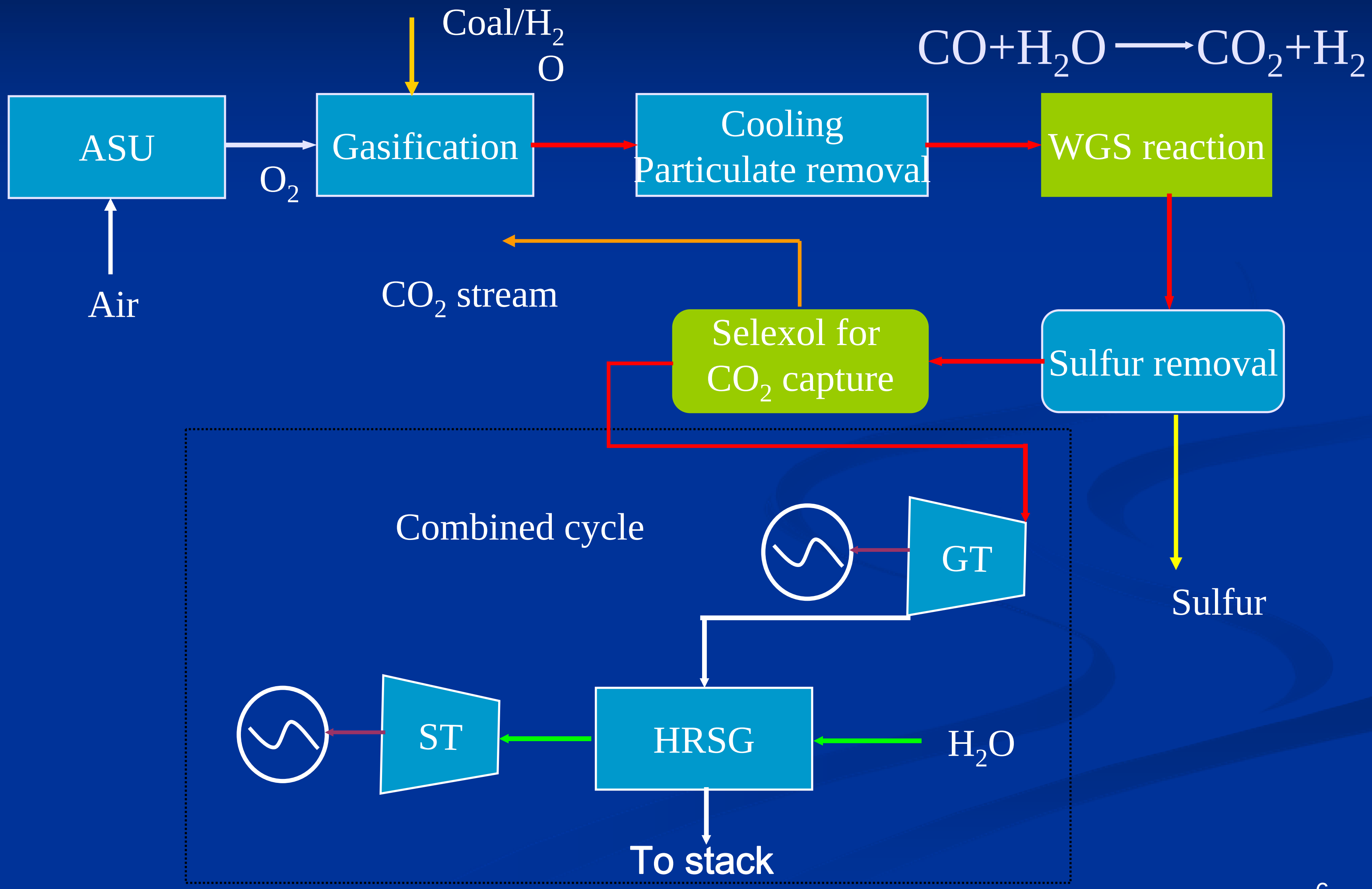


The Integrated Environmental Control Model (IECM)

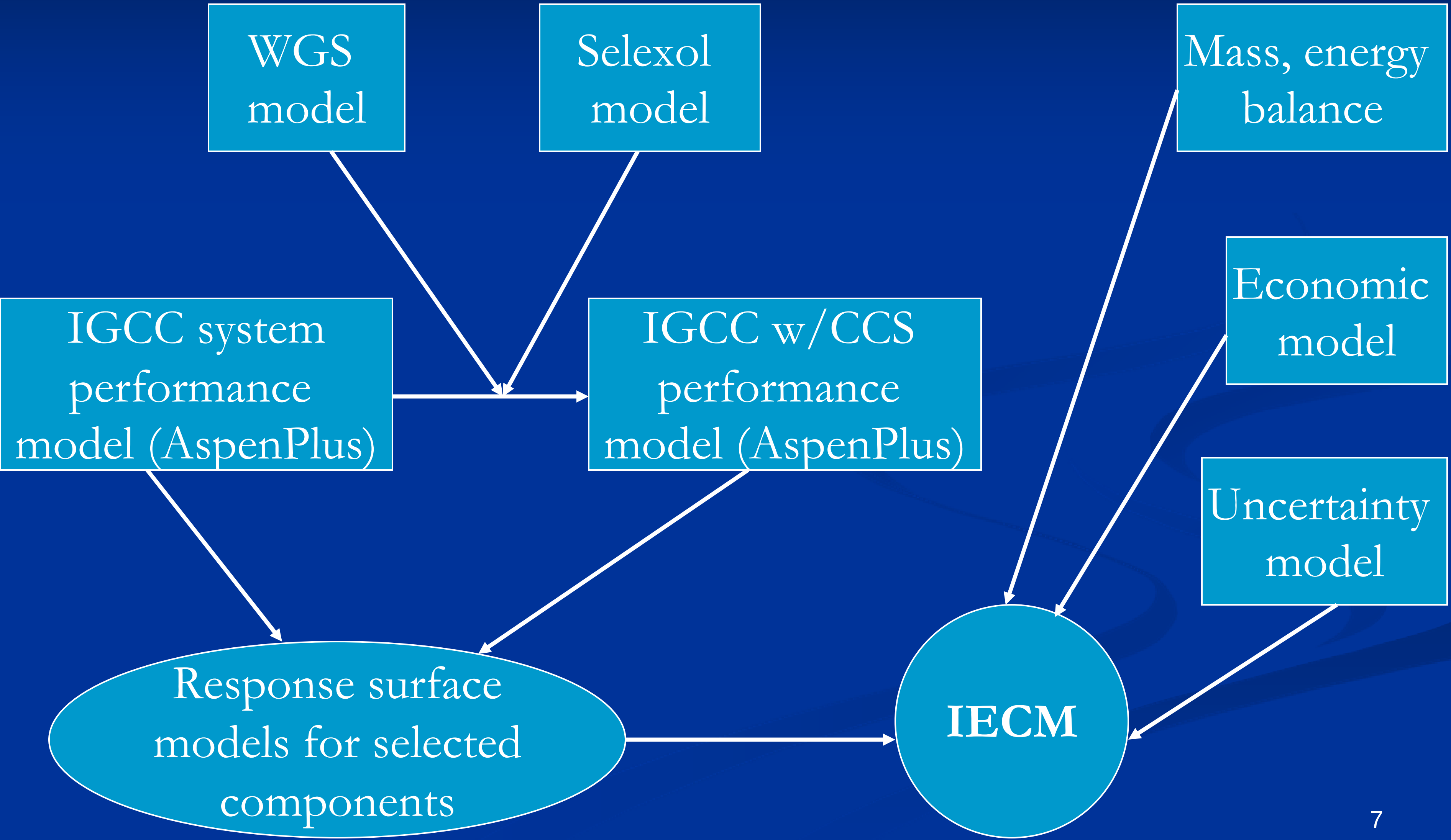
- Free Web Download :
  - www. iecm-online.com
- Technical Support:
  - PED.modeling@netl.doe.gov



IGCC with CO_2 Capture



Modeling Approach for IGCC Systems



Design Assumption for IGCC Power Plant Case Studies

Parameter	Value
GE quench gasifier	2 or 1 operating plus one spare
Gas turbine	GE 7FA (2 or 1 turbines)
Steam cycle (HRSG)	1400 psi/1000°F/1000°F
Design ambient conditions	59 °F/14.7 psia
Capacity factor	75%
Fixed charge factor	14.8%
Cost year	2002
For CO_2 capture plant	
Overall CO_2 capture efficiency	90%
CO_2 product pressure	2100 psia
CO_2 transport and storage cost	10 $/tonne CO_2

Effects of CO_2 capture
(Pittsburgh #8 coal)

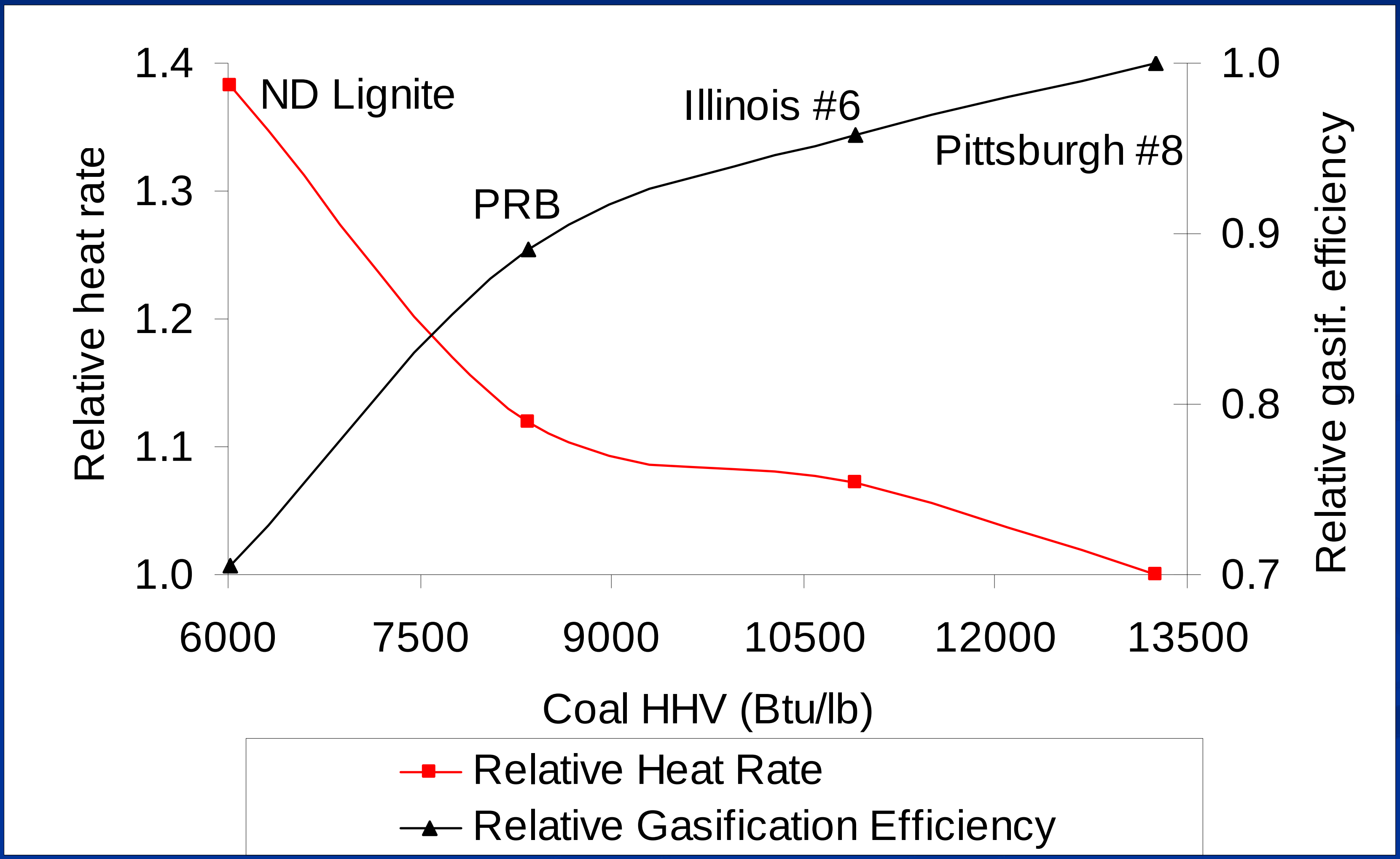
	TCR ($/kW)	COE ($/MWh)	Thermal efficiency (HHV)	Net power (MW)	CO_2 emission (kg/kWh)
Reference plant	1312	48.4	37.1%	538	0.82
Capture plant	1714	69.9	32.0%	502	0.10
Change %	30.6%	44.4%	-16.0%	-6.7%	-87.8%

Effects of Coal Composition

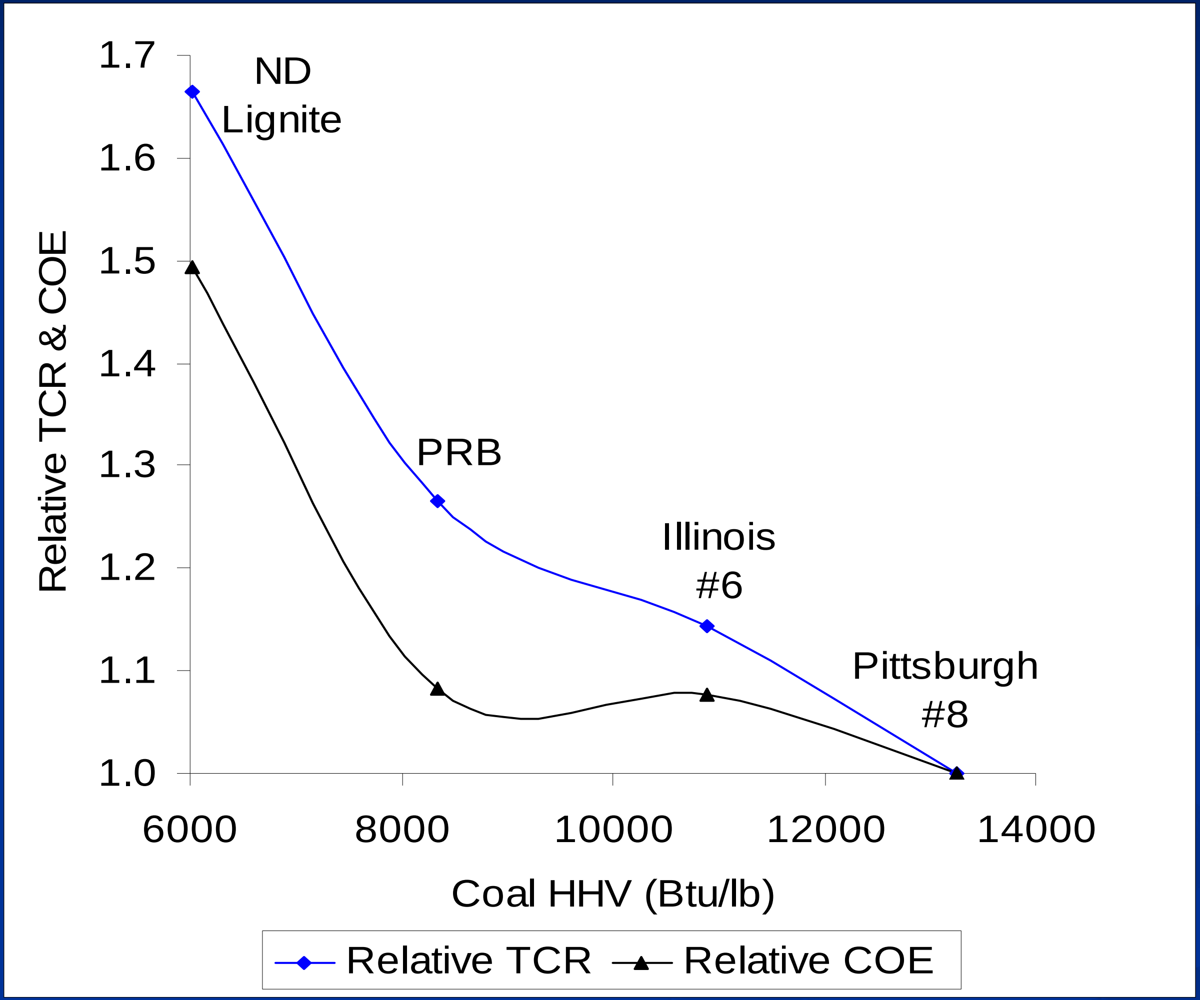
Coal type	Pittsburgh #8	Illinois #6	Wyoming PRB	ND Lignite
Coal rank	Bituminous	Bituminous	Sub-bituminous	Lignite
HHV (Btu/lb)	13,260	10,900	8,340	6,020
Total water in slurry	34%	37%	44%	50%

(Source: EPRI)

Effect of Coal Quality on Efficiency



Effect of Coal Quality on Total Capital Reqm't (TCR) and Cost of Electricity (COE)



Coal price ratios based on minemouth prices:
Pitts #8: Illinois #6: PRB: Lignite = 1.0: 0.67: 0.2: 0.26

Reference plant efficiency − Capture plant efficiency

Reference plant efficiency

Effects of CO_2 Capture Efficiency

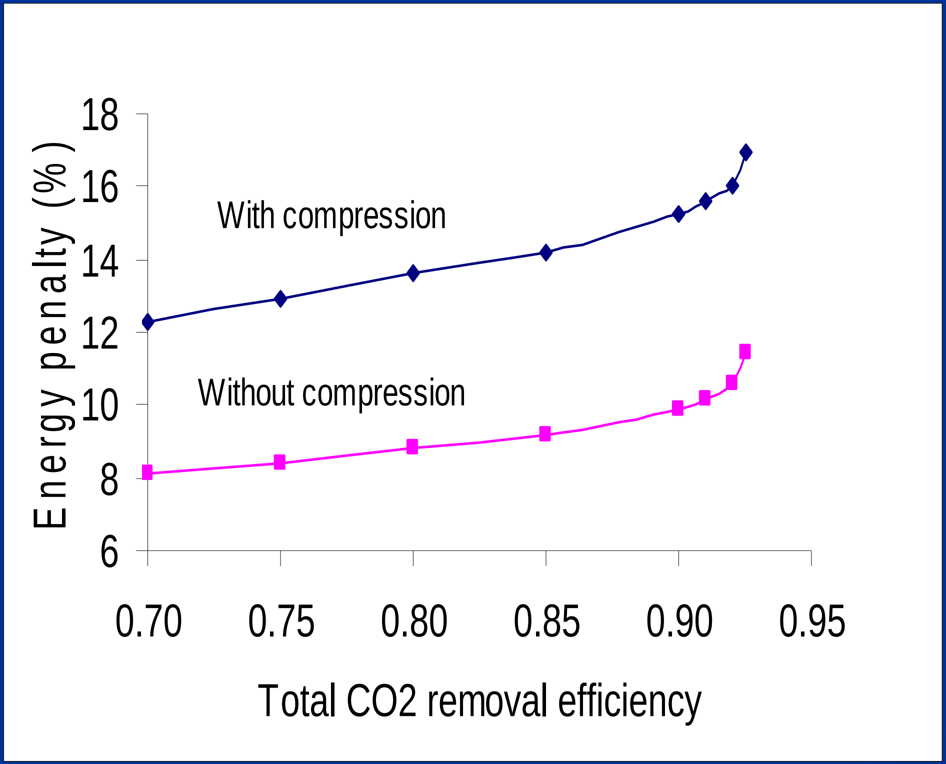
CO_2 capture efficiency= $$\frac{CO_2 \quad captured(mole)}{Total \quad carbon \quad in \quad syngas \quad from \quad gasifier(mole)}$$

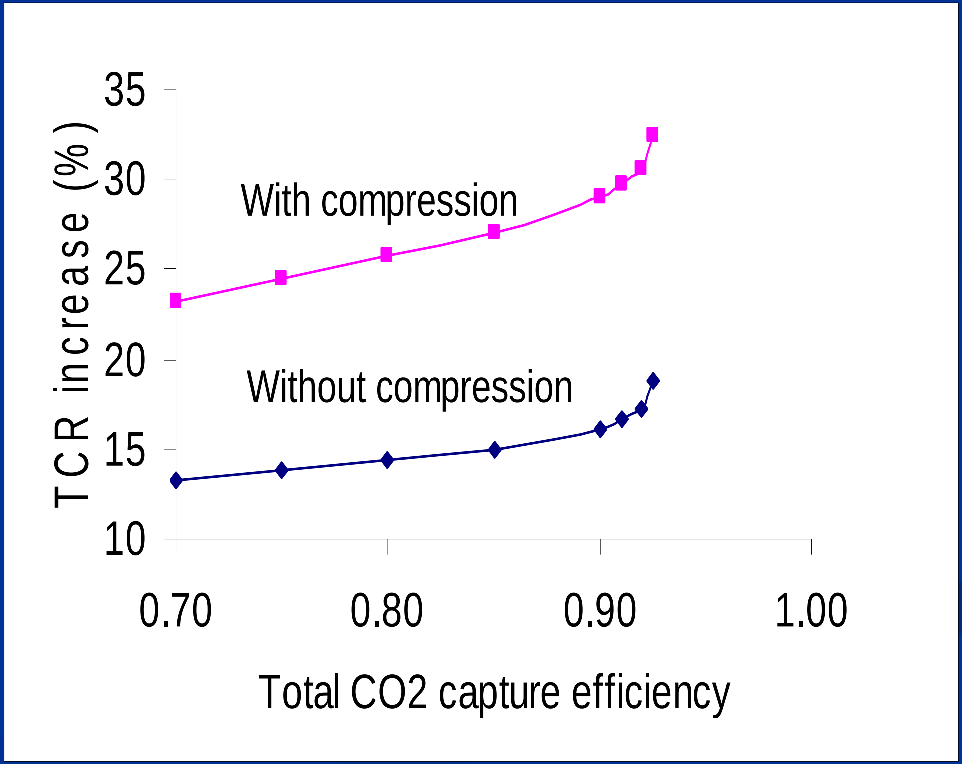
CO_2 Avoidance Cost = $$\frac{COE_{cap} - COE_{ref}}{(CO_2 / kWh)_{ref} - (CO_2 / kWh)_{cap}}$$

Energy Penalty (EP) = $$\frac{\mathrm{Re}f. \quad plant \quad eff. - Cap. \quad plant \quad eff.}{\mathrm{Re}f. \quad plant \quad eff.}$$

Effect of Capture Efficiency on Energy Penalty and TCR

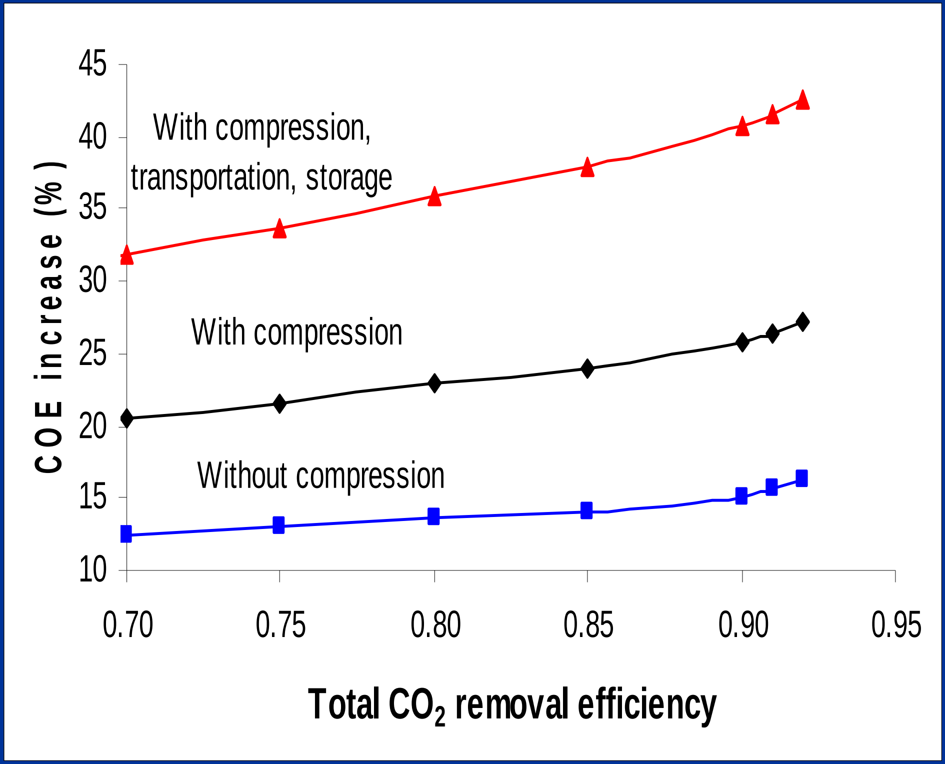
(Pittsburgh #8 coal, Reference plant net power output: 267 MW)

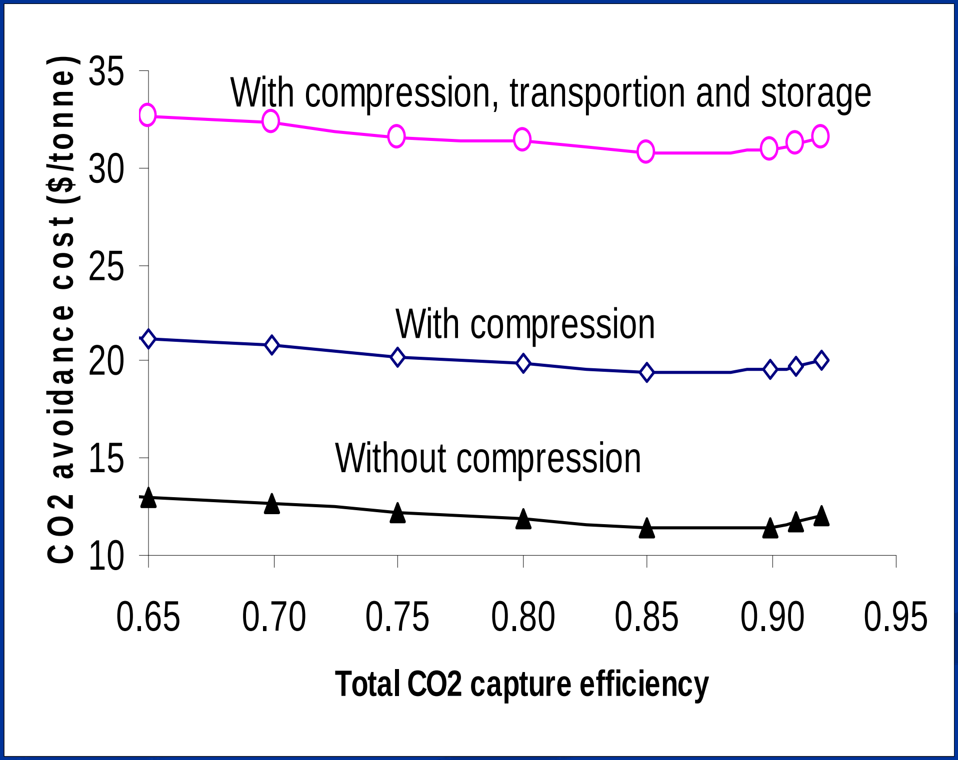




Effect of Capture Efficiency on COE and Avoidance Cost

(Pittsburgh #8 coal, Reference plant net power output: 267 MW)





Preliminary Uncertainty Analysis

Probability distributions assigned to:

- **Basic IGCC process**
  - – Component capital costs
  - – Indirect costs (e.g., process contingencies)
  - – Fixed and variable O&M costs

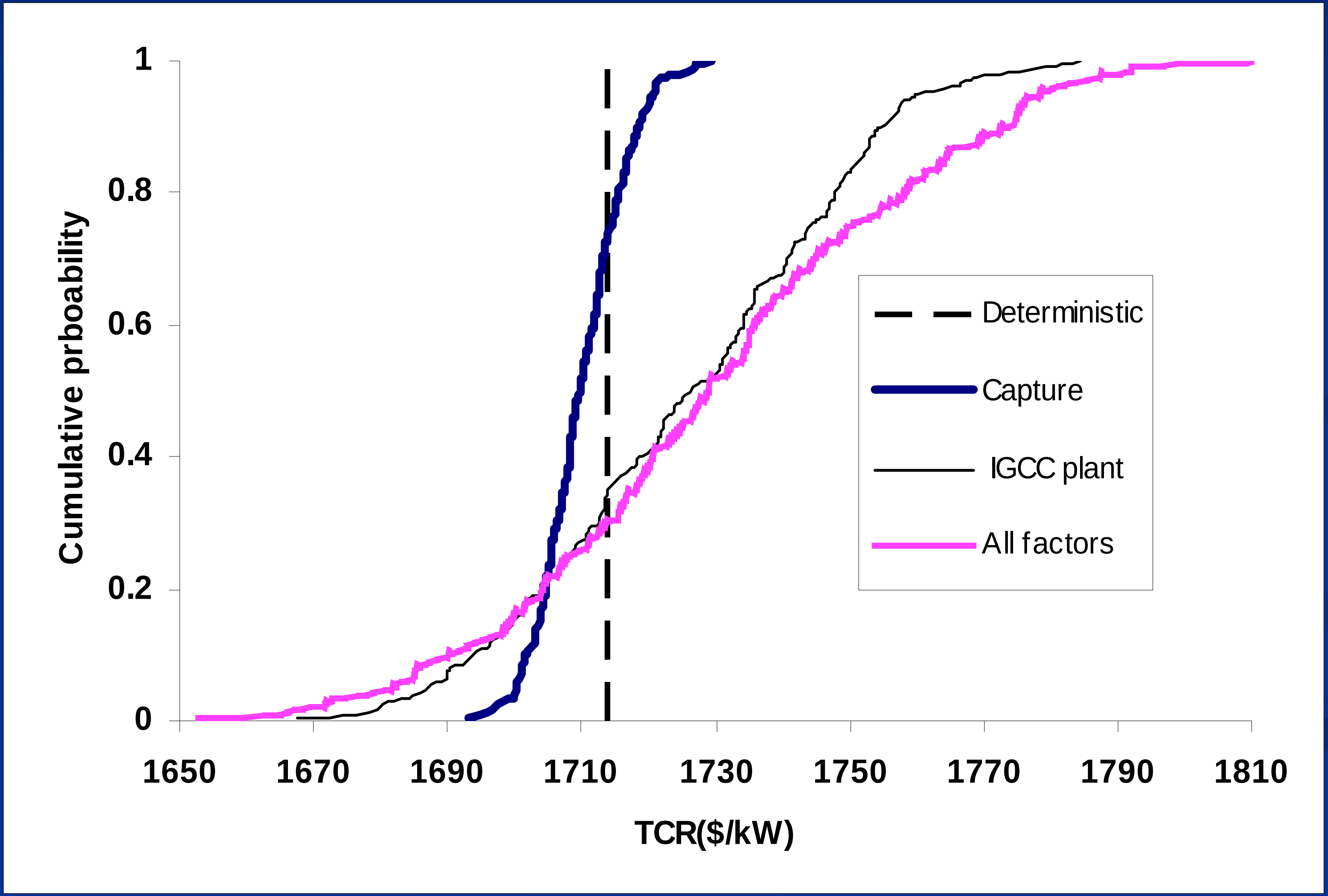
- **CO_2 capture technologies**
  - – WGS and Selexol performance
  - – WGS and Selexol capital cost
  - – WGS and Selexol O&M cost

Distribution Functions for Capture Processes

Model parameter	Unit	Nominal value	Distribution function
Mole weight of Selexol	lb/mole	280	Triangular(265,280,285)
Pressure at flash tank 1	Psia	60	Uniform(40,75)
Pressure at flash tank 2	Psia	20	Uniform(14.7,25)
Pressure at flash tank 3	Psia	7	Uniform(4,11)
Power recovery turbine efficiency	%	75	Uniform(70,80)
Selexol pump efficiency	%	75	Uniform(70,80)
Recycle gas compressor efficiency	%	75	Uniform(70,80)
CO_2 compressor efficiency	%	79	Triangular(75,79,85)
Cost parameter	Unit	Value	Distribution function
WGS catalyst cost	$/ft^3	250	Triangular(220,250,290)
Selexol solvent cost	$/lb	1.96	Triangular(1.32,1.96,2.9)
Process contingency of WGS system	% of PFC	5	Triangular(2,5,10)
Selexol process contingency system	% of PFC	10	Triangular(5,10,20)
Maintenance cost of WGS system	% of PFC	2	Triangular (1, 2, 5)
Maintenance cost of Selexol system	% of PFC	2	Triangular(1,2,5)

CDF of Capture Plant TCR

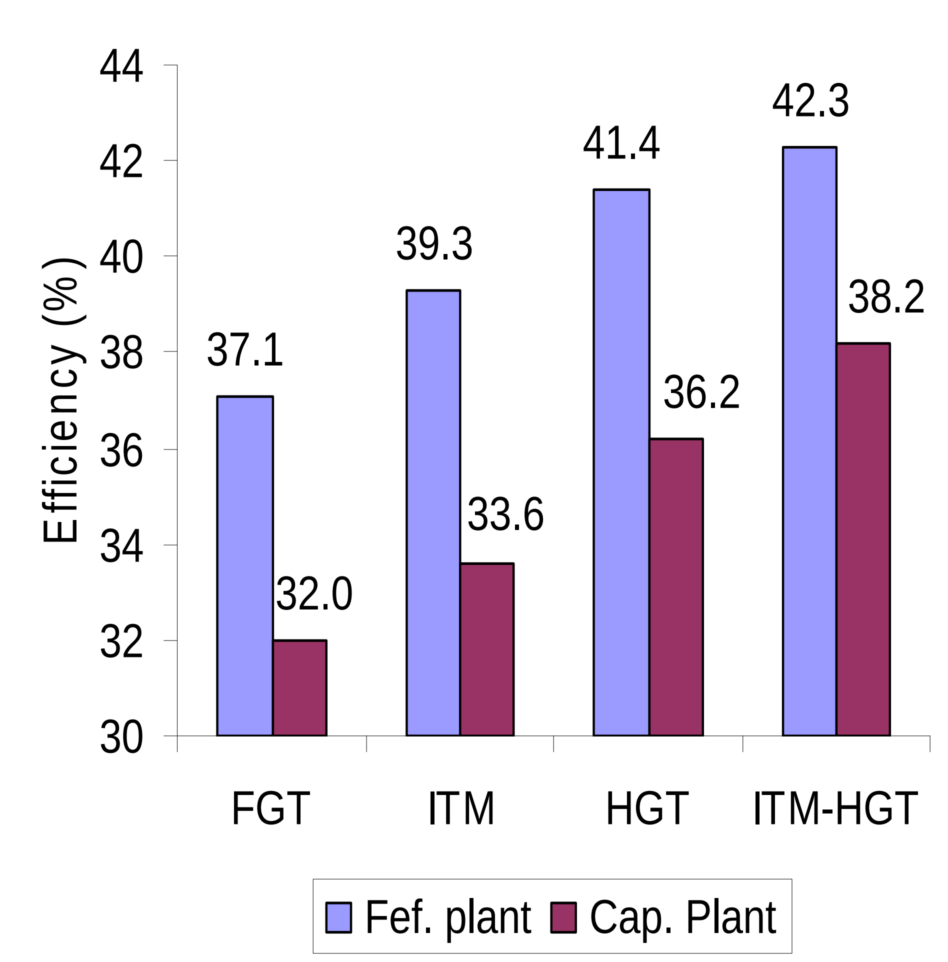
(Pittsburgh #8 coal, Net power output: 502 MW)

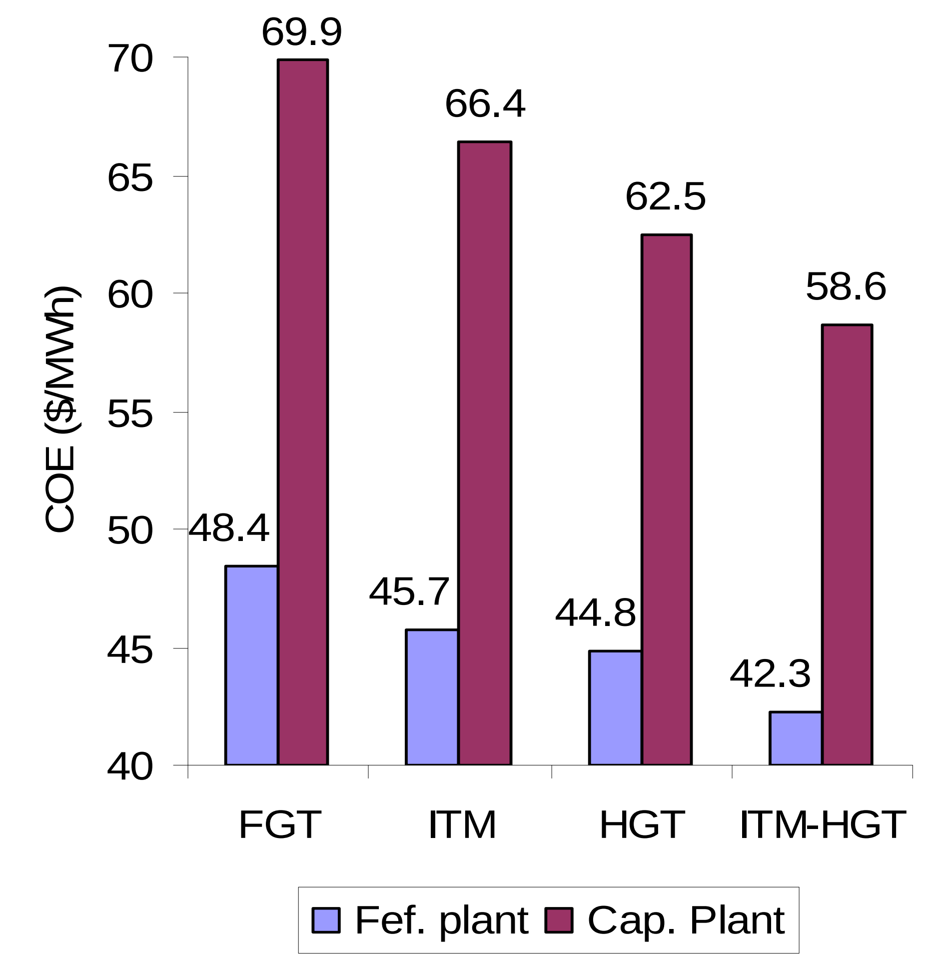


Advanced IGCC Technology

- **Advanced gasifier**
  - Higher efficiency, reliability, and operating pressure
- **Advanced air separation unit (ASU)**
  - High thermal integration with IGCC system
- **Syngas cleanup process**
  - Less expensive particulate removal systems or hot gas filtration
- **Advanced gas turbines**
  - Higher efficiency and capacity to burn syngas and hydrogen-rich fuels
- **Optimal integration of new technologies and components**

Efficiency and Cost of Electricity for Advanced Plant Designs





Conclusions

- Many factors affect the performance and cost of an IGCC with CCS:
  - Coal rank has a strong influence on performance and cost with or without CCS. Higher rank coals are preferred for the systems analyzed here
  - Current case studies show that with a Selexol-based CO_2 capture process, CO_2 avoidance cost is lowest when the total CO_2 removal efficiency is in the range of 85%~90%

Conclusions (con't)

- Most of the uncertainty in capital cost of an IGCC capture plant comes from the IGCC process rather than the capture process
- Expected advances in oxygen production and gas turbine technologies can greatly improve the performance and cost of IGCC systems with CCS