



EPRI

ELECTRIC POWER
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Integrated Gasification Combined Cycles with CO₂ Capture

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Advanced Generation

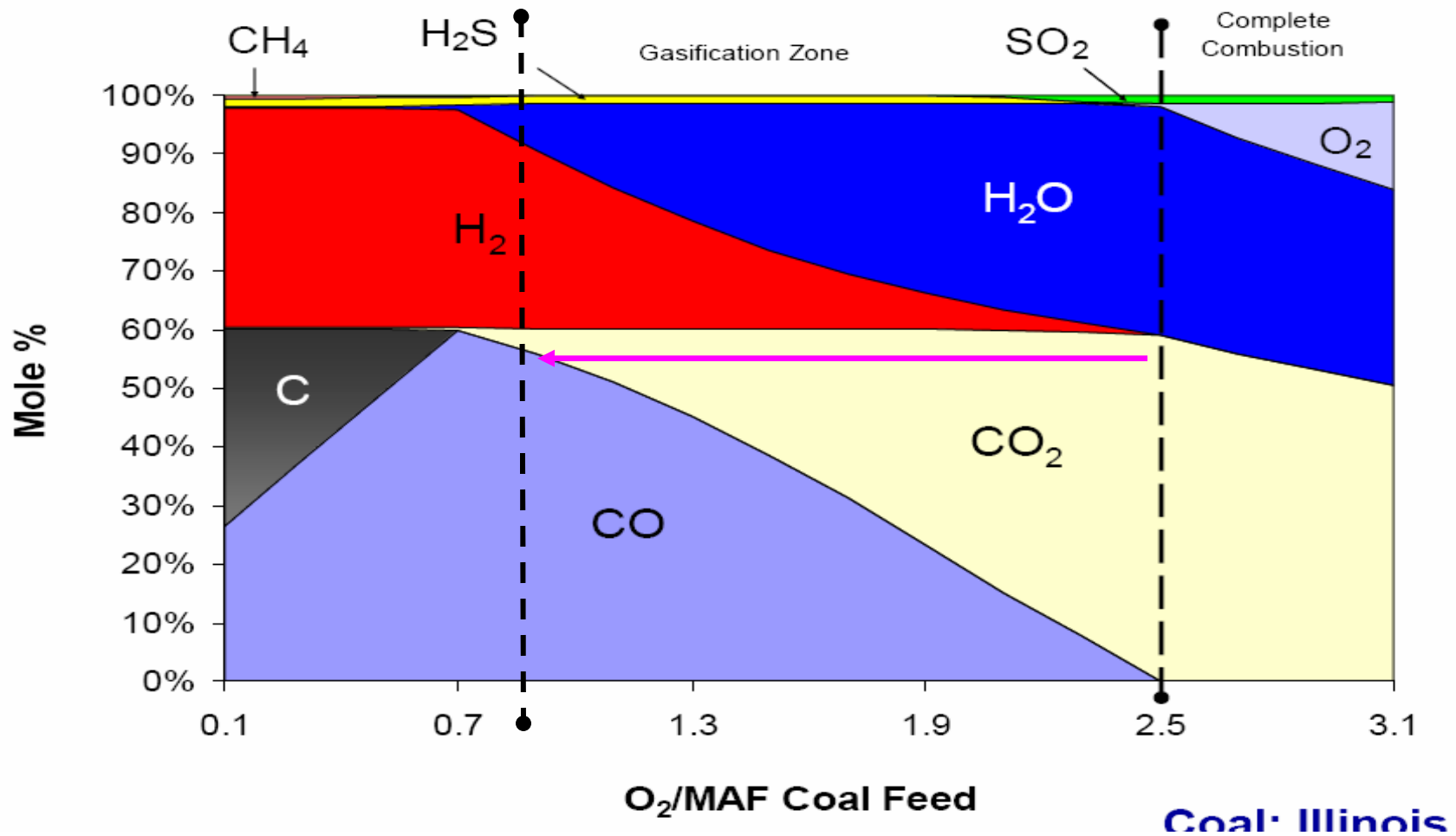
Outline

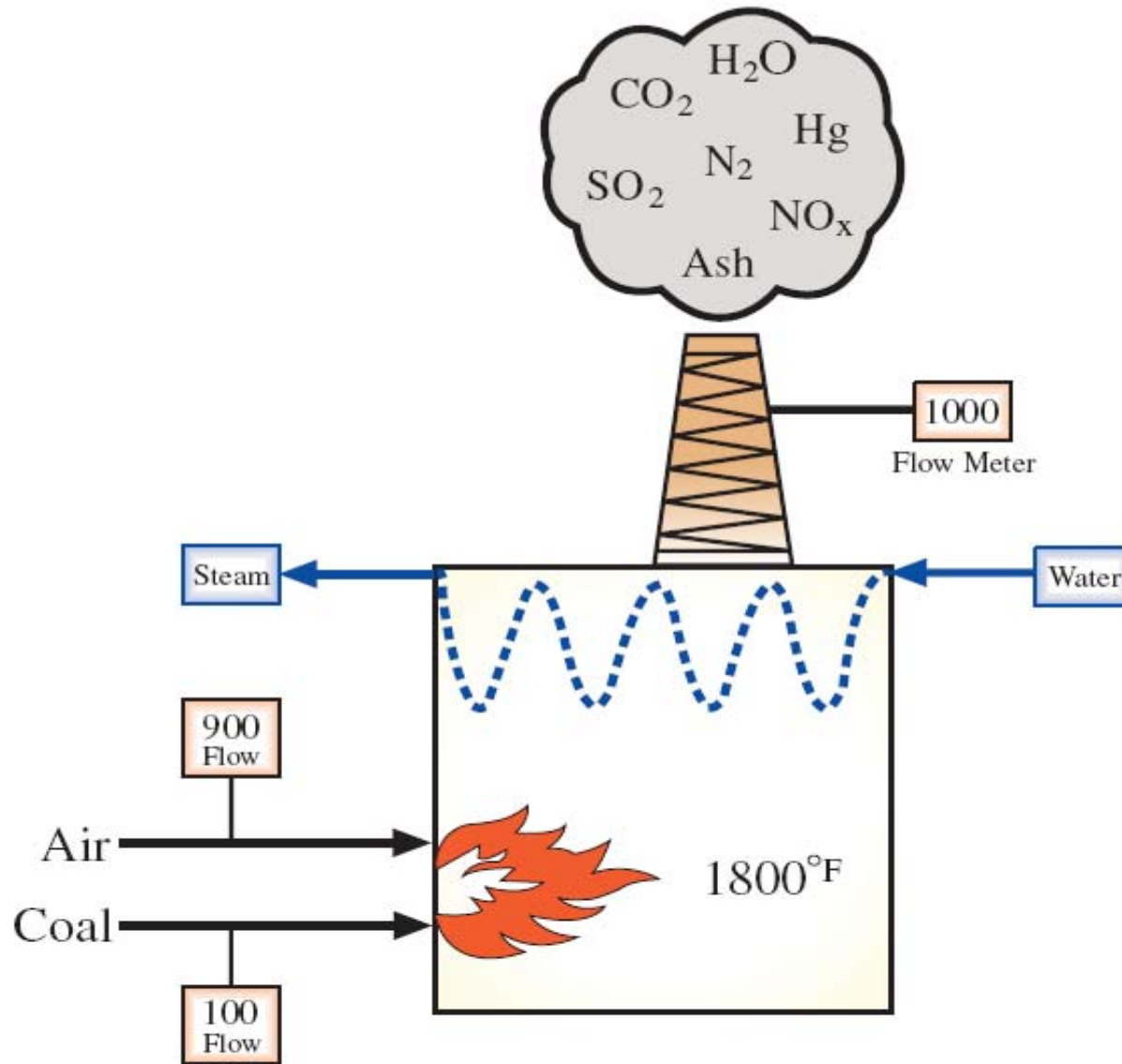
- What is IGCC?
- IGCC with CO₂ capture compared to other fossil fuel power generation options
- IGCC commercial status
- Research, Development and Demonstration needs for IGCC with CO₂ capture

What is gasification?

- Similar to combustion but with less than half the amount of oxygen needed to fully burn the coal
- Combustion: excess air
- Gasification: excess fuel (by a lot!!)

Combustion & Gasification Products



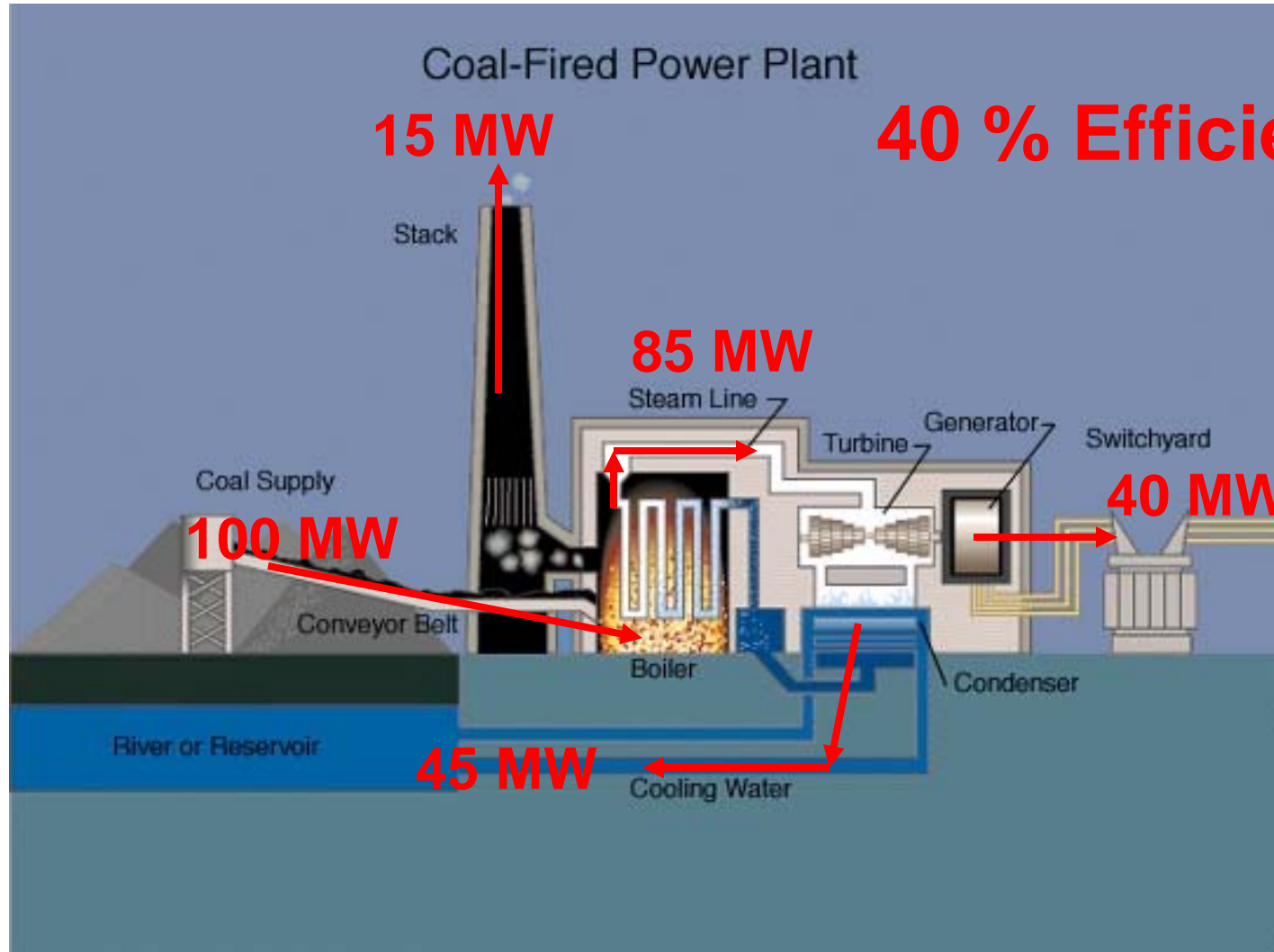


Coal Boiler

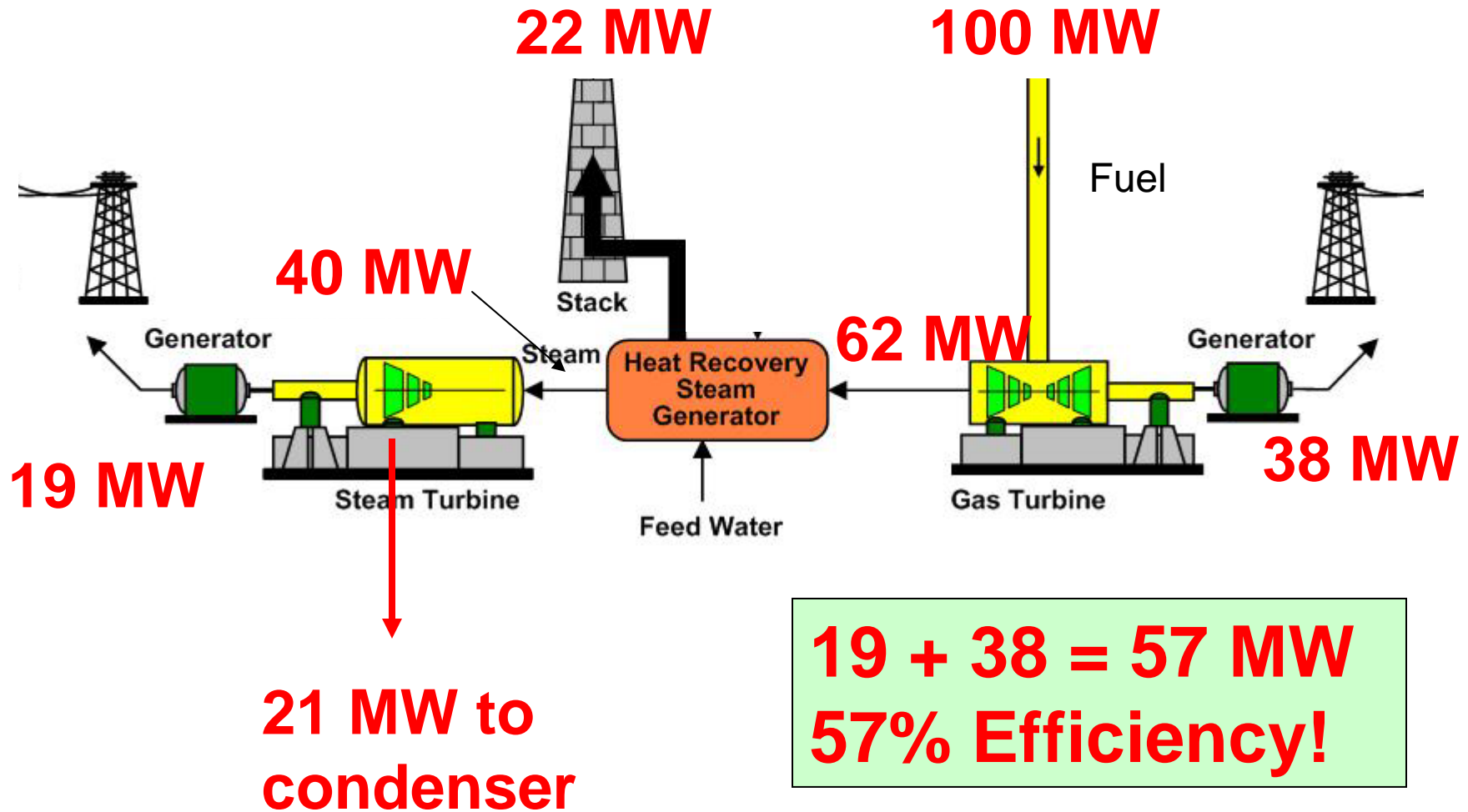
Combustion vs Gasification

- SO_2 & SO_3 must be scrubbed out of stack gas
- NO_x controlled with low NO_x burners and catalytic conversion (SCR)
- Large volume of flyash & sludge causes disposal issues
- Hg removed by contacting flue gas with activated carbon
- CO_2 must be separated from stack gas
- H_2S & COS are easily removed and converted to solid sulfur
- NH_3 washes out of gas with water, thermal NO_x controlled by diluent injection in CT
- Ash is converted to glassy slag which is inert and usable
- Hg removed by passing high pressure syngas thru activated carbon bed
- CO can be shifted to CO_2 & removed from high pressure syngas

Conventional Coal Plant

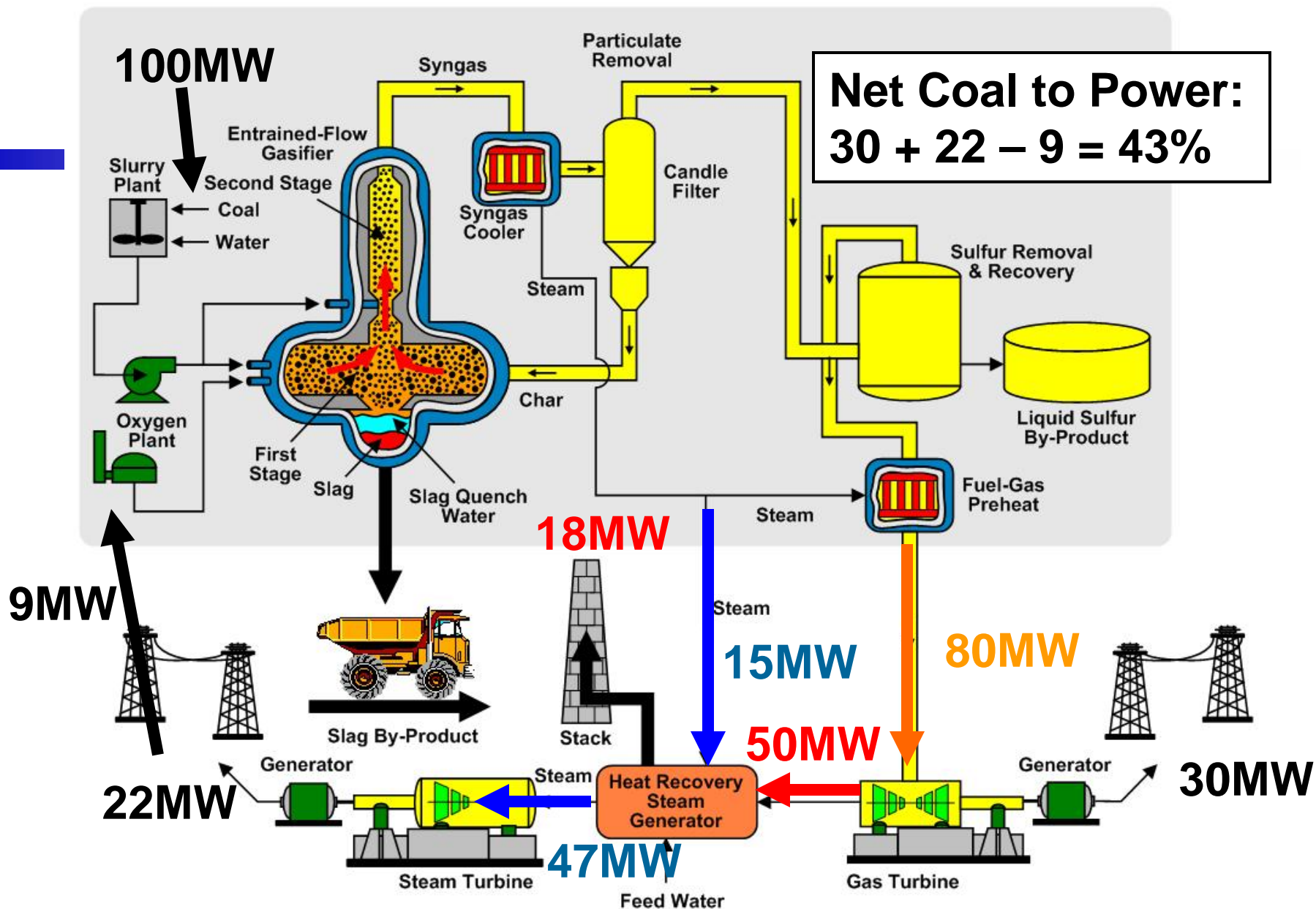


Combined Cycle



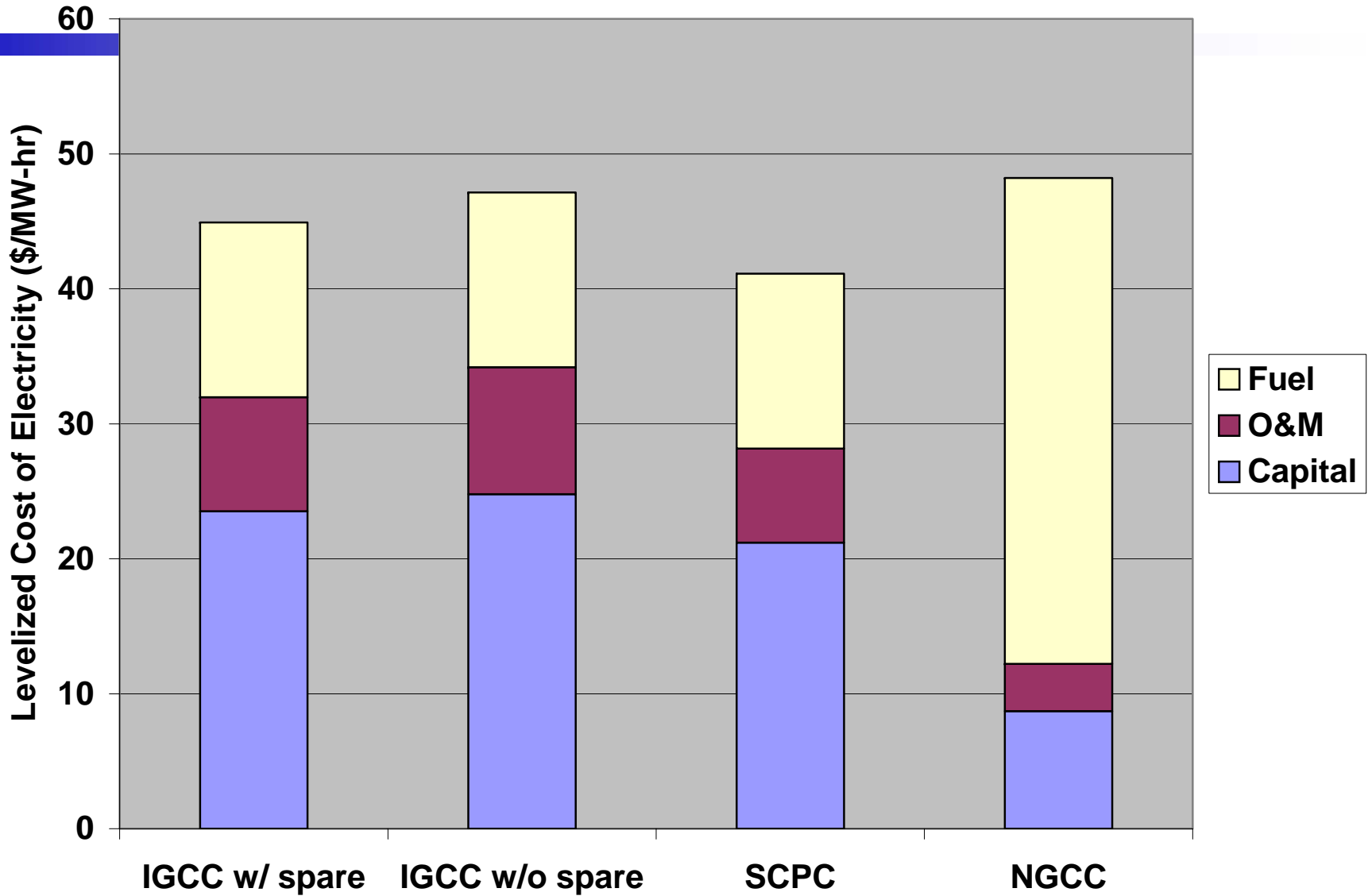
Combined Cycle



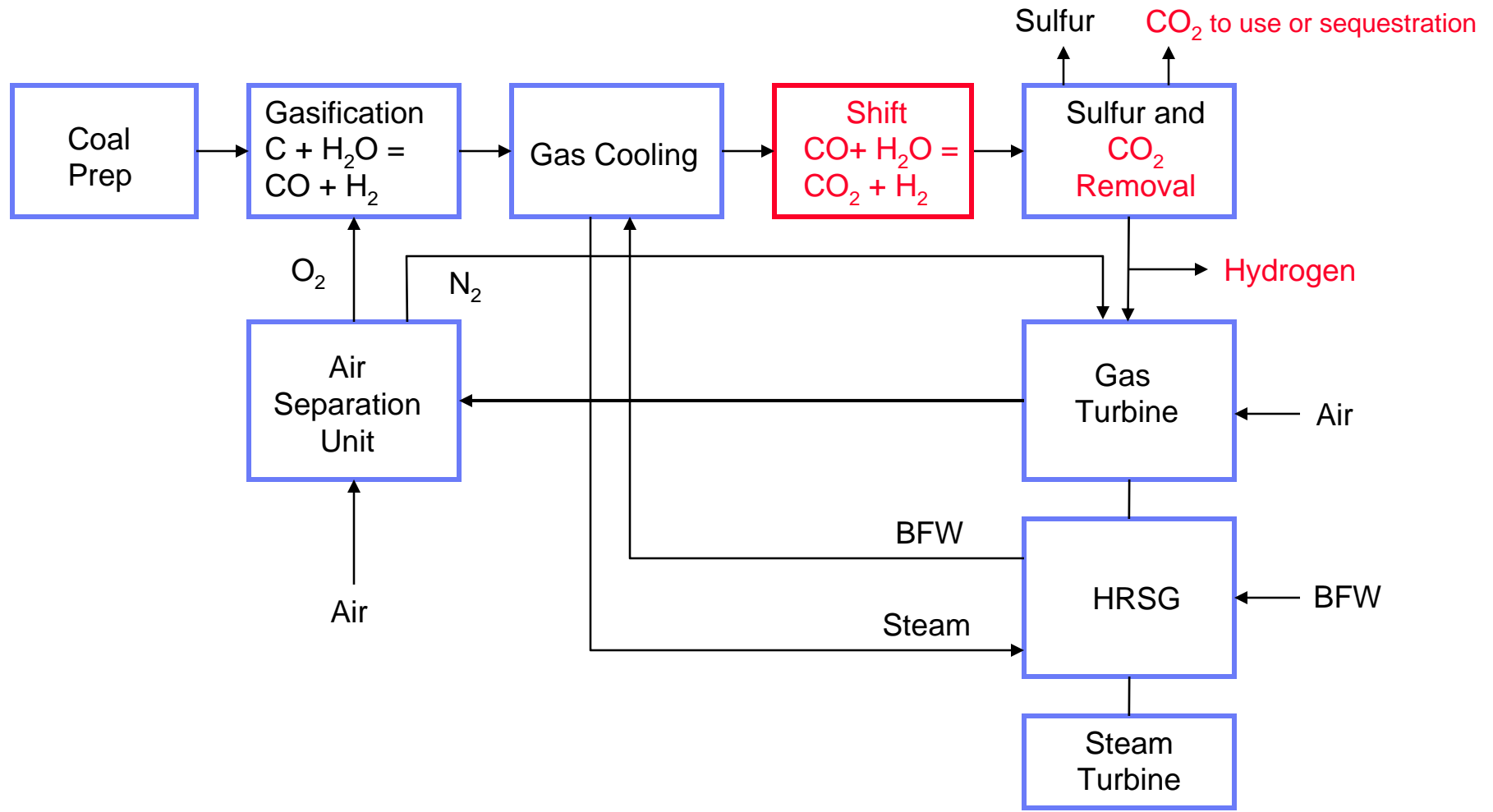


Levelized Cost of Electricity

(Assumes \$1.50/MMBtu Coal, \$5/MMBtu Natural Gas)



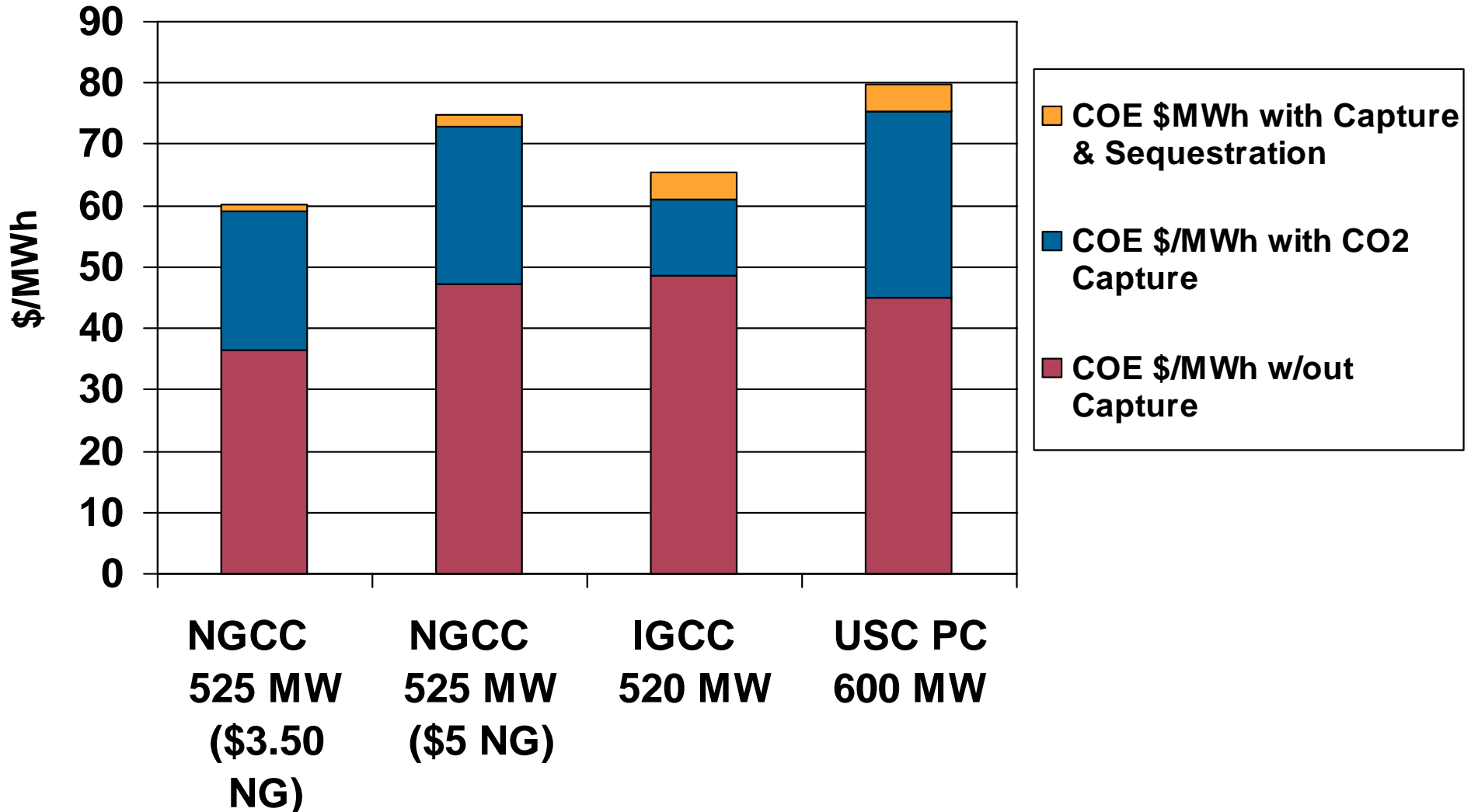
IGCC with CO₂ Removal and Optional Hydrogen Co-Production



CO₂ Capture Comparison

	Stream Pressure	CO ₂ Volumetric Concentration in Stream	CO ₂ Partial Pressure
Natural Gas Combined Cycle	100 kPa	4%	4 kPa
Supercritical Coal Combustion	100 kPa	13%	13 kPa
IGCC	5700 kPa	40%	2280 kPa

Costs of Electricity from New Fossil Fuel Power Plants with & without CO2 Capture (based on today's technology)



Existing Coal-based IGCCs



Puertollano (Spain)



Wabash (Indiana)



Polk (Florida)



Buggenum (NL)

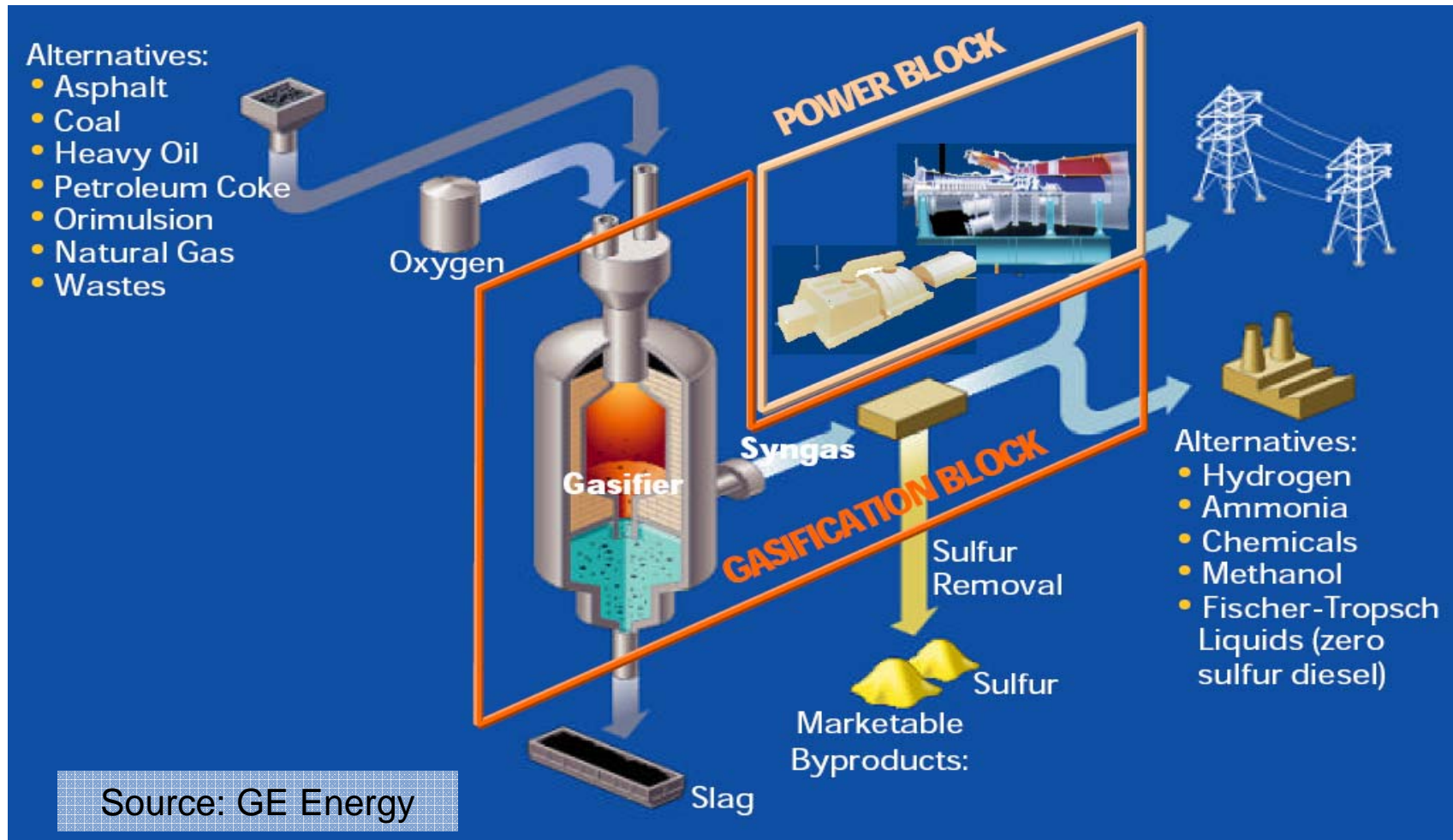
Coal Based IGCC Plants

Project/ Location	Combustion Turbine	Gasification Technology	Net Output MW	Start-Up Date
Nuon Buggenum Netherlands	Siemens V 94.2	Shell (Offered jointly with Krupp- Uhde)	253	Jan 1994
Wabash River, IN	GE 7 FA	E Gas (ConocoPhillips)	262	Oct 1995
Tampa Electric, FL	GE 7 FA	Texaco (GE Energy)	250	Sept 1996
ELCOGAS Puertollano Spain	Siemens V 94.3	Prenflo (Offered jointly with Shell)	300	Dec 1997

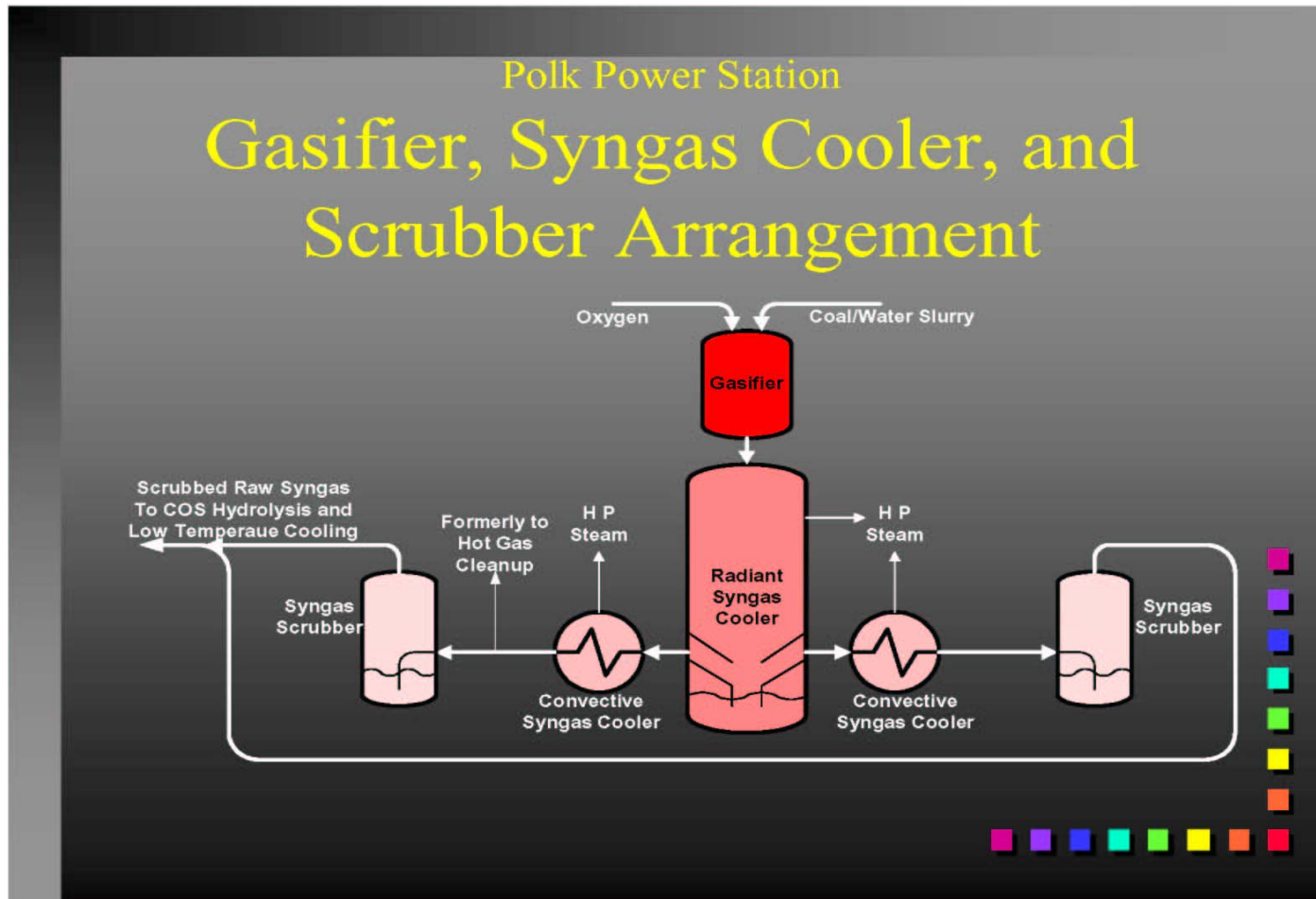
Salient Characteristics of Major Gasification Technologies

Technology Name/ Design Feature	GE Energy (formerly Texaco)	E-Gas (ConocoPhillips)	Shell
Feed System	Coal in Water Slurry	Coal in Water Slurry	Dry Coal. Lock Hopper & Pneumatic Conveying
Gasifier Configuration	Single Stage Downflow	Two Stage Upflow	Single Stage Upflow
Gasifier Wall	Refractory	Refractory	Membrane Wall
Pressure (psig)	500-1000	Up to 600	Up to 600
Notes	Offered as Quench or with Heat Recovery	Currently only offered with Heat Recovery	Currently only offered with Heat Recovery

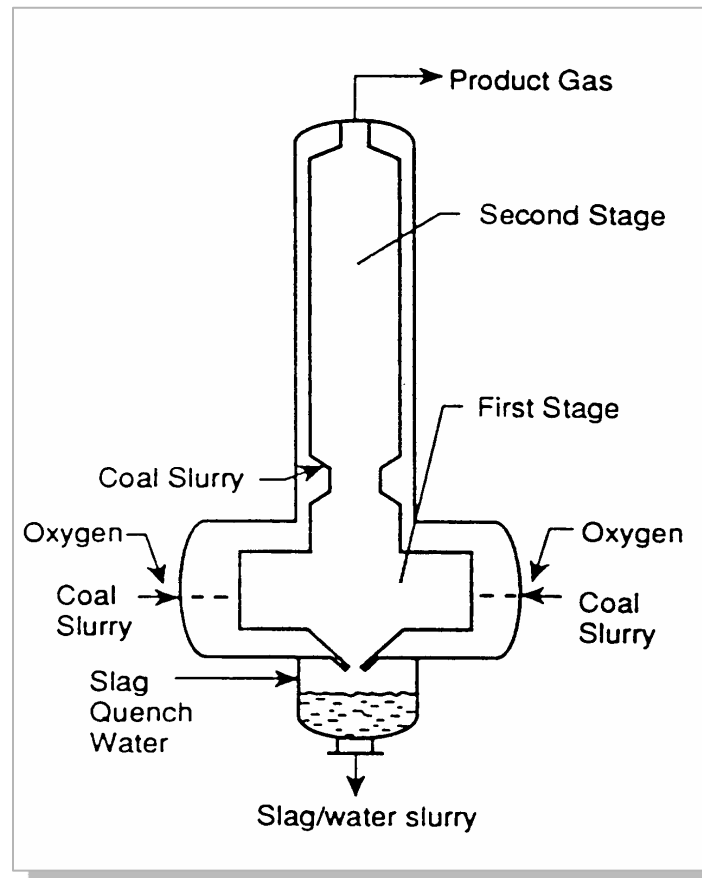
GE Energy Quench Gasifier



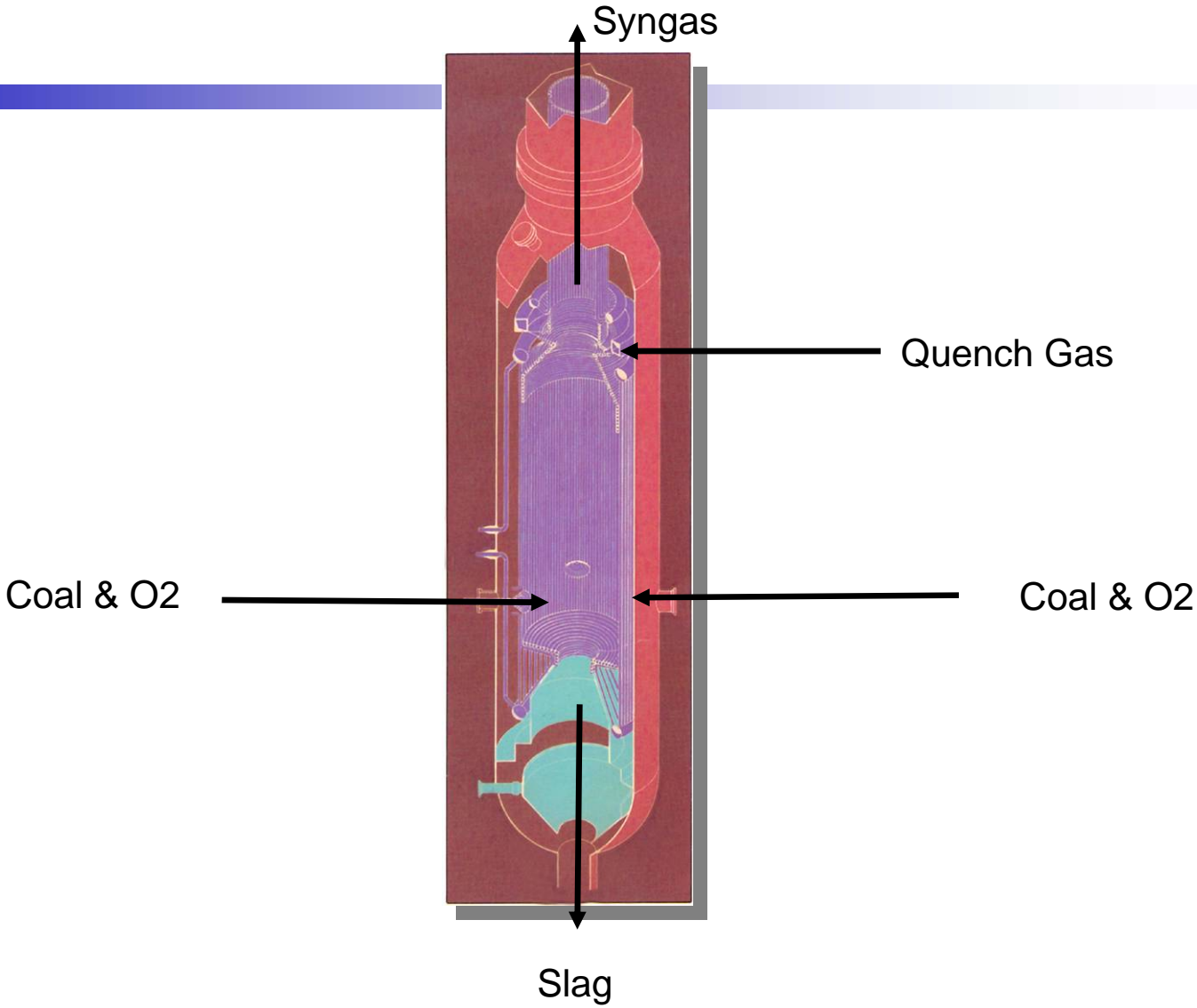
Tampa Electric – Gasification Arrangement



E-Gas Gasifier—As used at Wabash IGCC (Technology now owned by ConocoPhillips)



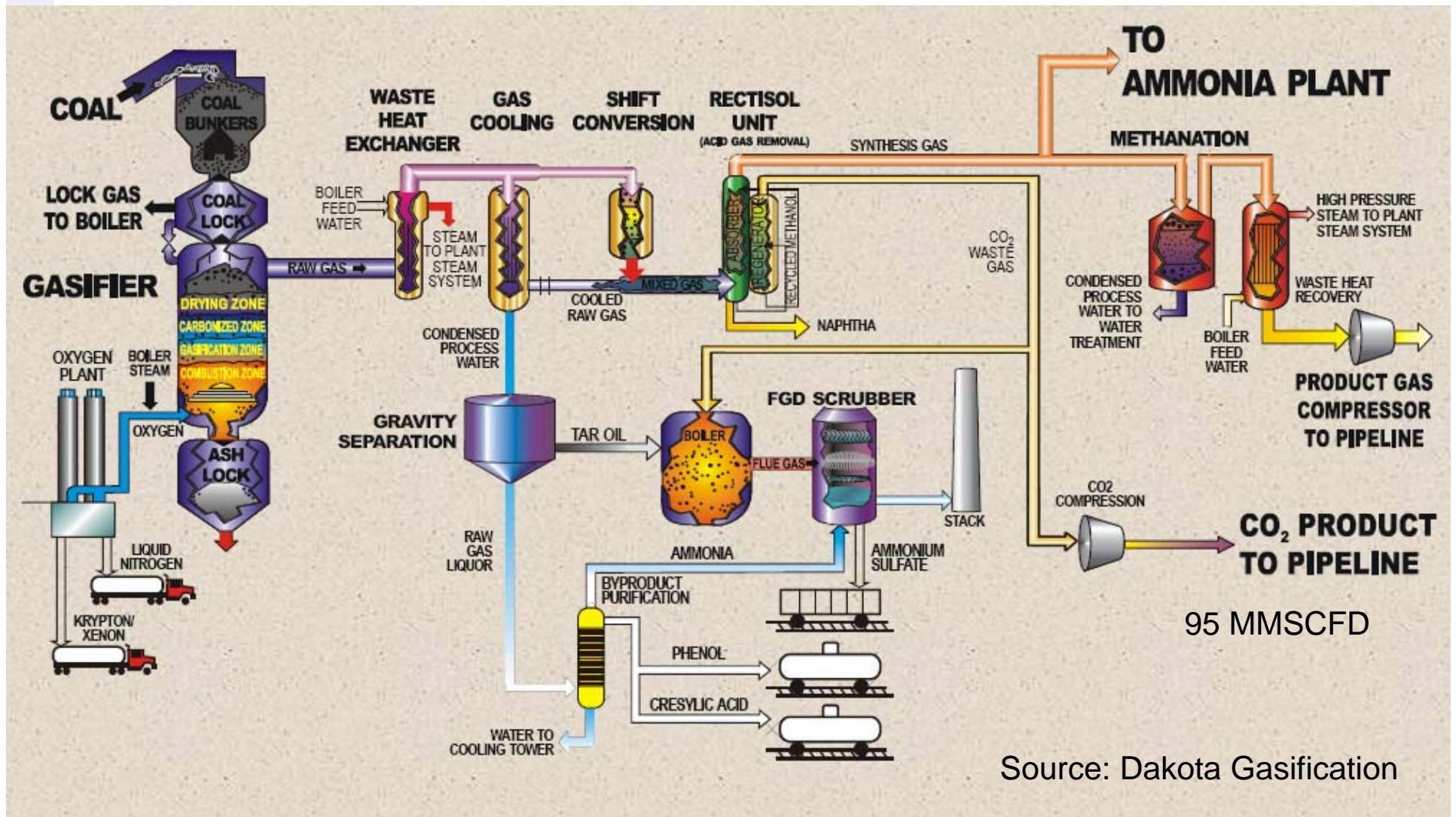
Shell Gasifier Cutaway



Worldwide IGCC Experience

- Four coal based IGCC plants Tampa, Wabash, Buggenum and Puertollano.
- Eight operating IGCC plants based on Petroleum Residuals. Three more in construction. These plants represent considerable additional commercial operating experience for the many components that are common with coal based IGCC plants (ASUs, Gas clean up, Sulfur recovery, Combined Cycles, SCR etc).
- Cumulative Combustion Turbine experience on a wide variety of syngas compositions and heating values (range 100-350 Btu/SCF) is well over a million hours.

Great Plains Synfuels Plant



Source: Dakota Gasification

IGCC CO₂ Recovery R&D Needs

- All the technology necessary for an IGCC with 90% CO₂ capture has been demonstrated at commercial scale except:
 - An advanced (F class or better) combustion turbine fired on near 100% H₂
 - Current OEM restrictions on H₂ content limit CO₂ capture to about 85%
- Need to develop a CT which can accept the syngas produced by 90% CO₂ capture

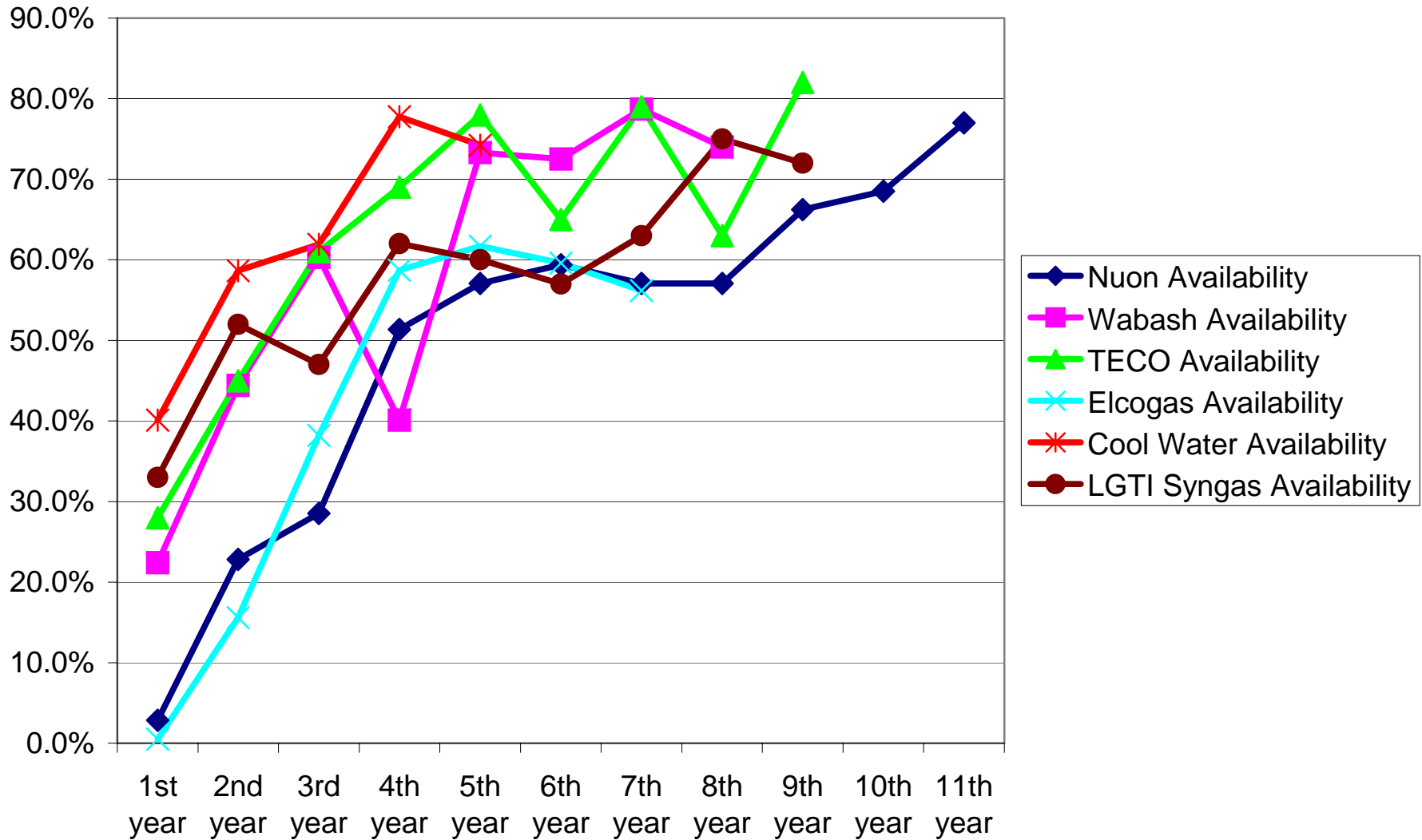
IGCC Demonstration Needs

- Even though all the different pieces of an IGCC with CO₂ capture have been demonstrated, they have never been demonstrated together in one plant
 - Water-Gas Shift of syngas and CO₂ capture and compression has been demonstrated at Great Plains Gasification
 - Integration of gasification and combined cycles has been demonstrated at 4 large facilities
 - Still need to demonstrate IGCC plus water-gas shift and CO₂ capture and compression in an integrated plant to identify any operations and controls issues

IGCC Improvement Opportunities

- Reduce ASU power consumption
 - New ASU – perhaps Ion Transfer Membrane (ITM)?
 - An ASU at 200-300°C would be nice.
- Gas separation membranes and processes that can operate at warmer temperatures and that can also reduce the auxiliary power requirements for separation and compression.
- Gas turbine redesign to recover the derated performance (efficiency) with hydrogen firing.
- Longer term possibilities such as the Clean Power Systems concept and Solid Oxide Fuel Cell with Oxygen Transfer Membrane on Anode gas would eliminate the need for shift and CO₂ removal from the syngas since the flue gas is essentially CO₂ and water.

IGCC Availability History (excludes operation on back-up fuel)



Coal IGCC- Historical Causes of Outage

Project/Cause	Wabash	Tampa	Nuon	ELCOGAS
Coal Feeding	No	Minor	Minor	Yes
Injector Tip Life	90 days	60-90 Days	> 1 year	> 1 year
Refractory Wear	~ 2 years	~ 2 years	Not significant	Not significant
Slag Tap Blockage	Yes	Yes	No	Yes
Circ. Slag Water Erosion/Corrosion	Minor	Yes	Yes	Yes
Syngas Cooler Fouling	Yes – but can clean in situ	Radiant – No Convective - Yes	Minor – Rappers work well	Yes – but has not been major outage cause
Candle Filter Failure	Yes – but improved	Not applicable	Yes – but now solved	Yes
Gas Turbine Vibration	No	No	Yes – but improved	Yes – improved but fuel switch is problematic

IGCC: Ideas to improve RAM

- Develop improved refractory improvement
 - (or improved flux to lower gasifier temperature and extend refractory life)
- Develop gasifier instrumentation to guide operations
 - More reliable thermocouples and gasifier temperature measurement
 - On line slag analysis to prevent plugging
 - On line pH measurement in circulating slag/ash loops
 - On line slurry analysis
 - Demonstrate rapid on-line syngas composition measurement via laser adsorption spectroscopy
- Research methods to prevent syngas cooler plugging/fouling
- IGCC dynamic models & adaptation for operator training
- Improved feed injectors
- Reliability survey of existing gasification plants
- More durable warm gas filter elements
- CFD modeling of gasifiers



The End