“IGCC 101” for

Steve Jenkins
URS Corporation
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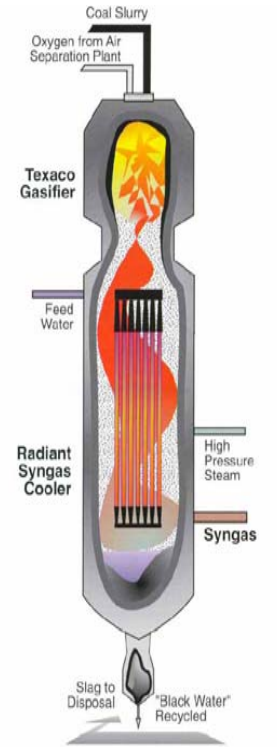
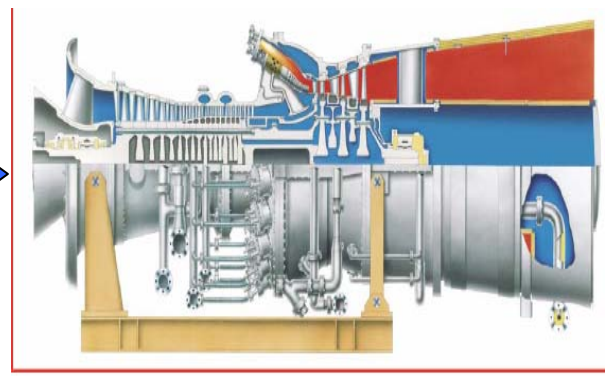
Topics

- Gasification 101
- History of modern coal gasification and IGCC
- Environmental performance of IGCC
- IGCC technology suppliers
- Comparisons of IGCC and SCPC
- Federal incentives for IGCC development
- Overall technology assessment

What is IGCC?

Integrated Gasification Combined Cycle = IGCC





Gasification 101

- First Law of Gasification – It's not combustion!

- So how is it different from combustion?

Combustion

$$C + O_2 \rightarrow CO_2$$

Combustion of coal produces CO_2 and heat, which is used to produce steam for power generation in a steam turbine generator

What is IGCC?

- Integrates two distinct technologies:
  - Coal gasification from the chemical industry
  - Combined cycle power generation from the power industry

- Advantages of IGCC
  - Can use a wide range of feedstocks
  - Takes advantage of high efficiency combined cycle power generation technology
  - Has low emissions and saleable byproducts

Gasification

What is Gasification?

- Thermal conversion of carbon-based materials at 1,400-2,800°F, with a limited supply of pure oxygen, to a synthetic gas, or *syngas*

- It's not combustion!

- Gasification uses only a fraction of the oxygen that would be needed to burn the coal
  - Combustion: excess air
  - Gasification: air starved

What is Gasification?

- Syngas is 35% H_2, 45% CO, 5% H_2O, 15% CO_2 with a small amount of methane
- The syngas can be used as a fuel to generate power, or to make chemicals & fuels
- Heating value is 250 Btu/scf (1/4 of natural gas)

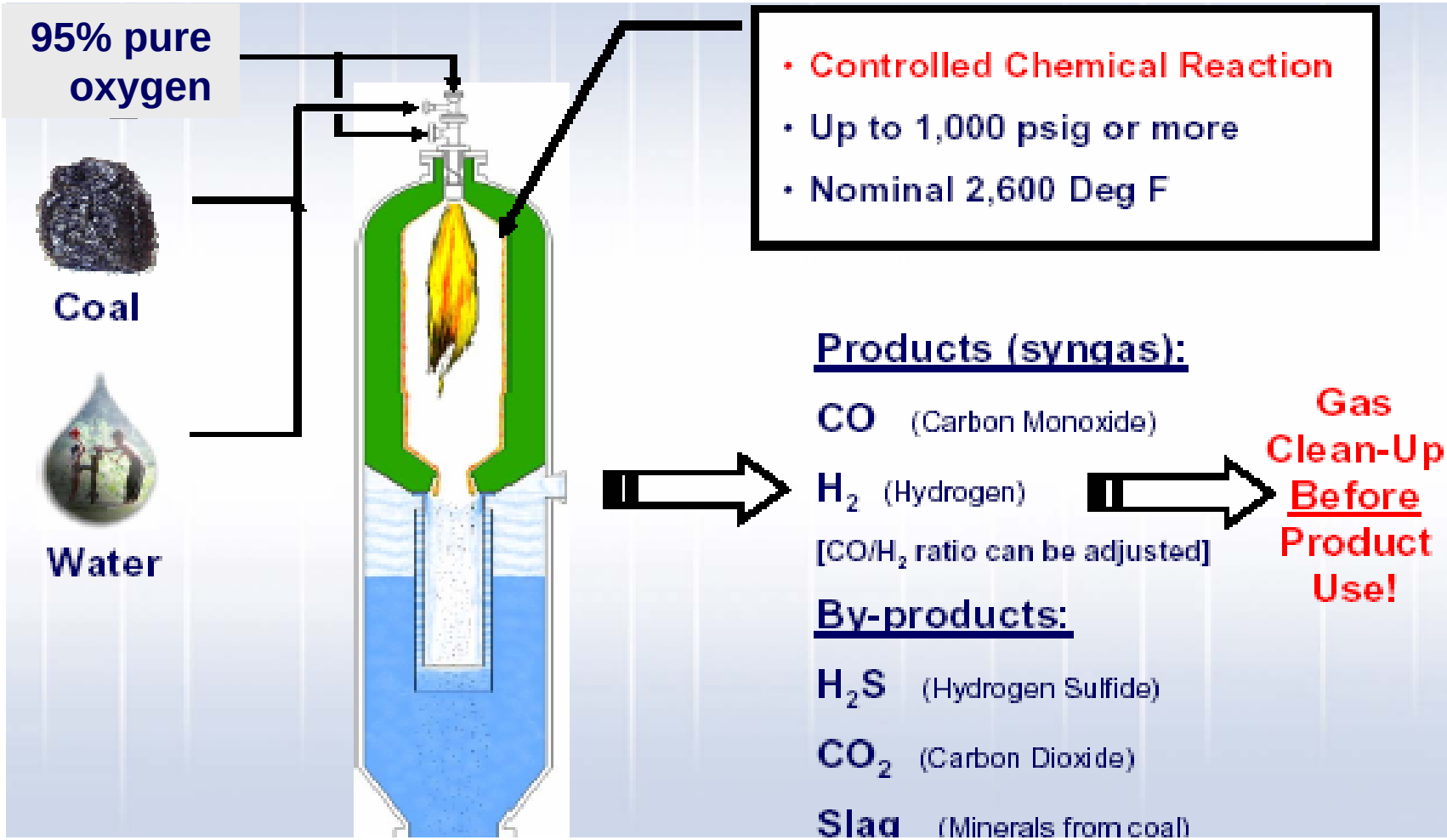
How has Gasification been Used?

- Making “town gas” from coal

- Fuels
  - Germany in WWII – no access to oil, but lots of coal
  - Fischer-Tropsch process produced diesel and gasoline
  - Cars and trucks used small wood gasifiers for fuel

Modern Coal Gasification

Modern Coal Gasification



Commercial-scale Gasification

SASOL

- Located in South Africa
- Started up in 1955
- Lurgi gasifiers (97)
- Fischer-Tropsch process converts syngas to liquid fuels
- Upgrades over the years
- Now processes 90,000 tons coal/day into 150,000 barrels/day of liquid fuels

Dakota Gasification Company
Great Plains Synfuels Plant

- Beulah, North Dakota
- Part of Basin Electric Power Cooperative
- Started up in 1984
- Converts 16,000 tons/day of North Dakota lignite to:
  - Synthetic natural gas
  - Fertilizers
  - Chemicals
  - CO_2: pressurized and piped 205 miles to Saskatchewan and sold for use in enhanced oil recovery by EnCana and Apache Canada

Eastman Chemical - Kingsport, Tennessee

- "Coal-to-Chemicals" Facility
- Started up in 1983
- Originally part of Eastman Kodak
- Texaco gasifiers
- Gasifies 1,200 TPD Central Appalachian medium sulfur coal
- Sulfur compounds and ash are removed from the syngas
- Syngas is used to make methanol, acetic acid, acetic anhydride, methyl acetate… and

Kodak Film….and

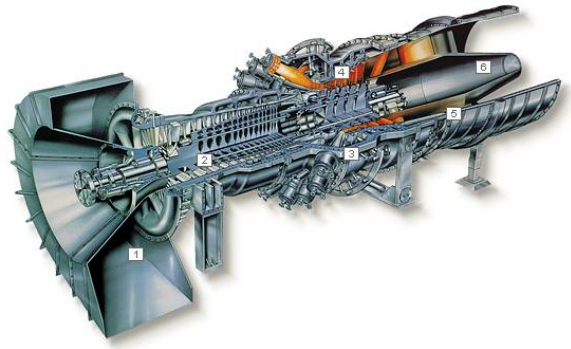
Consumer Products

So That's the Gasification Part, Now on to the Combined Cycle Part of IGCC

Combined Cycle Power Generation

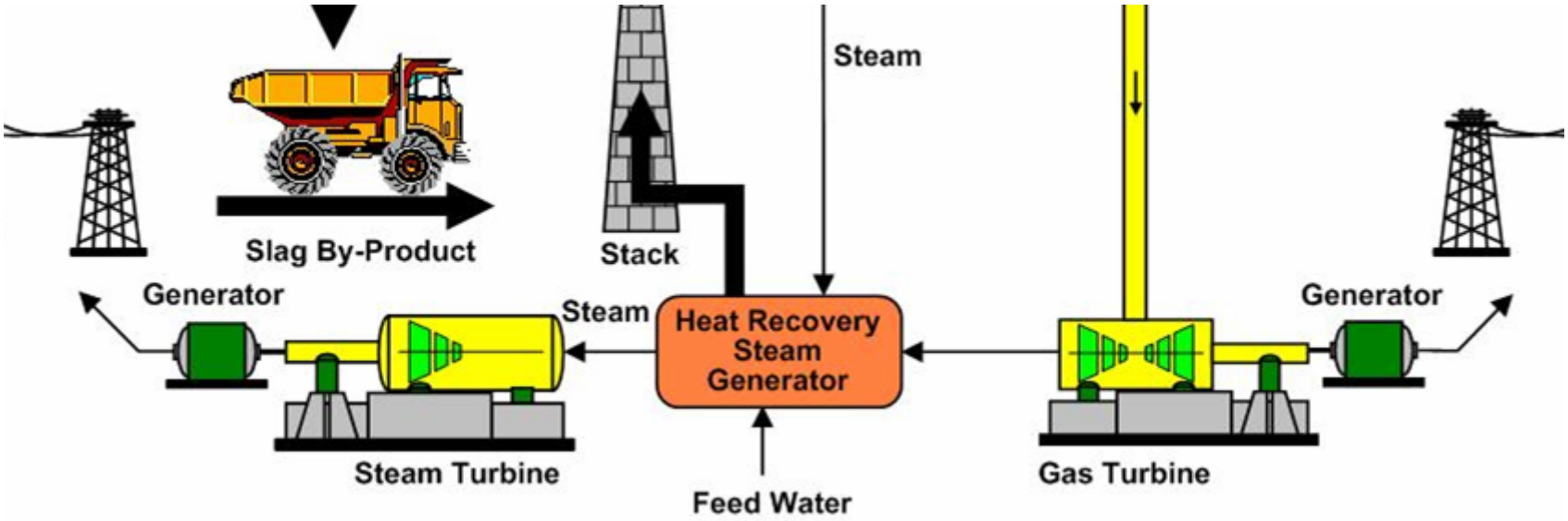
What is Simple Cycle Power Generation?

- Simple cycle combustion turbine burns a fuel
  - Fuel oil
  - Natural gas
  - Biogas
  - Jet fuel



- Combustion turbine turns a generator, producing electricity
- Hot exhaust gas (>1,000 °F) exits though a stack
- Efficiency = 35%

What is Combined Cycle Power Generation?



- Hot exhaust gas from combustion turbine is ducted through a Heat Recovery Steam Generator, or HRSG (boiler), where steam is produced
- Steam is piped to a conventional steam turbine-generator, producing more electricity

Combined Cycle

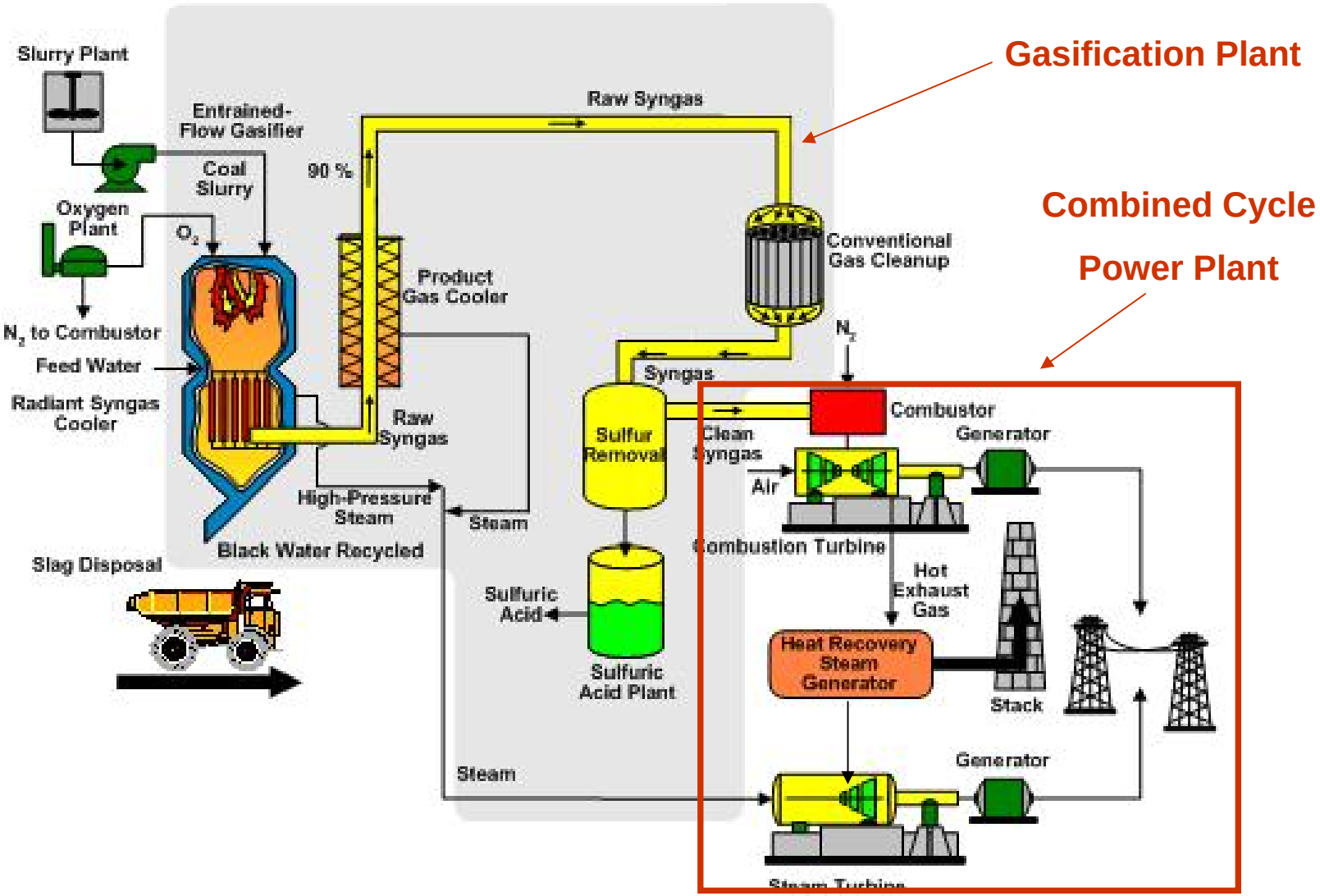
- Combination of simple cycle combustion turbine generator + steam turbine generator = combined cycle
- Conventional steam turbine generator efficiency = 35%
- Combined cycle efficiency = 55^{+}%

Combined Cycle – 2 Combustion Turbines and 1 Steam Turbine

How Does IGCC Work?

- Integrate the coal gasification process with a combined cycle power plant
- Instead of using natural gas or fuel oil in the combined cycle power plant, convert coal to a clean-burning syngas and use it as a fuel
- How?

IGCC


Gasification Plant
Combined Cycle
Power Plant
Slurry Plant
Entrained-
Flow Gasifier
Coal
Slurry
Oxygen
Plant
O_2
N_2 to Combustor
Feed Water
Radiant Syngas
Cooler
Raw Syngas
90 %
Product
Gas Cooler
Conventional
Gas Cleanup
N_2
Syngas
Raw
Syngas
High-Pressure
Steam
Steam
Black Water Recycled
Slag Disposal
Sulfur
Removal
Clean
Syngas
Combustor
Generator
Air
Combustion Turbine
Hot
Exhaust
Gas
Heat Recovery
Steam
Generator
Stack
Sulfuric
Acid
Sulfuric
Acid Plant
Steam
Generator
Steam Turbine

Benefits of IGCC

- Take advantage of low-cost coal or pet coke
  - Coal @$2.00/mmBtu, pet coke @$1/mmBtu
  - Natural gas @ $6+/mmBtu
- Take advantage of high efficiency of combined cycle power block
- Environmental profile: air, water, solid byproducts

Where has IGCC Been Used?

Cool Water IGCC Demonstration Project Daggett, CA

Cool Water IGCC Demonstration Plant

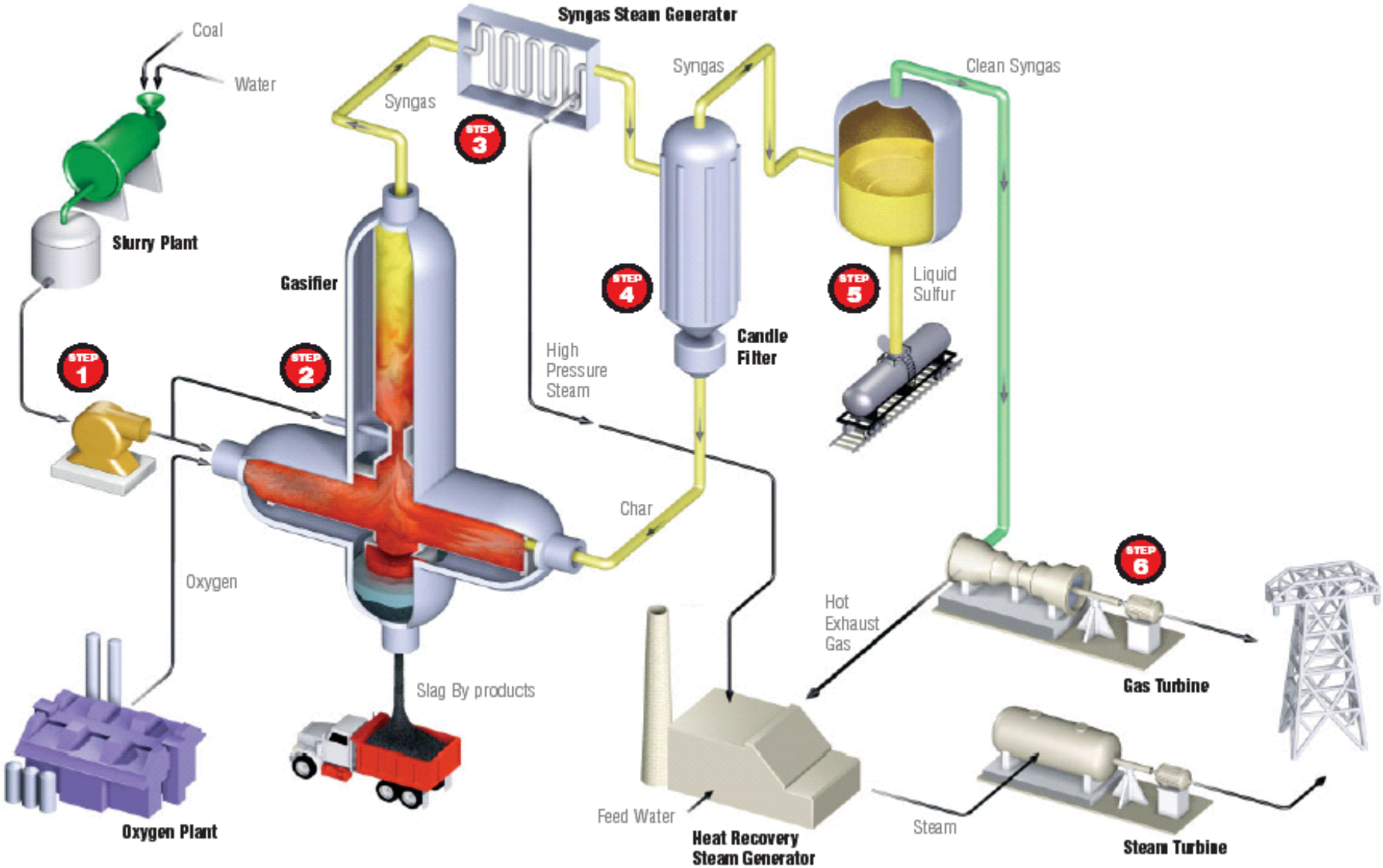
- First demonstration of IGCC in the U.S.
- Mid to late 1980s
- 110 MW size
- Texaco gasifier and GE combined cycle
- Co-funded by Southern California Edison, Texaco, GE & EPRI
- Considerable information provided for development of full-scale commercial plant

SG Solutions
Wabash River Generating Station
W. Terre Haute, IN

Wabash River Generating Station

- Start-up July 1995
- ConocoPhillips (formerly Destec) E-Gas gasifier
- 2,500 TPD coal and/or pet coke
- DOE Clean Coal Technology Program – repowering of existing unit
- Power generation
  - Combustion turbine: 192 MW
  - Steam turbine: 120 MW
  - Internal load: -50 MW
  - Net output: 262 MW

A Look Inside the Process

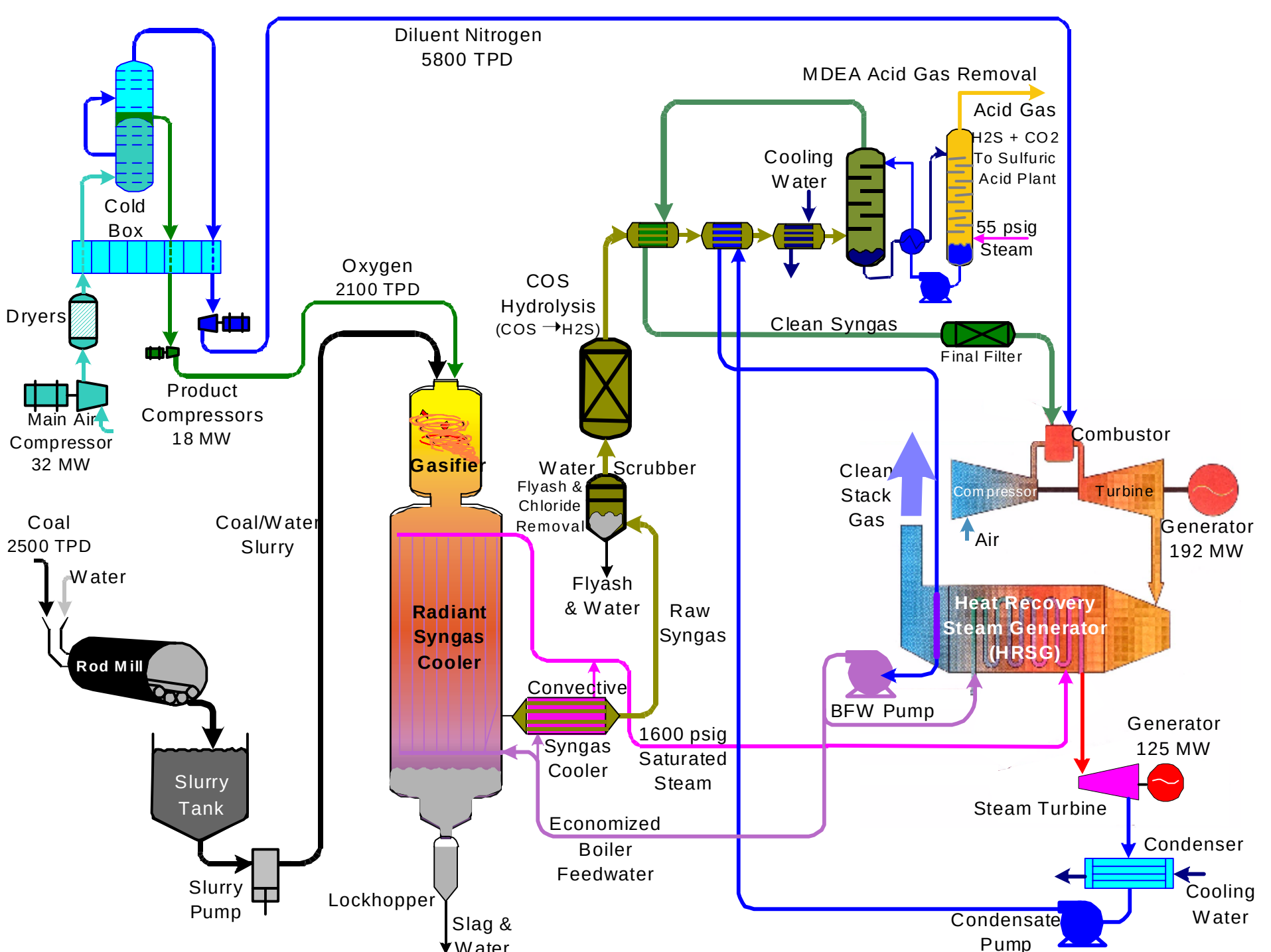


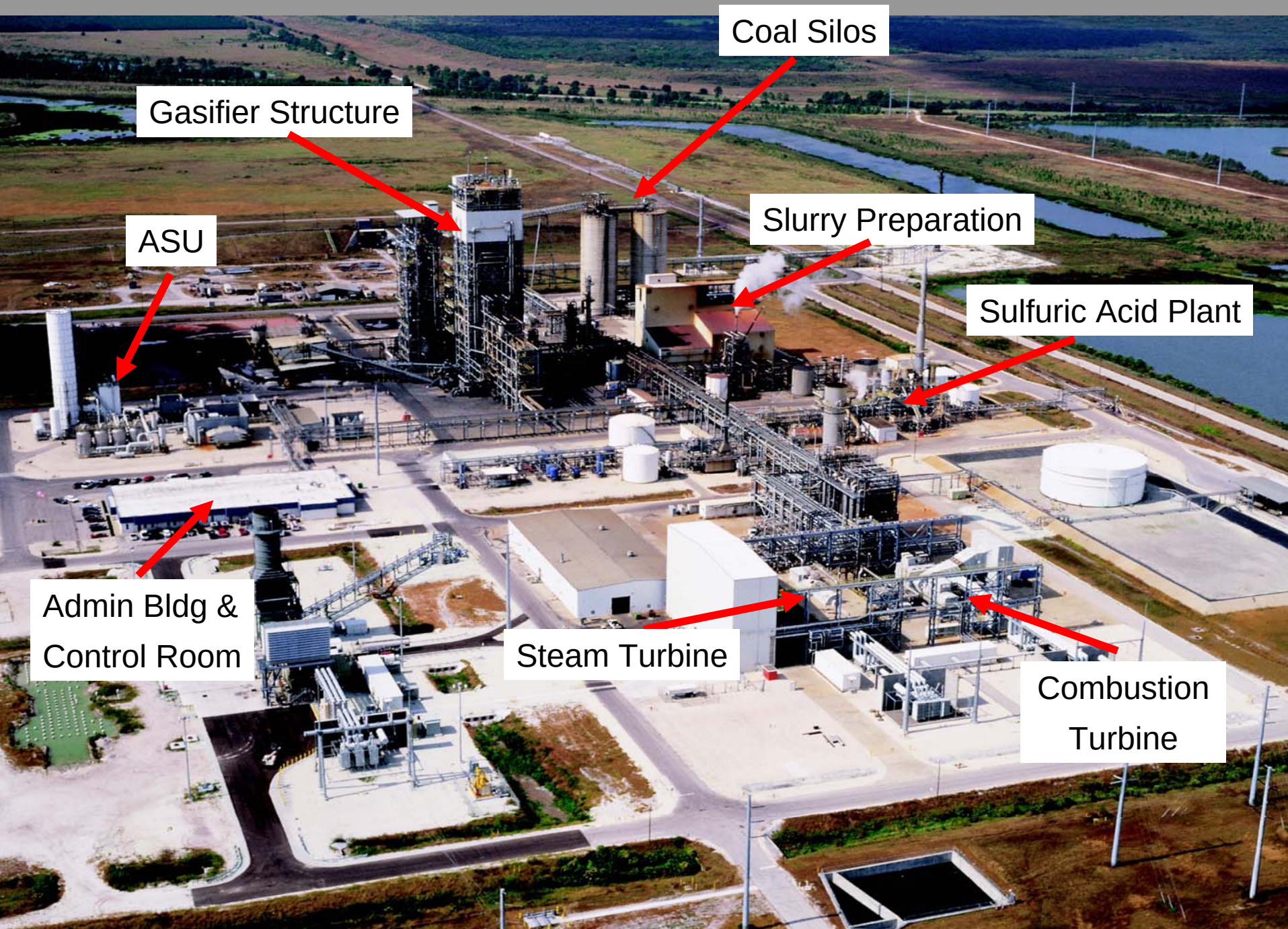
ConocoPhillips

Tampa Electric Company
Polk Power Station
Mulberry, FL

Polk Power Station

- Start-up July 1996
- GE Energy (formerly Texaco) gasifier
- 2,500 TPD coal/pet coke blend
- DOE Clean Coal Technology Program – new plant
- Power generation
  - Combustion turbine: 192 MW
  - Steam turbine: 120 MW
  - Internal load: -60 MW
  - Net output: 252 MW


Diluent Nitrogen
5800 TPD
MDEA Acid Gas Removal
Acid Gas
H2S + CO2
To Sulfuric
Acid Plant
Cooling
Water
55 psig
Steam
Cold
Box
Dryers
Main Air
Compressor
32 MW
Oxygen
2100 TPD
Product
Compressors
18 MW
COS
Hydrolysis
(COS → H2S)
Clean Syngas
Final Filter
Combustor
Compressor
Turbine
Generator
192 MW
Air
Clean
Stack
Gas
Gasifier
Water Scrubber
Flyash &
Chloride
Removal
Coal
2500 TPD
Water
Coal/Water
Slurry
Rod Mill
Slurry
Tank
Slurry
Pump
Radiant
Syngas
Cooler
Flyash
& Water
Raw
Syngas
Heat Recovery
Steam Generator
(HRSG)
BFW Pump
Convective
Syngas
Cooler
1600 psig
Saturated
Steam
Generator
125 MW
Steam Turbine
Condenser
Cooling
Water
Economized
Boiler
Feedwater
Lockhopper
Slag &
Water
Condensate
Pump


Coal Silos
Gasifier Structure
ASU
Slurry Preparation
Sulfuric Acid Plant
Admin Bldg &
Control Room
Steam Turbine
Combustion
Turbine

Existing IGCC Plants using Coal

Company	Facility	Location	Feedstock	Gasifier Technology
Tampa Electric	Polk Power Station	Mulberry, FL	coal/coke	GE Energy
SG Solutions/ PSI Energy	Wabash River	W. Terre Haute, IN	coal/coke	ConocoPhillips
Nuon	Willem Alexander Central	Buggenum, Netherlands	coal/biomass	Shell
ELCOGAS	Puertollano	Puertollano, Spain	coal/coke	Prenflo

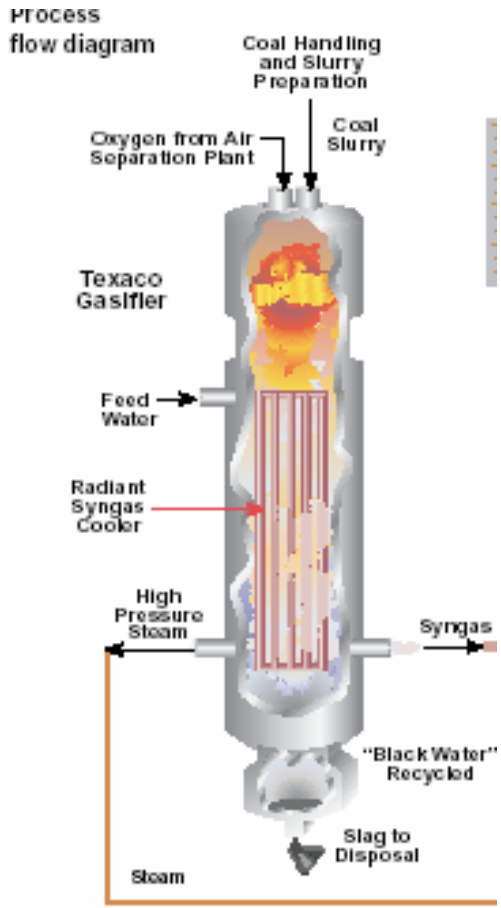
Gasification and IGCC Plants

- There are 117 operating gasification plants with a total of 385 gasifiers (not IGCC plants) in operation worldwide
- They are used primarily for gasifying coal, pet coke, natural gas, and refinery wastes
- They produce syngas for use in making hydrogen for ammonia, Fischer-Tropsch transportation fuels, and some power

IGCC Technology Suppliers

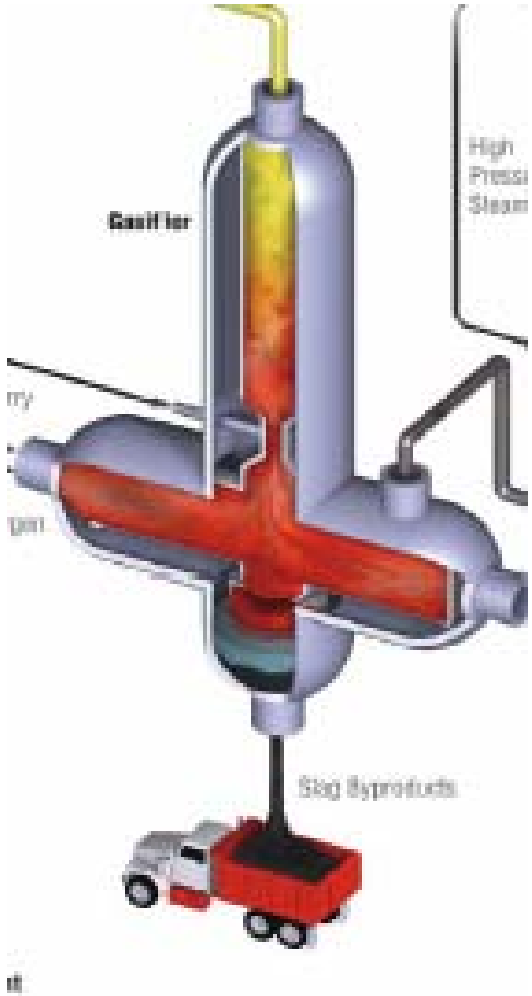
GE Energy (Texaco process)

- Slurry feed
- Refractory-lined gasifier
- Good for bituminous coal, pet coke, or blends of pet coke with low-rank coals
- GE Energy provides gasification technology
- GE Power provides combined cycle plant
- Alliance with Bechtel for EPC and guarantees on total IGCC plant



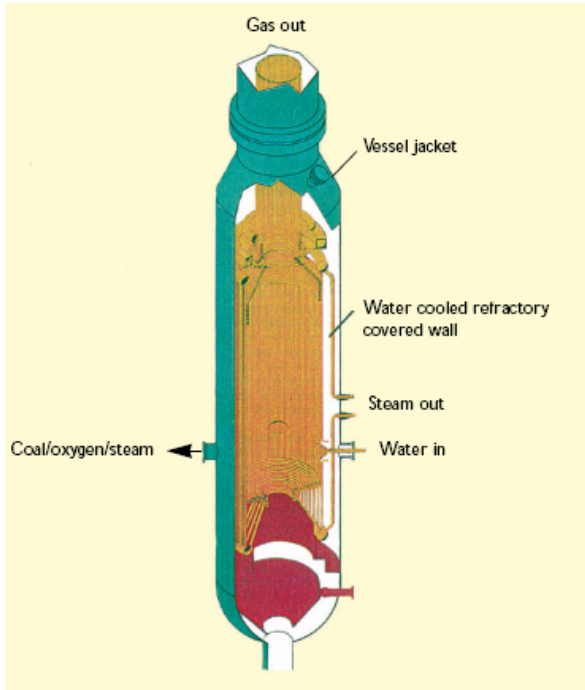
ConocoPhillips (E-Gas process)

- Slurry feed
- Refractory-lined gasifier
- Good for a wide range of coals, pet coke, and blends
- ConocoPhillips provides gasification technology
- Siemens provides combined cycle plant
- Alliance with Fluor for EPC and guarantees on total IGCC plant



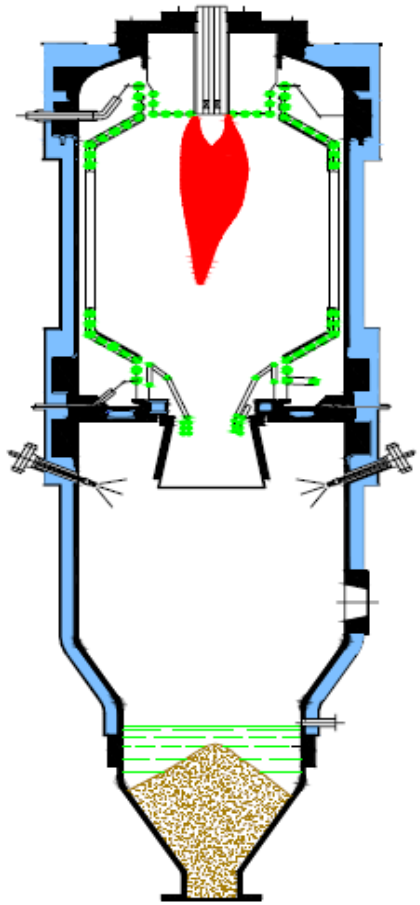
Shell

- Dry feed
- Waterwall in gasifier
- Good for wide variety of feedstocks, from pet coke to PRB
- Shell provides gasification technology
- Alliance with Black & Veatch and Uhde for EPC
- Open on supply of combined cycle plant



Siemens (FutureEnergy)

- Dry feed
- Waterwall screen in gasifier
- Good for a wide variety of feedstocks, from bituminous to low-rank coals
- Siemens provides gasification and power block
- EPC and guarantees to be determined



Status of Commercial IGCC

- New fleet taking advantage of 10-11 years of operation and lessons learned from Polk Power Station and Wabash River
- While IGCC is not yet commercially proven at large scale, it is commercially available
- Range of suppliers to choose from, for a wide variety of coals and other feedstocks
- EPC contracts can provide good guarantees

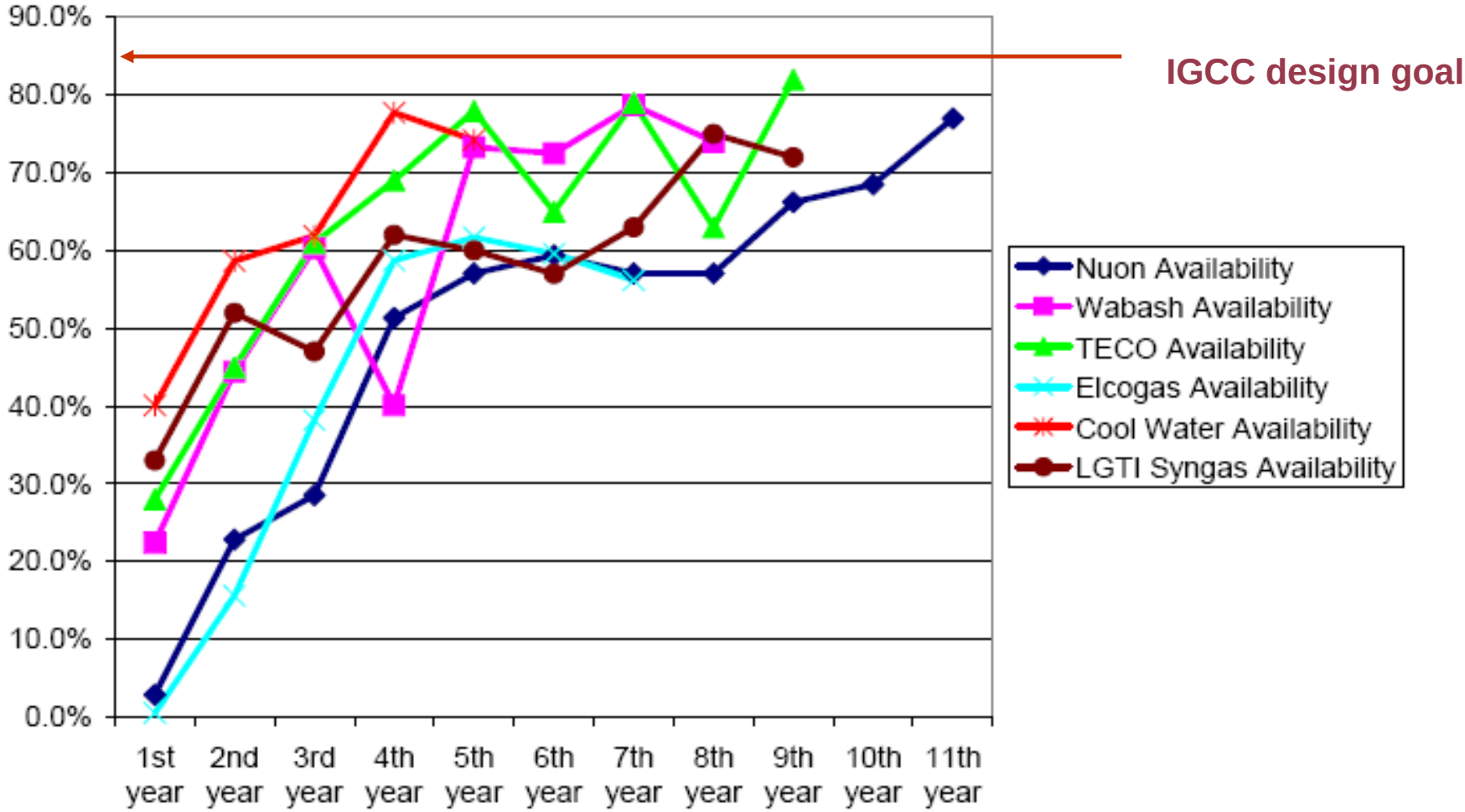
Proposed IGCC Projects

Company	Facility	Location	Feedstock	Gasification Technology
AEP	Great Bend/Mountaineer	OH or WV	Coal	GE
Duke (Cinergy)	Edwardsport	Edwardsport, IN	Coal	GE
EnergyNorthwest	Pacific Mountain Energy Center	Port of Kalama, WA	PRB/pet coke	ConocoPhillips
ERORA	Cash Creek Generation	Owensboro, KY	Coal	GE
ERORA	Taylorville Energy Center	Taylorville, IL	Coal	GE
Excelsior Energy	Mesaba	Taconite, MN	PRB/Illinois #6/pet coke	ConocoPhillips
Southern Company and Orlando Utilities	Orlando Gasification Project	Orlando, FL	PRB	KBR
Tondu	Nueces IGCC	Corpus Christi, TX	Pet coke	Shell

Capacity of Proposed IGCC Facilities

- 600 MW (net) “reference plant” based on sufficient syngas to fully load two F class gas turbines (i.e. GE 7FB or Siemens SGT-6 5000F)
- Gross output: 780 MW
- Net output: ~630 MW
- Internal load: 150 MW (19% of gross output)
- Feedstock requirements
  - Pet coke: 4,000 tons/day
  - Bituminous coal: 6,000 tons/day
  - PRB:7,800^{+} tons/day

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



Source: EPRI

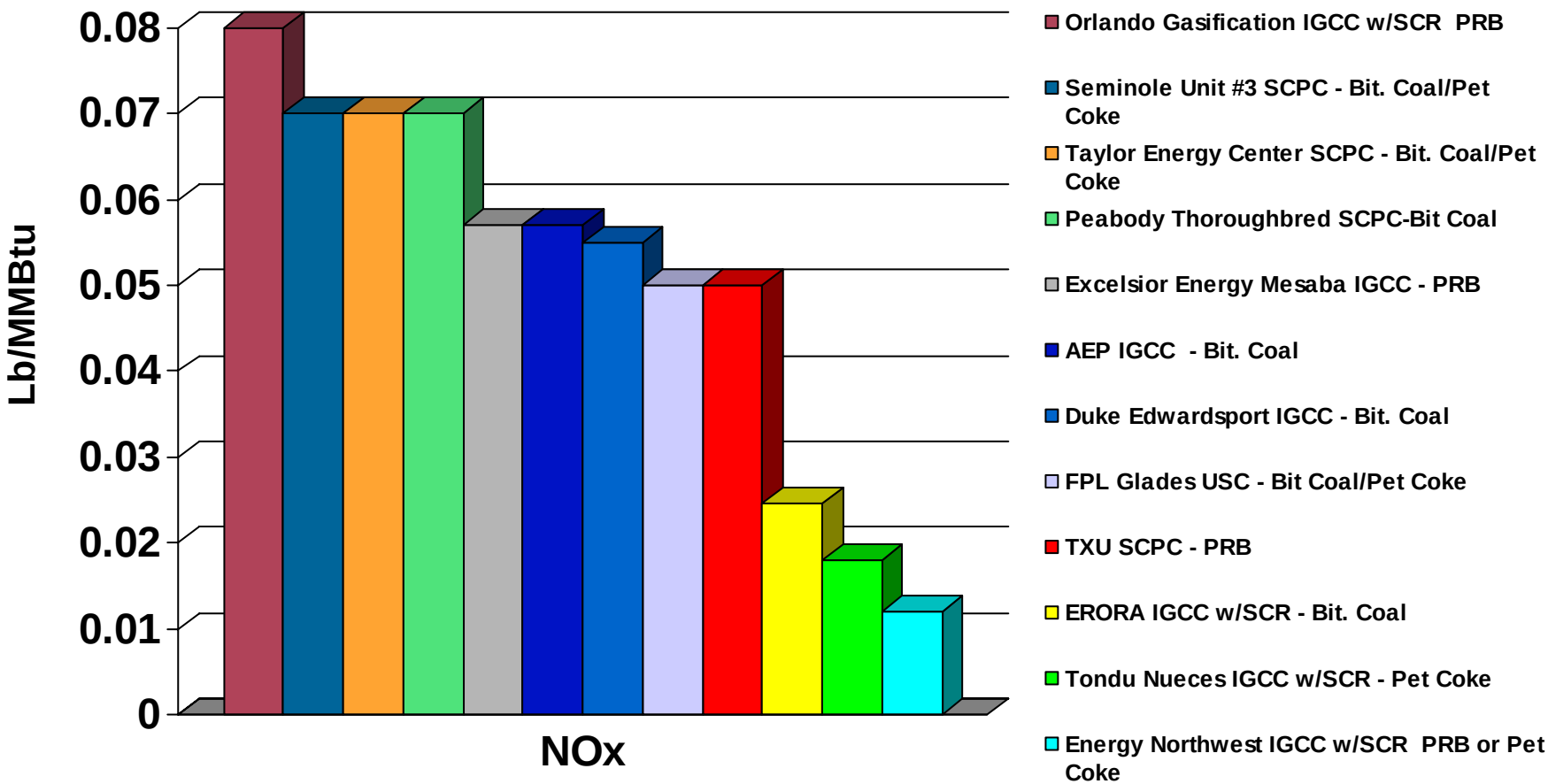
IGCC Availability Improvements

- Lessons learned from 10-11 years of experience at Wabash River and Polk Power Station
  - Materials of construction
  - Spare equipment
  - Gasifier refractory
  - Burner design
- Next generation of IGCC should reach 85% availability
- Spare gasifier train may achieve 90% availability
  - Significant cost adder
- Back-up fuel can also improve unit's availability
- Options must be balanced against cost

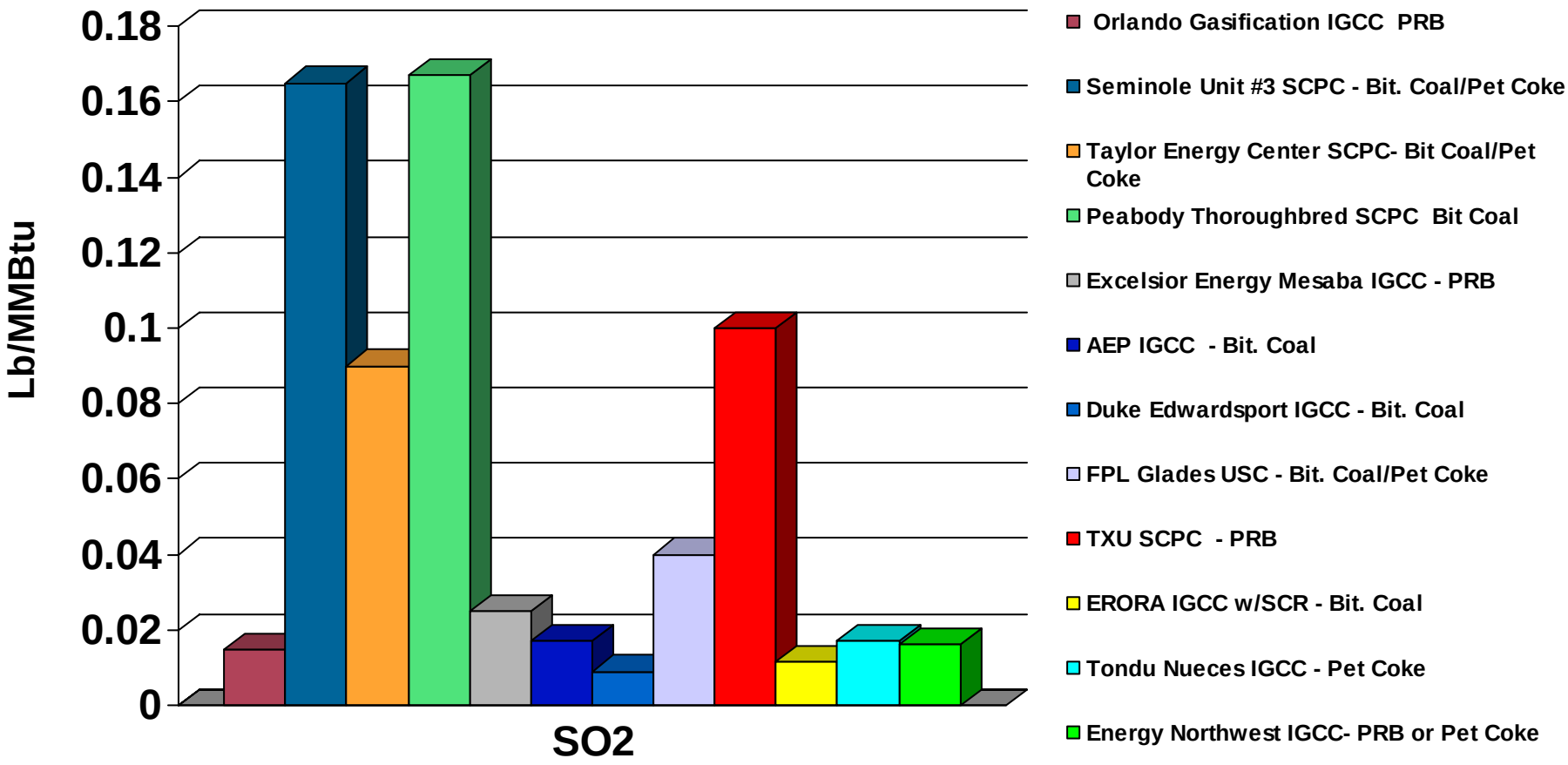
Environmental Profile Comparisons

Air Emissions

Air Emission Comparisons - NOx



Air Emission Comparisons – SO_2



Mercury Removal

- Advantage of IGCC – remove the mercury prior to combustion of the syngas
- Pre-sulfided activated carbon beds
- >94% removal of vapor-phase mercury
- Forms a mercury-sulfur complex
- Spent carbon disposed of in drums once/year

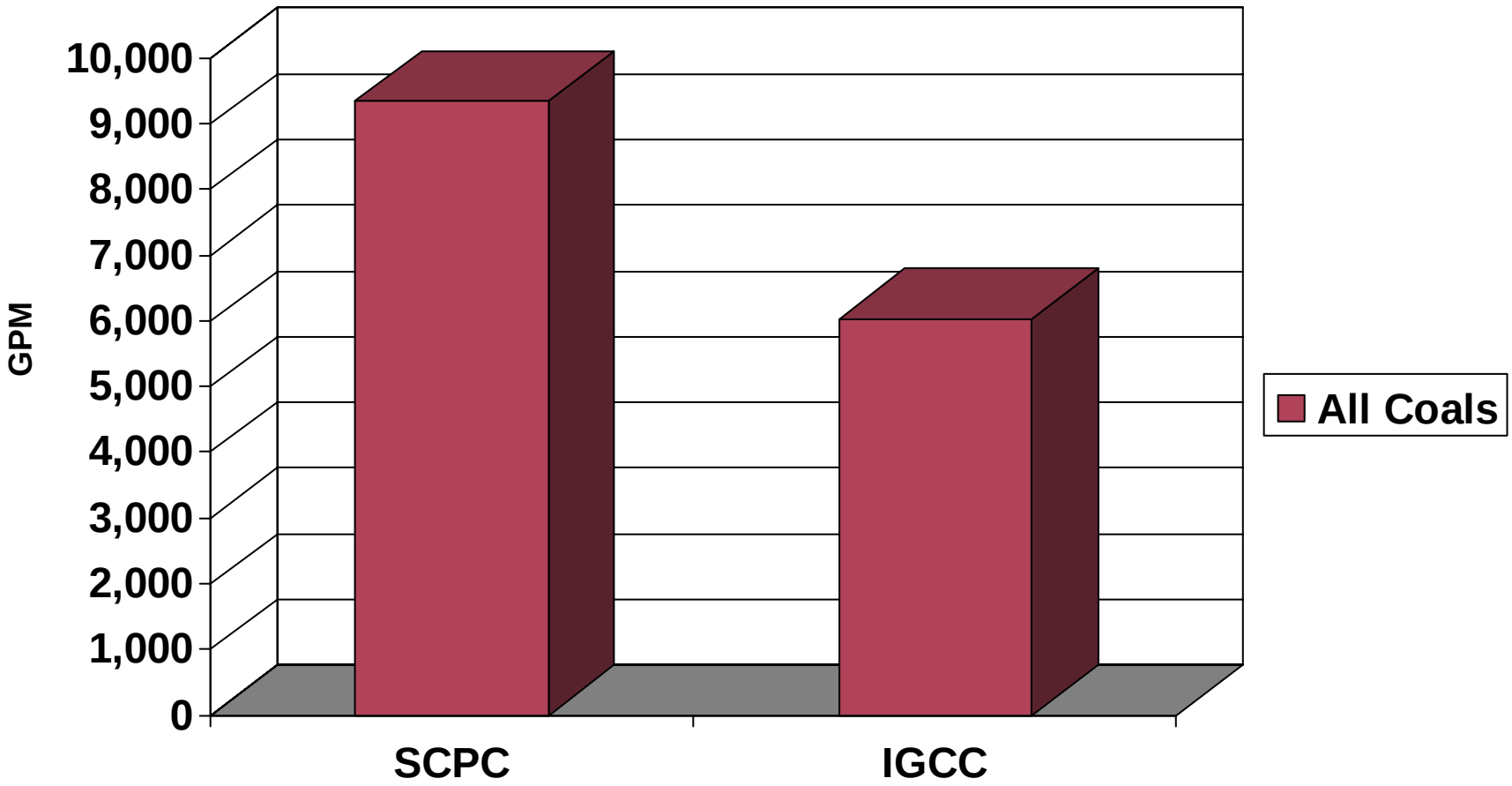
Water Consumption

- IGCC plants use less water than SCPC plants
- Important in western states

Water Consumption – IGCC vs SCPC

- FGD System
  - IGCC has no FGD system, so there are no large requirements for water to produce limestone slurry
- Cooling Water
  - Example: for 740 MW (gross) IGCC unit, 440 MW is from CTs and 300 MW is from the ST
  - So only ~40% of output is from ST
  - Cooling water make-up needs are decreased by ~60%
- Process water
  - IGCC can have need for coal slurry preparation and water scrubbing

Water Use – SCPC vs IGCC (500 MW)



Source: US EPA

Solid Byproducts

- IGCC plants generate less solid by-products than PC plants

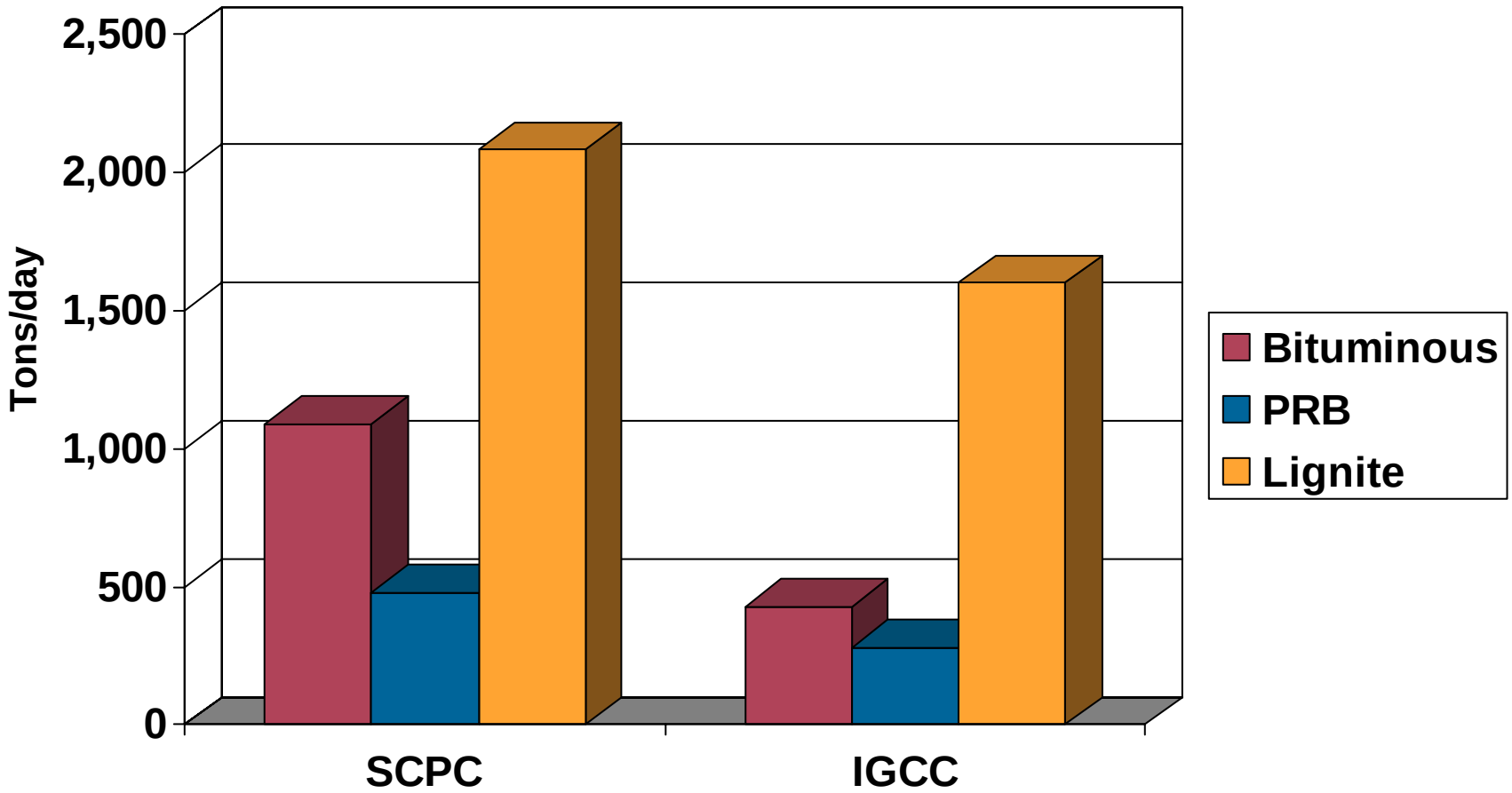
Comparison of Solid Byproducts – IGCC vs SCPC

	Solid Wastes	Market Use	Land Requirements
IGCC	Small volumes of sulfur and slag	Excellent markets for sulfur and slag	Temporary storage for slag and molten sulfur
SCPC	Large volumes of fly ash, bottom ash, FGD byproduct	Markets may or may not exist	Hundreds of acres if CCPs not marketable

Solid Byproducts

- Ash is removed in molten form, then quench-cooled to form glassy, inert, saleable slag
- Use for making cement, asphalt filler, roofing shingles

Solid Byproducts - SCPC vs IGCC (500 MW)



Source: US EPA

CO_2 Capture

- Technically feasible, but needs to be demonstrated at full-scale on IGCC
- Different technologies available, with a wide range of costs
- Syngas must be chemically modified first
- CO_2 is concentrated and separated from the syngas
- Large-scale CTs being developed to combust hydrogen-rich syngas

CO_2 Storage

- Once you remove the CO_2, where do you put it?
- CO_2 can be used for Enhanced Oil Recovery
- Might be stored geologically
- Industry needs commercial-sized project to further this important technology

Proposed IGCC Projects w/CO_2 Capture

Company	Facility	Location	Feedstock	Gasification Technology
BP/Edison Mission Energy	Carson Hydrogen Power Project	Los Angeles, CA	Pet coke	GE
Hunton Energy	Lockwood Road	Sugar Land, TX	Pet coke	GE or CoP

Federal Incentives for IGCC

- Energy Policy Act of 2005
  - Tax incentives – but law written in a way that precludes use of PRB – this is being fixed in follow-on legislation and will allow for next round of applications later this summer
  - Loan guarantees
    - DOE still working on regulations
    - No appropriations yet for DOE to implement this program
    - No appropriations from congress for many of the EPAct incentive programs

Federal Incentives for IGCC

- Application process is very competitive
- What can help make an application successful?
  - A site
  - A technology
  - Permits
  - Approval from a commission
  - Use of PRB in next round of applications
  - CO_2 capture and storage as part of the project

Overall Technology Assessment - IGCC

- IGCC can provide:
  - High efficiency
  - High availability
  - Fuel flexibility
  - Superior environmental profile
  - Marketable by-products
  - Future CO_2 capture

Want to Learn More?

- Gasification Technologies Council
- www.gasification.org
- Regulatory Workshop
  - March 14
  - Renaissance Denver Hotel
  - No cost for regulatory staff
  - IGCC 101
  - Environmental regulatory issues
  - Economic regulatory issues
  - Register on-line

Questions?

Contact Info

Steve Jenkins

813-874-0777