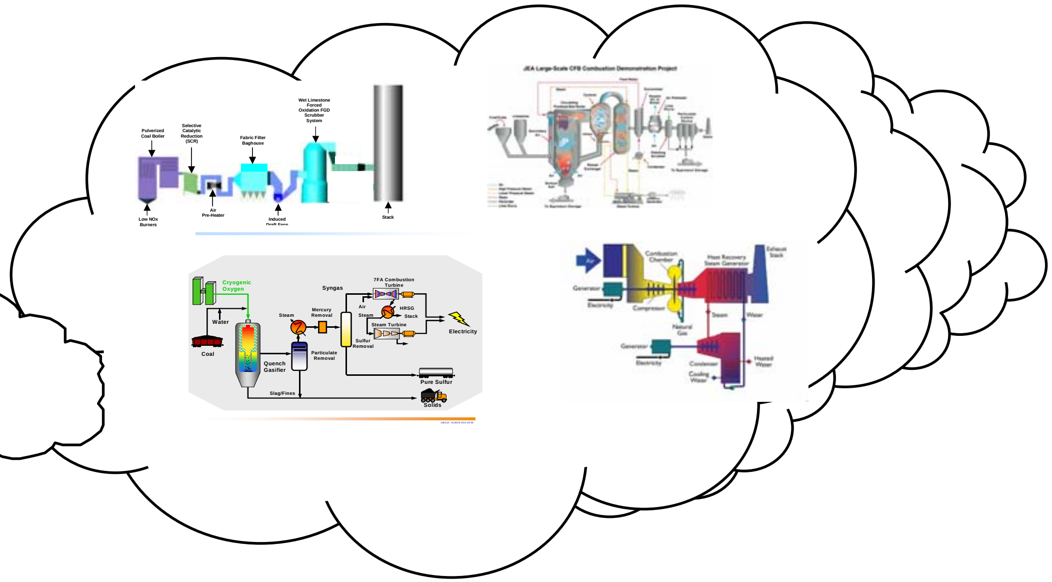
IGCC

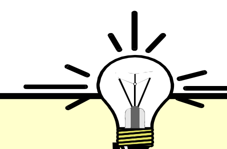
Pathway for a Future for Coal

Michael J. Mudd

Manager Generation Technologies

What technology should we use for our next generation???



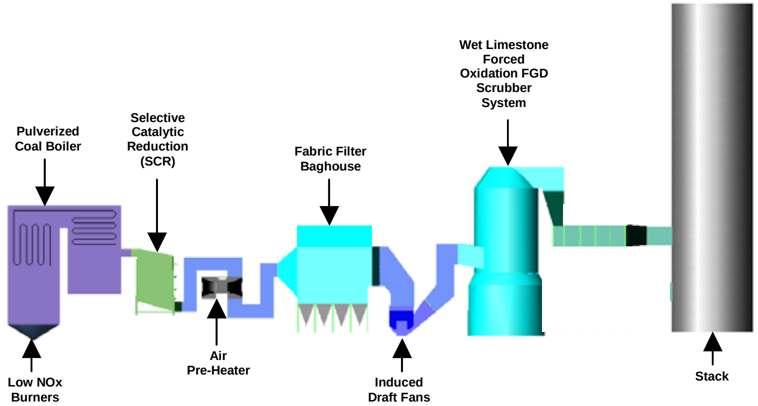


The answer is not a simple one!

Generating Technology Options

	PC	IGCC	CFB	NGCC
Nominal Capacity (MW)	600	600	400	500
Heat Rate (BTU/kWh)	8700	8500	9500	7000
EPC Cost ($/kW)	1200	1450	1300	400
Total Plant Cost ($/kW)	1450	1750	1550	470
Cost of Electricity ($/MWh)	53	60	56	52

Source: EPRI estimates



Source Alstom Power

Pulverized Coal (PC) Plants

***Take away**: PC is the least-cost option for new coal plants when the cost of CO_2 removal is not considered.*

Generating Technology Options

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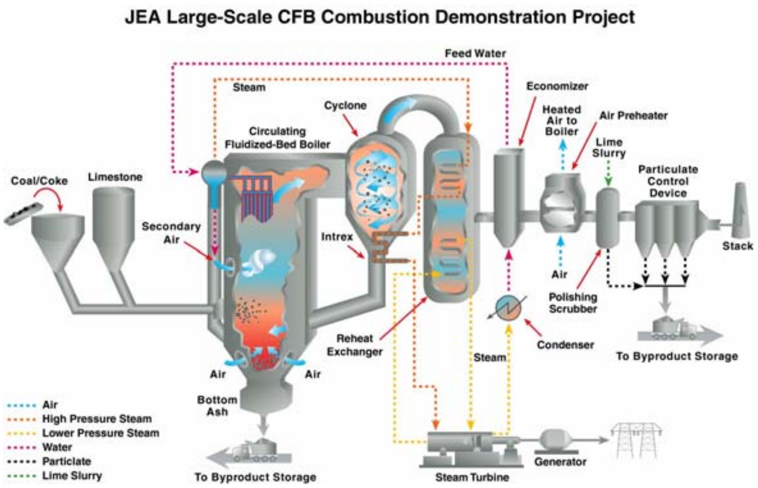

Circulating Fluidized Bed (CFB) Plants

Source US Department of Energy

Take away *CFB is the technology of choice for low-BTU coals such as lignite. CFB technology does not currently provide better options for CO_2 removal.*

Generating Technology Options

	PC	IGCC	CFB	NGCC
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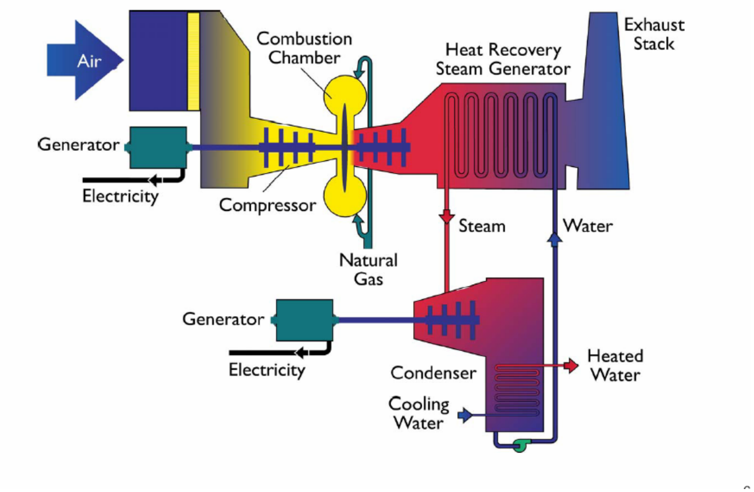

Source EPRI

NGCC (Natural Gas Combined Cycle) Plants

Take away*: NGCC is currently the least-cost option and allows the most MWs for the least capital at risk, but their dispatch depends on gas price; the average capacity factor of NGCC plants in 2003 was about 25%.*

Generating Technology Options

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Nominal Capacity (MW)	600	600	400	500
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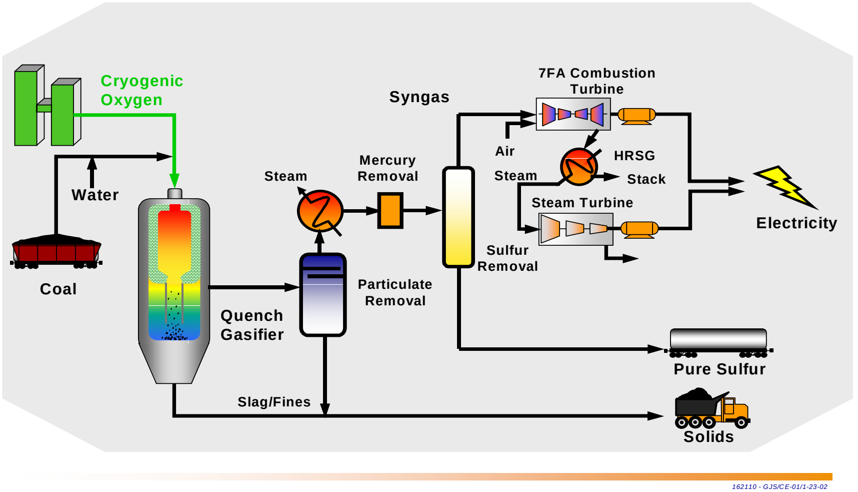
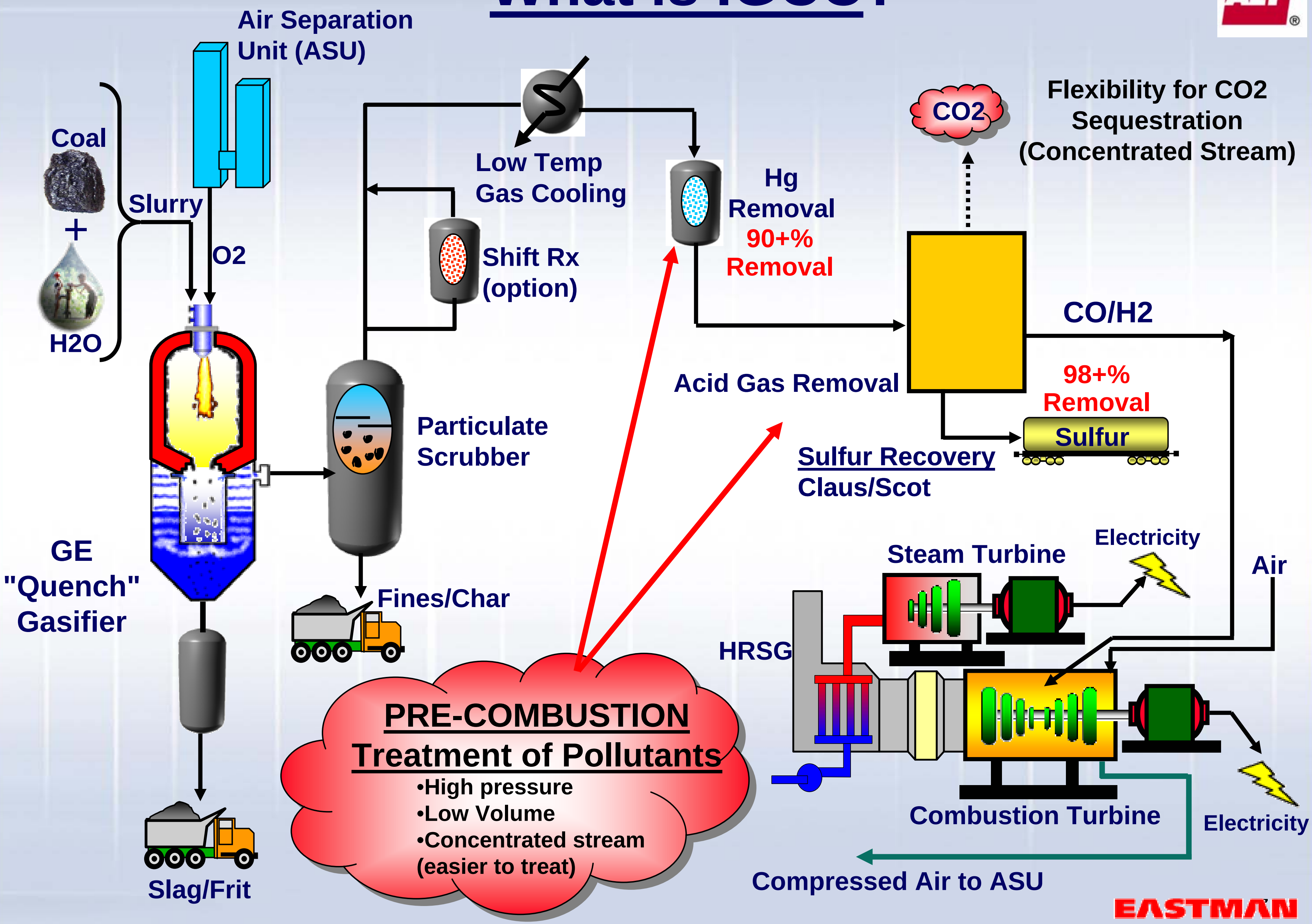


Source US Department of Energy

Integrated Gasification Combined Cycle (IGCC) Plants

***Take away**: EPRI studies are indicating that IGCC Plant costs are approaching those of conventional technologies; this is yet to be tested in the marketplace with real contracts.*

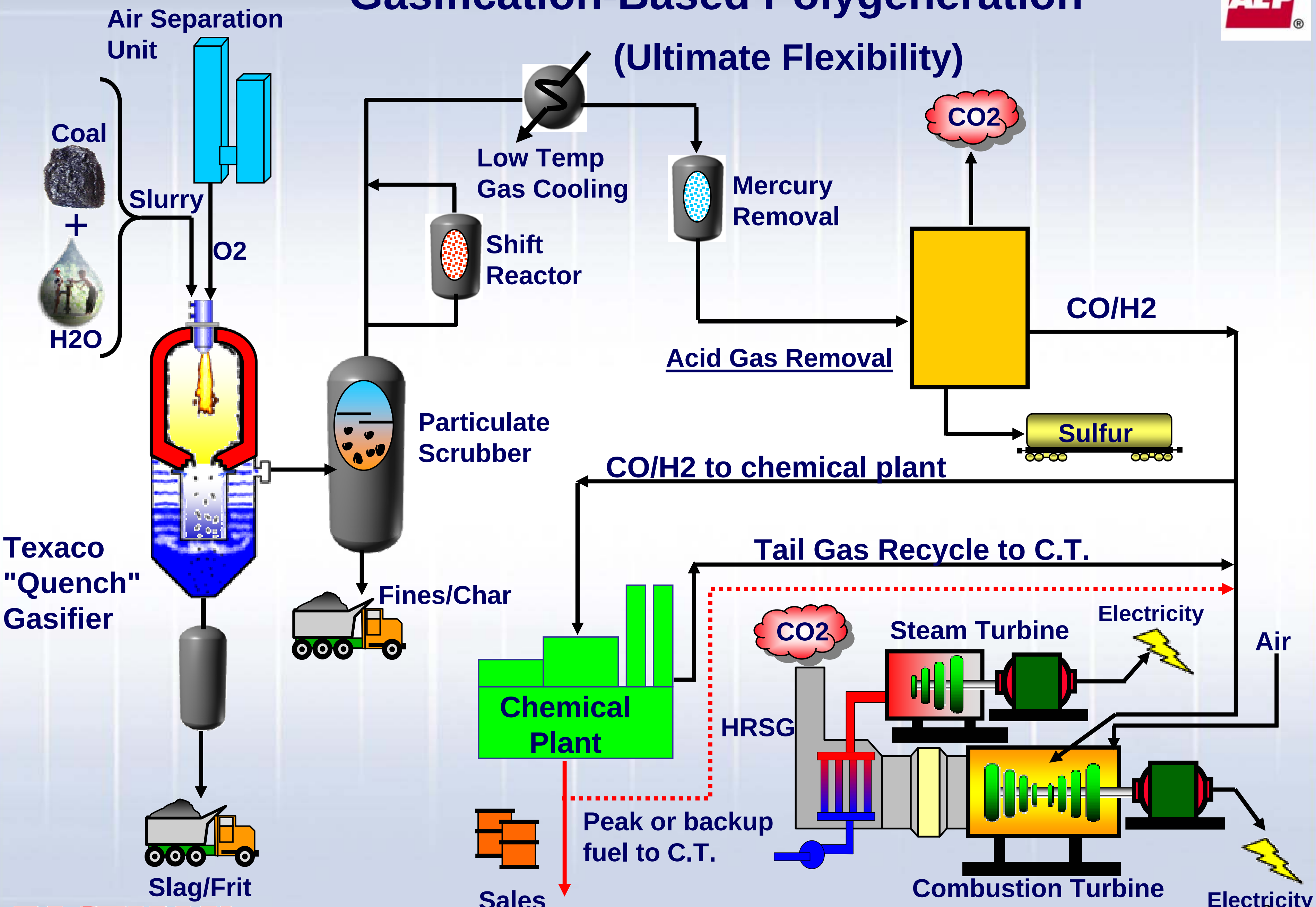
What is IGCC?



Air Separation Unit (ASU)
Coal
+
H2O
Slurry
O2
Low Temp Gas Cooling
Shift Rx (option)
Hg Removal
90+% Removal
CO2
Flexibility for CO2 Sequestration (Concentrated Stream)
CO/H2
Acid Gas Removal
98+% Removal
Sulfur
Sulfur Recovery
Claus/Scot
Particulate Scrubber
GE "Quench" Gasifier
Fines/Char
Slag/Frit
Electricity
Steam Turbine
Air
HRSG
PRE-COMBUSTION
Treatment of Pollutants
•High pressure
•Low Volume
•Concentrated stream (easier to treat)
Combustion Turbine
Electricity
Compressed Air to ASU

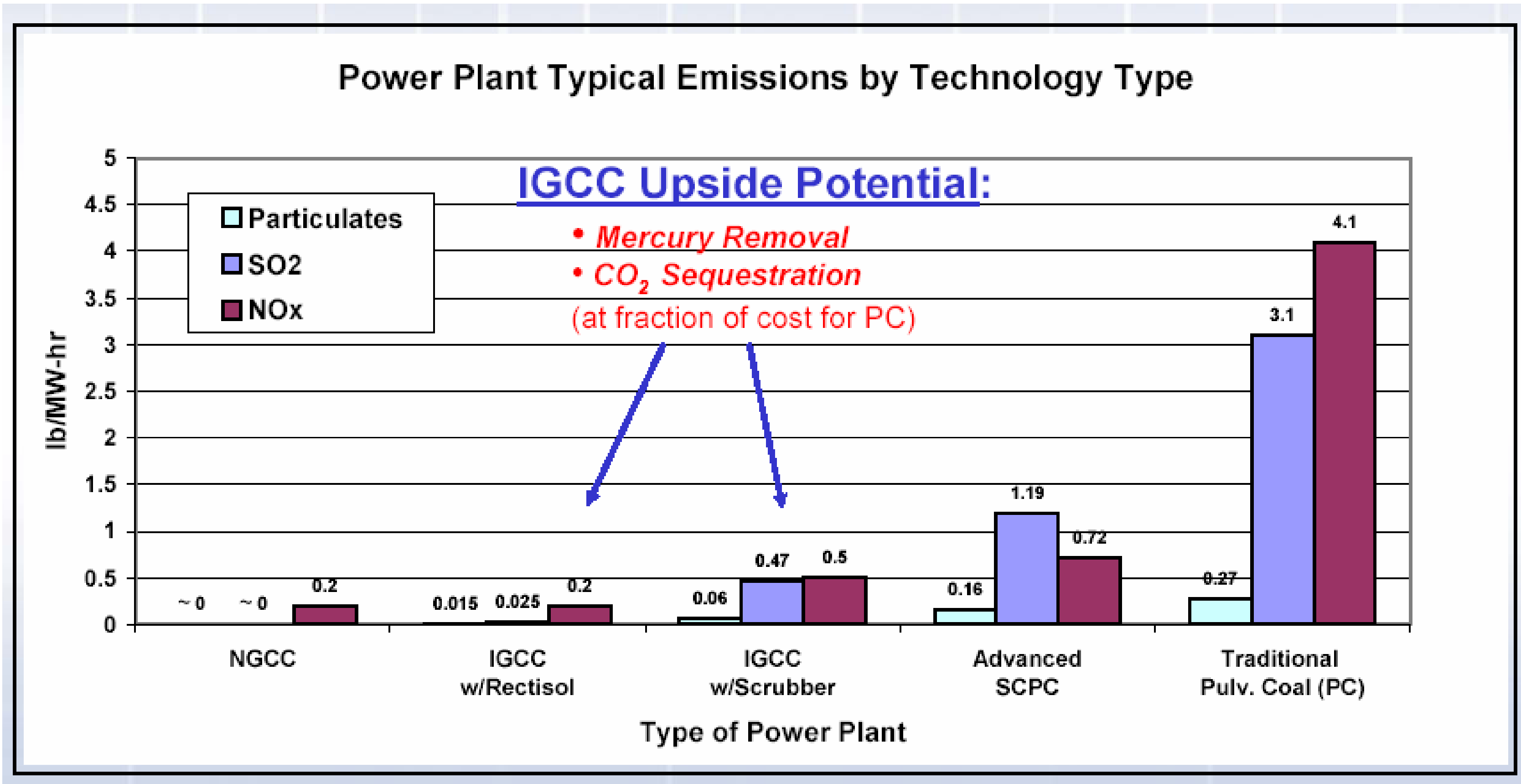
Gasification-Based Polygeneration

(Ultimate Flexibility)



EASTMAN

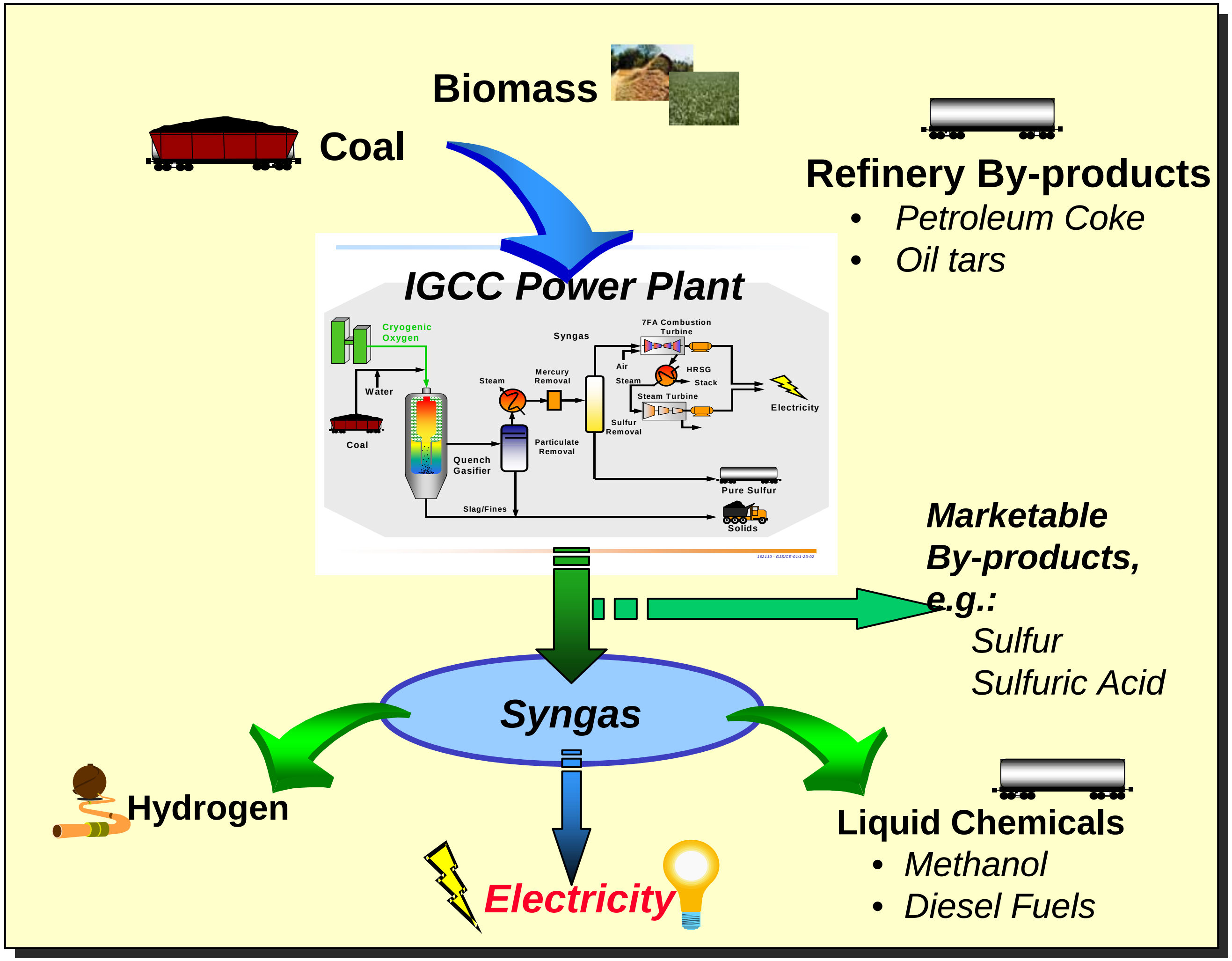
IGCC – Superior Environmental Performance



Source Eastman Chemical Company

***Take away**: IGCC's emissions are the lowest of any coal-based technology.*

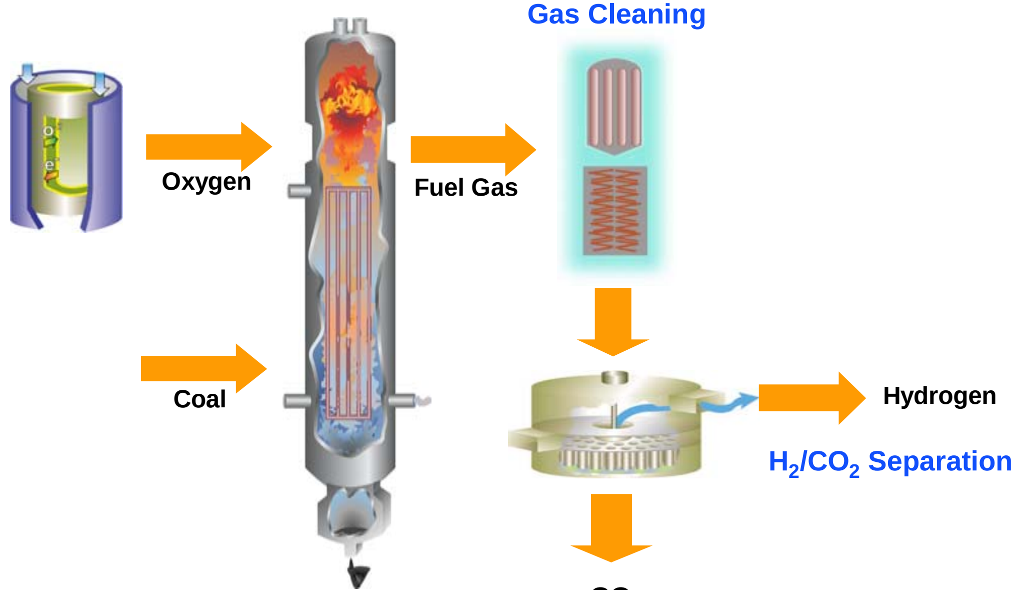
IGCC: Feedstock & By-product Flexibility



***Take away**: IGCC provides the options with both the feed stocks used and the products produced.*

IGCC – Pathway to Hydrogen Economy

H_2 and CO_2 from Syngas

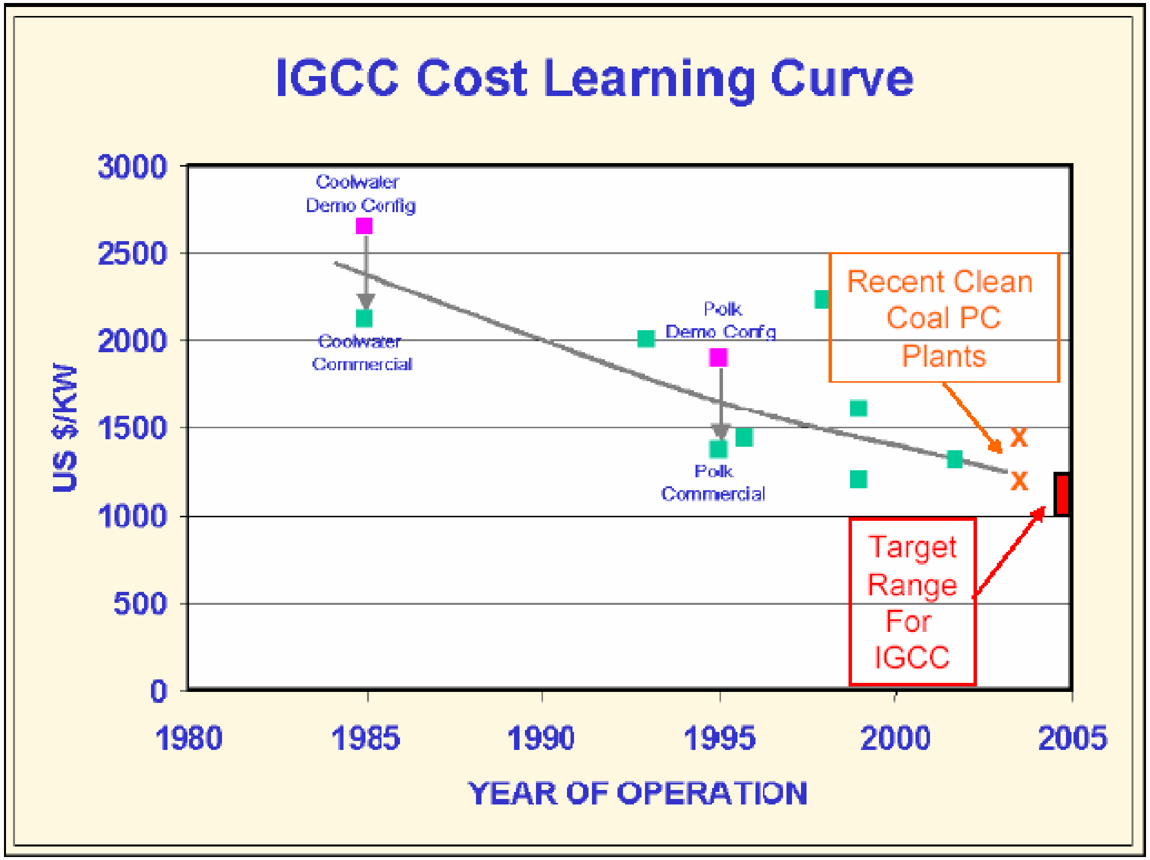


Source US Department of Energy

162110 - GJS/CE-01/1-23-02

***Take away**: IGCC provides the opportunity to separate CO2 and produce hydrogen from the syngas before combustion.*

IGCC – Costs

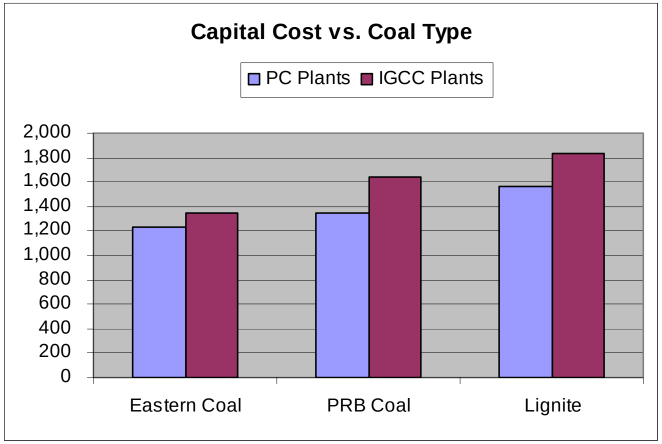


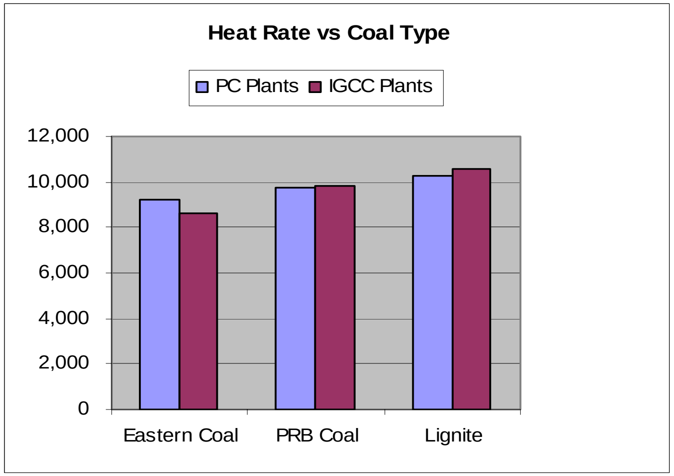
Source Eastman Chemical Company

***Take away**: Several IGCC plants must be built to reduce the capital cost and improve the operating availability.*

Impact of Coal Type on Technology Selection

Choices regarding coal type strongly influence technology selection





Source: EPRI

***Take away**: IGCC plants become less competitive with low-BTU coals. IGCC is not a silver bullet; having other technology options available is strategically important.*

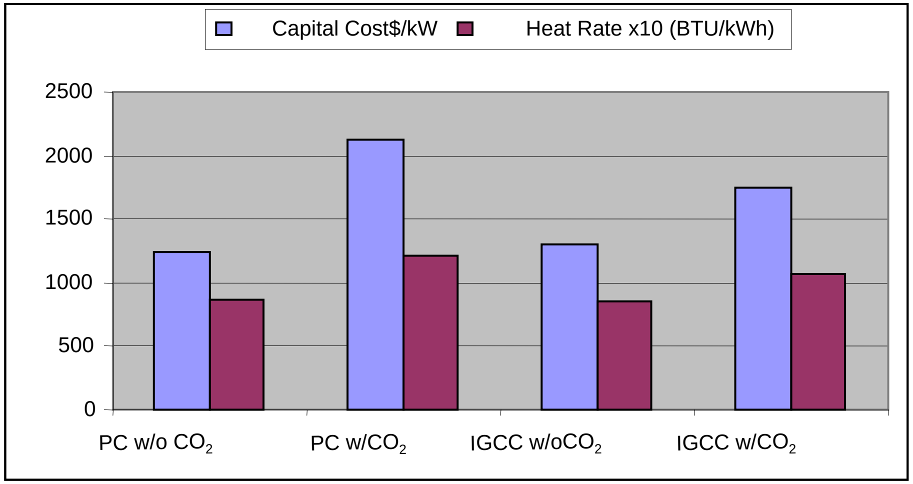
CO_2 Capture

Carbon capture ("scrubbing") is a difficult and expensive process:

- CO_2 is a very stable molecule
- CO_2 concentration is very low in flue gases
- Amine processes (MEA) are the only currently proven approach - ***high capital cost***
- A large amount of steam is required to regenerate the amine (strip the CO_2 from the "carbon getter") – ***large efficiency penalty***

Impact of Adding CO_2 Capture

	Pulverized Coal	IGCC	NGCC
Capital Cost	+65% to 75%	+30% to 40%	+85% to 90%
Efficiency	-30% to 35%	-18% to 22%	-20 to 25%
Cost of Electricity	+50%	+30%	+60%



Source: AEP , EPRI, and US DOE

Take away: *CO_2 scrubbing is very expensive; economic technologies do not now exist, however IGCC is currently more conducive to carbon capture.*

Carbon Capture R&D

Many Advanced Integrated Schemes Emerging

Coal Gasification

CO_2 Hydrates

Membranes

Advanced Scrubbers

Inexpensive Oxygen

Chemical Looping

Pulverized Coal

Oxygen Combustion

Membranes

Advanced Scrubbers

New Sorbents

Mineral Carbonation

Chemical Looping

Pathways to Zero Emissions

Producing a concentrated stream of CO_2 at high pressure:

- **Improves sequestration economics**
- **Reduces energy penalty**

Take away: *R&D and revolutionary technologies are required to keep coal viable. Less costly CO_2 capture technologies are being developed but are not currently available.* ***We are still looking for viable solutions****.*

Courtesy US Department of Energy

Ohio River Valley CO_2 Storage Project - Mountaineer Plant

Test well at Mountaineer Plant, 9172 ft. deep, to understand CO_2 storage capability of deep saline aquifer

$4.6-million project funded by DOE with cost sharing from AEP, Battelle, BP, Schlumberger, Ohio Coal Development Office

***Take away**: Mountaineer Project has shown that one cannot assume that there is ample CO_2 storage capability near all of our coal-fired plants.*

IGCC – The Good, the Bad, and the Ugly

- ***The good***
  - Superior efficiency on Eastern Bituminous Coal
  - Flexible byproduct processing
    - Tri-generation opportunities
    - Hydrogen production
  - Superior environmental performance
  - Conducive to Carbon Capture & Disposal
- ***The bad***
  - High capital cost
  - More IGCC plants must be built to reduce cost and improve availability
  - Currently not economical for low-BTU coals
- ***The ugly***
  - The business deal
    - Traditionally, there were no equipment suppliers, only technology licensers
    - Virtually all of the technology and performance risk has been on the plant owner

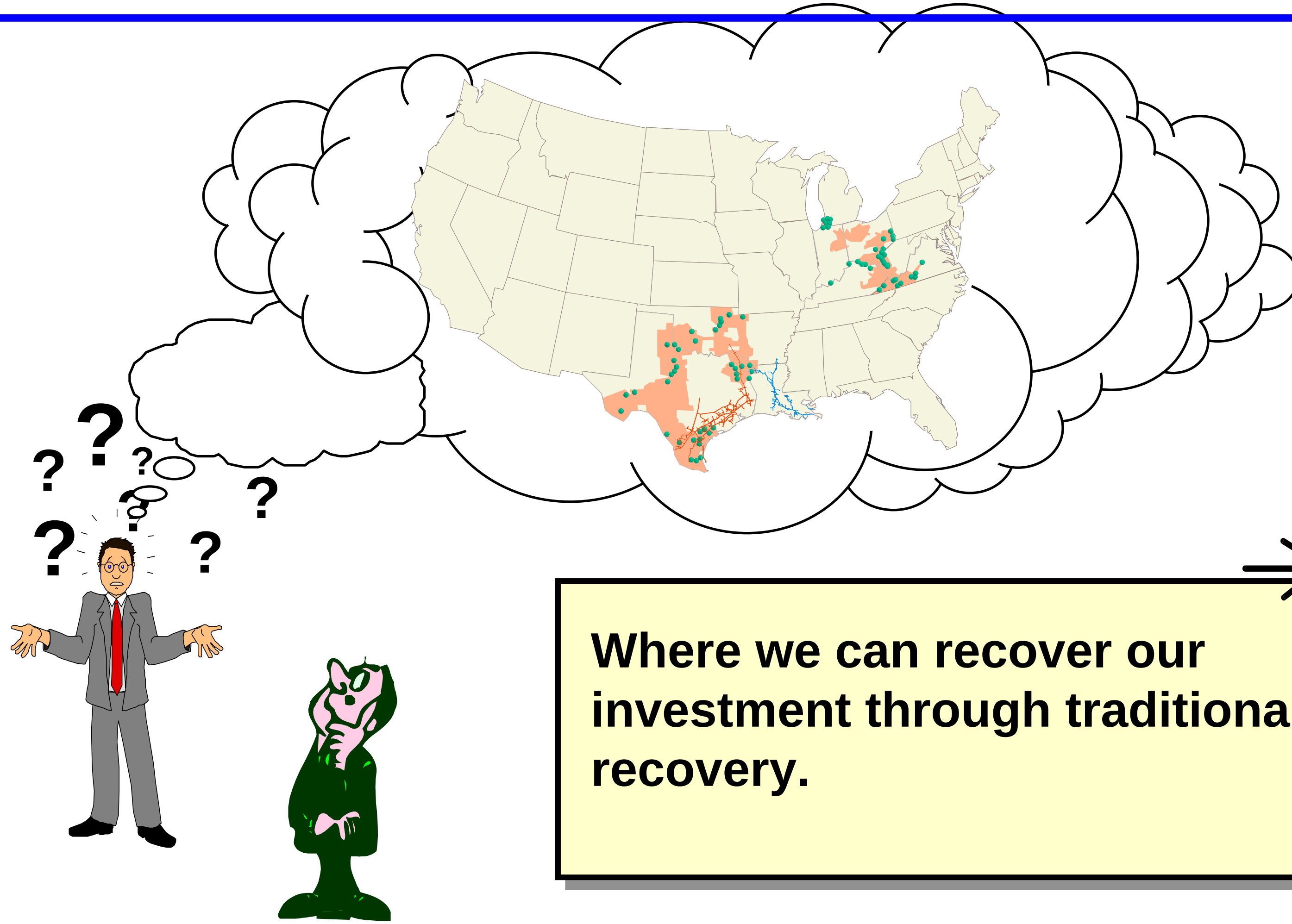
Paradigm Shift*: GE's acquisition of CTX, coupled with recent announcements of partnering between other IGCC licensors and EPC firms has addressed the "Ugly" and allows utilities to take advantage of the "good" and manage the "bad".*

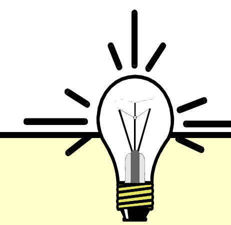
IGCC's Promise

- Lowest capital cost (when mature) among coal-based technologies
- Feedstock & product flexibility (with added cost)
  - Coal, petcoke, or biomass feedstocks
  - electricity, steam, syngas, liquid fuels, or chemical products
- Highest efficiency among coal-based technologies (when mature)
- Best emission characteristics among coal-based technologies
- Most carbon-friendly coal-based technology
- The technology of choice to KEEP COAL IN THE MONEY
  - Strategically important to the energy security and economy of our nation

Take Away: *The business paradigm has enabled building IGCC plants; we are now focusing on a regulatory paradigm that will enable building IGCC Plants*

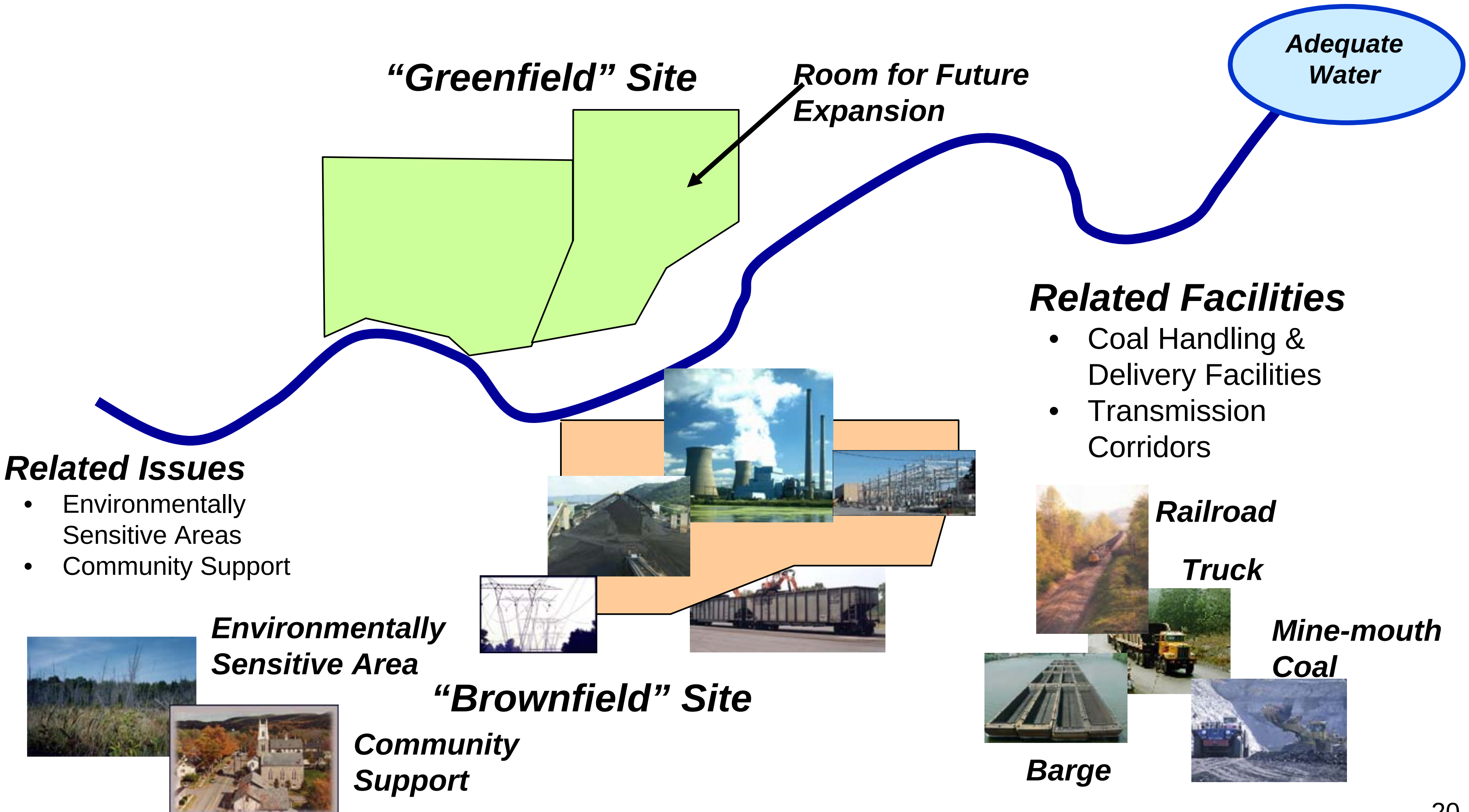
Next Decision: *Where Should we Build it???*





Where we can recover our investment through traditional rate recovery.

Site Selection – Site Needs & Issues



Key Technical Parameters

600 MW IGCC Unit

- 2 (1) x 2 x 2 x 1
  - 2 Operating Gasifiers plus one spare
  - 2 Combustion Turbines
  - 2 Heat recovery Steam generators
  - 1 Steam Turbine

		600 MW	1200 MW	
Fuel consumption:		**1.5/2.0**	**3.0/4.0**	**million tons per year**
Heat Rate HHV		**8,500**	**8,500**	**Btu/kWh**
Make-up water flow:		**3,000/5,500**	**6,000/11,000**	**gallons per minute**
Acreage:	**power block**	**30**	**45**	**acres**
	Gasification Island	**60**	**105**	**acres**
	rail loop	**150**	**150**	**acres**
	coal yard	**40**	**40**	**acres (inside rail loop)**
	solid waste disposal	**150**	**300**	**acres**
Total (rail delivery)		**390**	**600**	**acres**
Total (barge delivery)		**280**	**490**	**acres**
Operating staff:		**125**	**200**	

Site Selection Ranking Criteria

Item No.	Description of Characteristic	Musts	Wants	Importance Weighting Factor	Evaluation Criteria	Numerical Rating Factor
1	Plant Site Topography and Size	Sufficient land must be available for the plant footprint and associated facilities. Ground slope across the site, including material storage but excluding solid waste disposal, must not be more than 5% or less than 0.5%.	Minimize average ground slope (beyond 0.5%) and fill requirements in order to minimize costs for earthwork, retaining walls, erosion control, drainage, roadwork, and trackwork.	8	0.5 to 1.0 percent slope and less than 100,000 cy fill	5
					1.0 to 2.0 percent slope or 100,000 to 300,000 cy fill	4
					2.0 to 3.0 percent slope or 300,000 to 600,000 cy fill	3
					3.0 to 4.0 percent slope or 600,000 to 1,000,000 cy fill	2
					4.0 to 5.0 percent slope or more than 1,000,000 cy fill	1
2	Expandability for Future Units	None	Site should have room for expansion with at least one unit beyond base capacity (1,000 MW).	7	Can fite three or more units on site	5
					Can only fit two units on site	3
					Can only fit one unit on site	1
3	Distance from Potential Solid Waste Disposal Area	None	Minimize the distance to potential solid waste disposal areas.	7	Nearest disposal area adjacent to plant	5
					Nearest disposal area less than 1 mile	4
					Nearest disposal area 1 to 2 miles	3
					Nearest disposal area 2 to 5 miles	2
					Nearest disposal area more than 5 miles	1

Carbon Sequestration

AEP®

A Rough Scale for Ranking the Storage Potential of These Sites

- Battelle has developed and employed a subjective scale for rating these sites. The four categories as well as examples of the kinds of attributes assigned to each category are given below:
  - Good Prospective Sites – Presence of known thick, continuous, potentially permeable deep saline formations; excellent caprock likely; lack of major faulting and seismic activity; possibility of high injectivity with few wells, EOR or ECBM potential in the immediate vicinity; etc.
  - Fair Sites – Potential presence of known but poorly characterized saline reservoirs, potential to store CO_2 in known oil/gas/coal fields present in the area; no major faulting or seismic zones; sufficient depth, good caprock; potential for injection with a moderate number of wells; etc.
  - Acceptable Sites – Potential presence of saline reservoirs, oil/gas/coal fields with possibility of CO_2 storage but with limited injection rates; may require a large number of wells; caprock may need more careful assessment; presence of known fault zones in the vicinity, etc.
  - Low Potential Sites – No *known* deep saline formations, oil/gas fields, or coal seams; reservoirs too shallow; too close to freshwater zones; significant faulting or seismic activity present; not enough caprock; etc.

Business Sensitive

Battelle
The Business of Innovation

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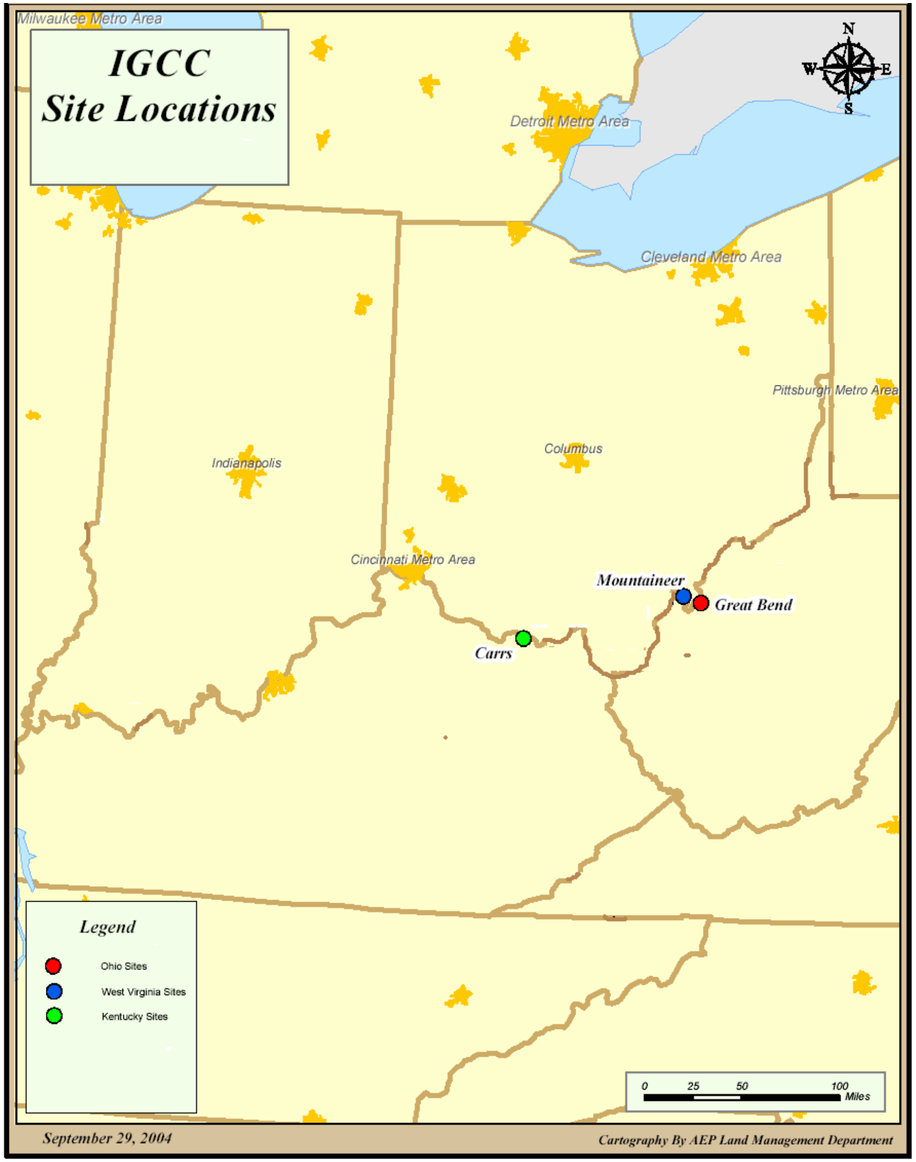
Site Locations



Next Steps

- Conduct site-specific investigations
- Negotiate with suppliers
- Secure regulated cost recovery

AEP System must move forward with IGCC plant by mid-2005

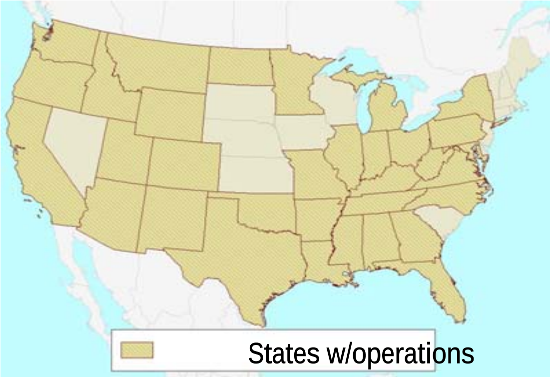
FutureGen

One billion dollar, 10-year demonstration project to create world's first, coal-based, zero-emission electricity and hydrogen plant with sequestration

President Bush, February 27, 2003

FutureGen Industrial Alliance

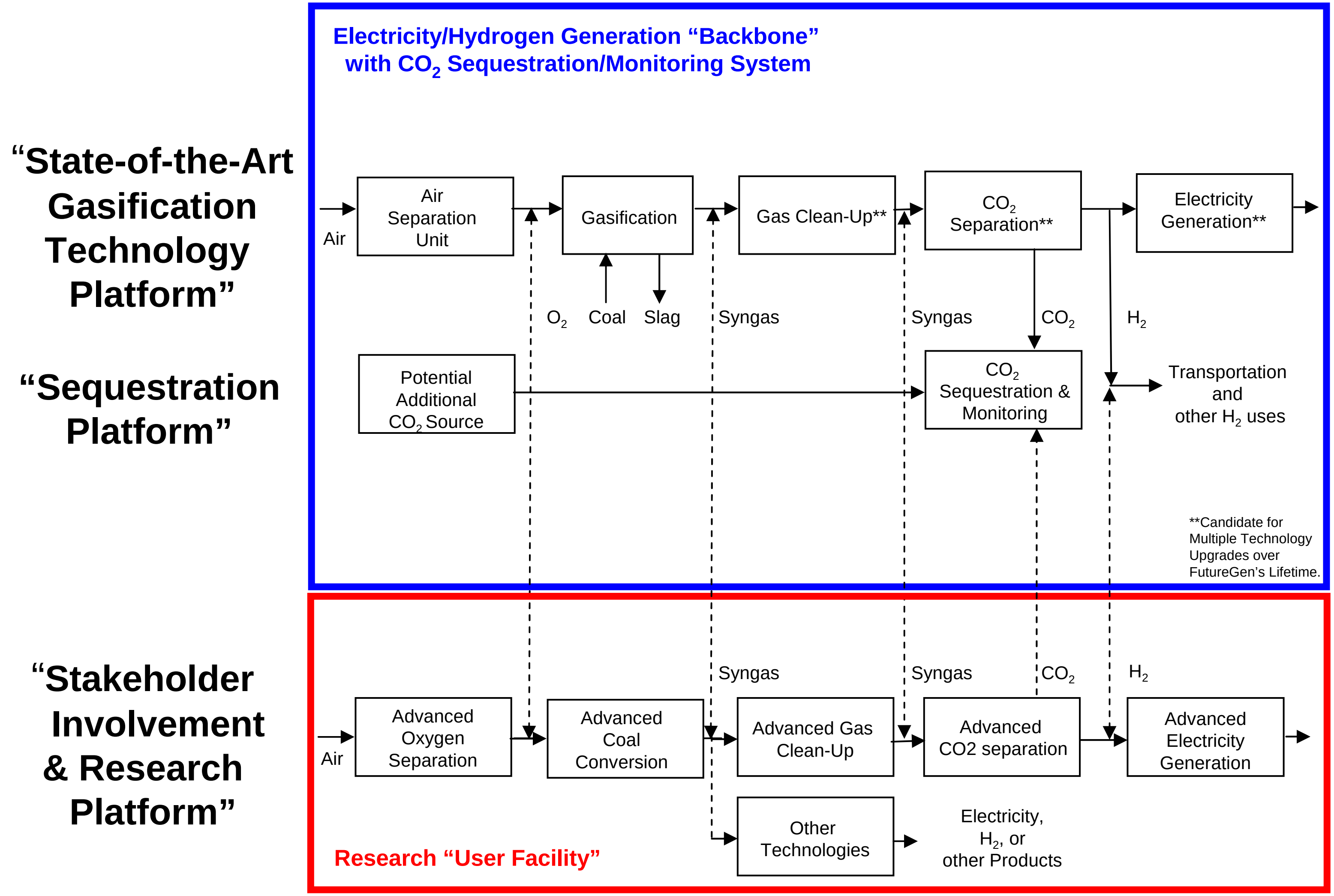
- **Membership:**
  - American Electric Power
  - Cinergy Corp.
  - CONSOL Energy Inc.
  - Kennecott Energy Company
  - PacifiCorp/ScottishPower
  - Peabody Energy
  - RAG American Coal Holding, Inc.
  - Southern Co.
  - The North American Coal Company
  - TXU
- **Characteristics:**
  - >45% of U.S. Coal Production
  - >20% Coal-Fueled Electricity Production
  - Operations in >30 States
  - Represent all major coal types



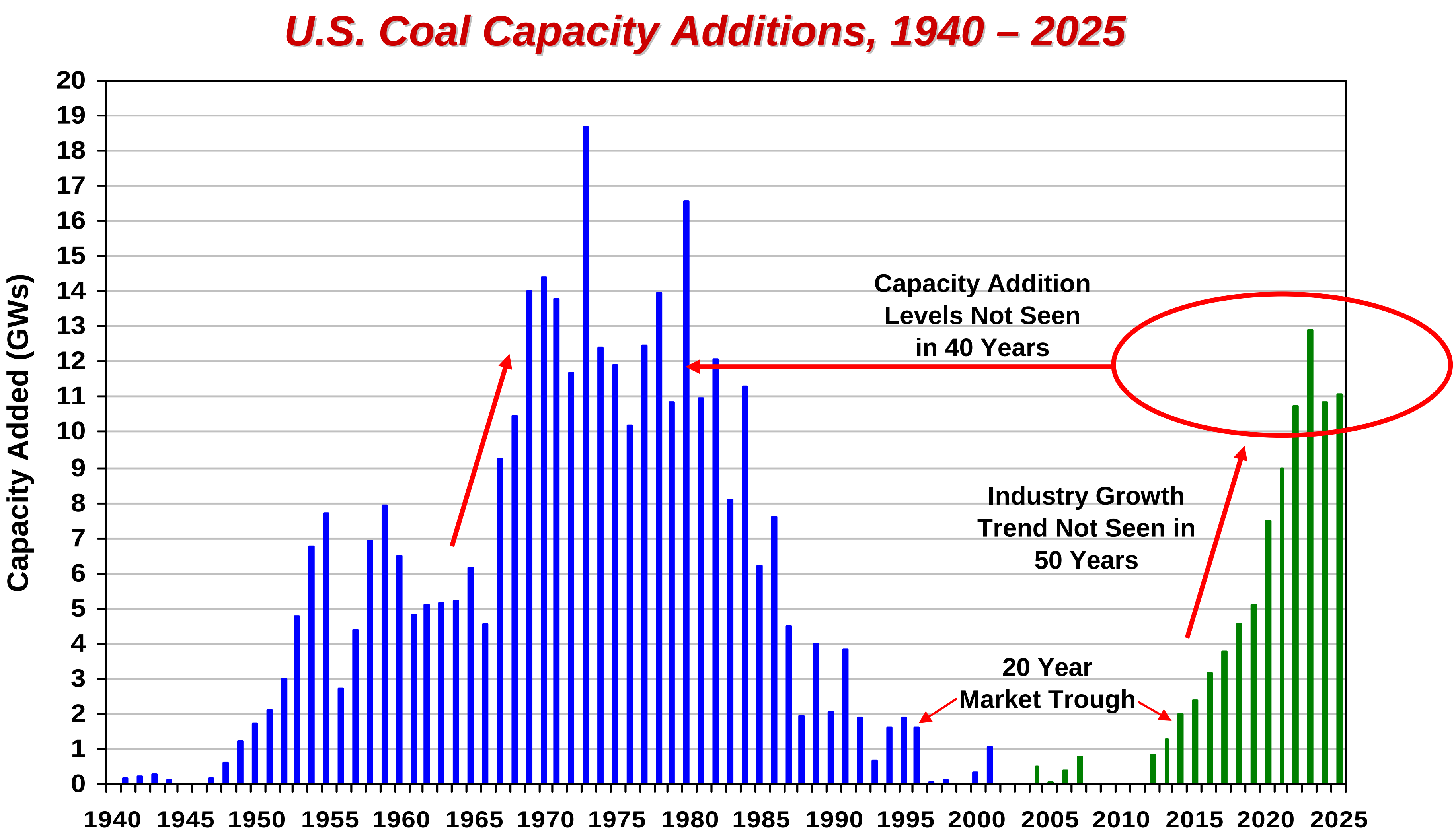
- **Open membership policy with an active recruiting effort**

FutureGen

Industry's View of the Facility



U.S. Forecasts Largest Coal Generation Capacity Installation in 40 Years



Source: U.S. Department of Energy NETL & Annual Energy Outlook 2005.