



Gasification 101



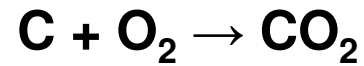
Steve Jenkins
CH2M HILL

Gasification Technologies Council
Regulatory Workshop
Tulsa, OK
June 17, 2008

Topics

- Gasification and IGCC “101”
- History of modern coal gasification and IGCC
- Gasification technologies
- IGCC plants
- Environmental issues (air, water, byproducts)

Combustion

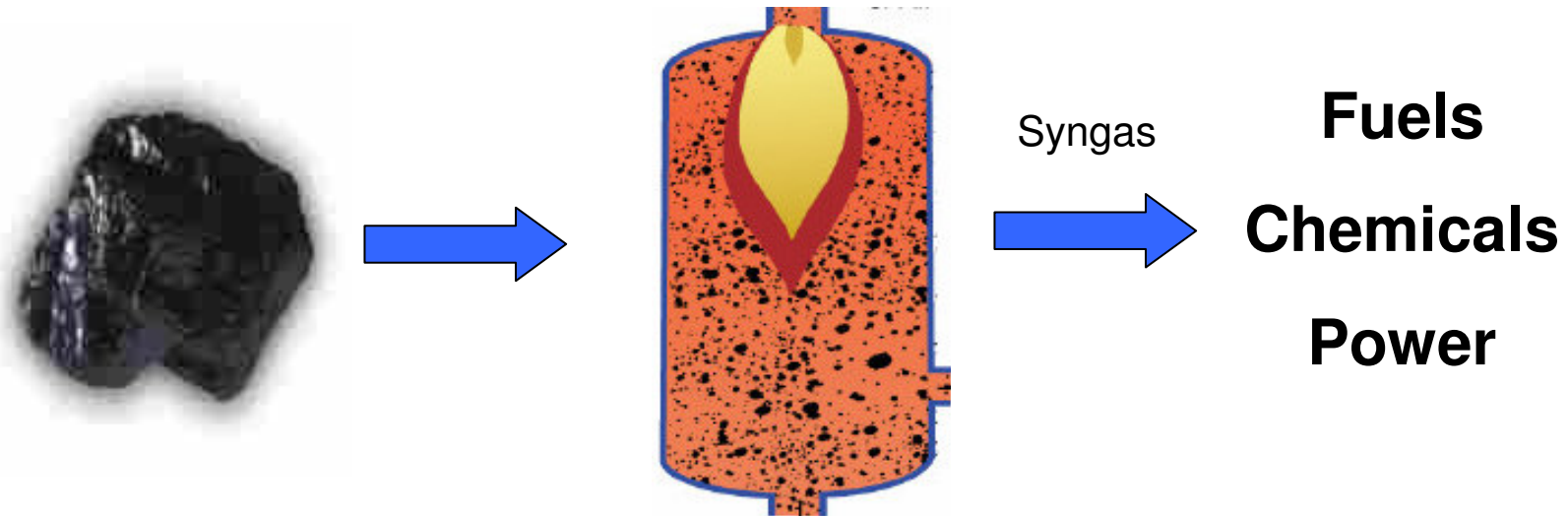


Combustion of coal produces CO_2 and heat, which is used to produce steam for power generation in a steam turbine generator

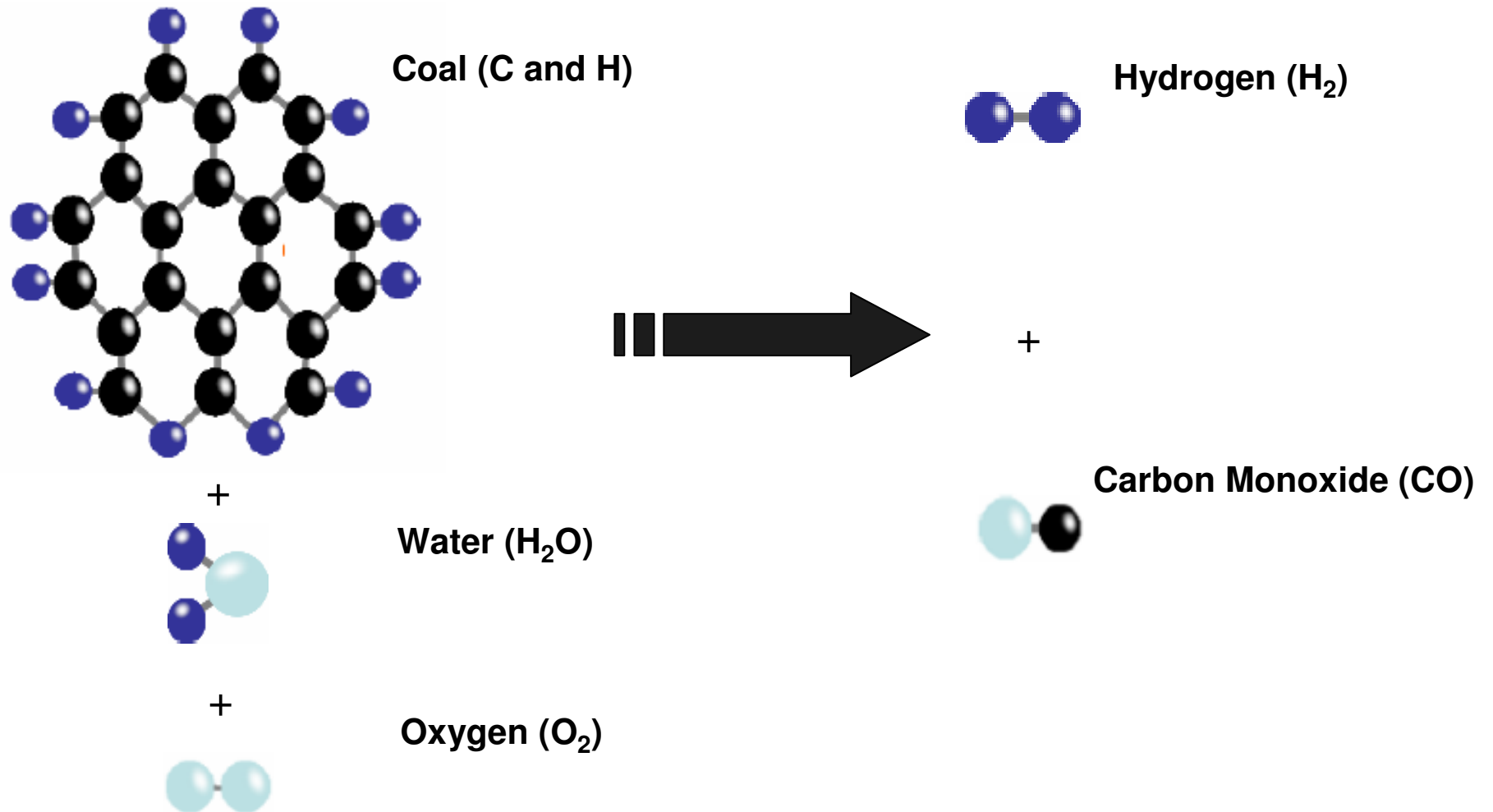
What is Gasification?

- Thermal conversion of coal at 1,400-2,800 °F, with a limited supply of air or oxygen, into 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?



Gasification



What's in the Syngas?

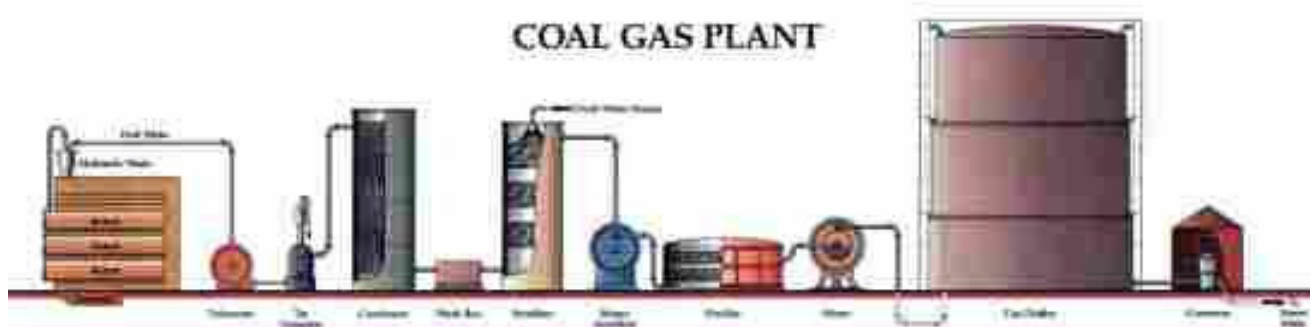
- Syngas contains mostly hydrogen, carbon monoxide, water vapor, carbon dioxide and methane
- Syngas can be used as a fuel to make chemicals and fuels, or for generating power
- Heating value is 250 Btu/ft³ (1/4 that of natural gas)
 - Air-blown gasifier syngas includes a large amount of nitrogen, and is diluted to 125 Btu/ft³

How has Gasification been Used?

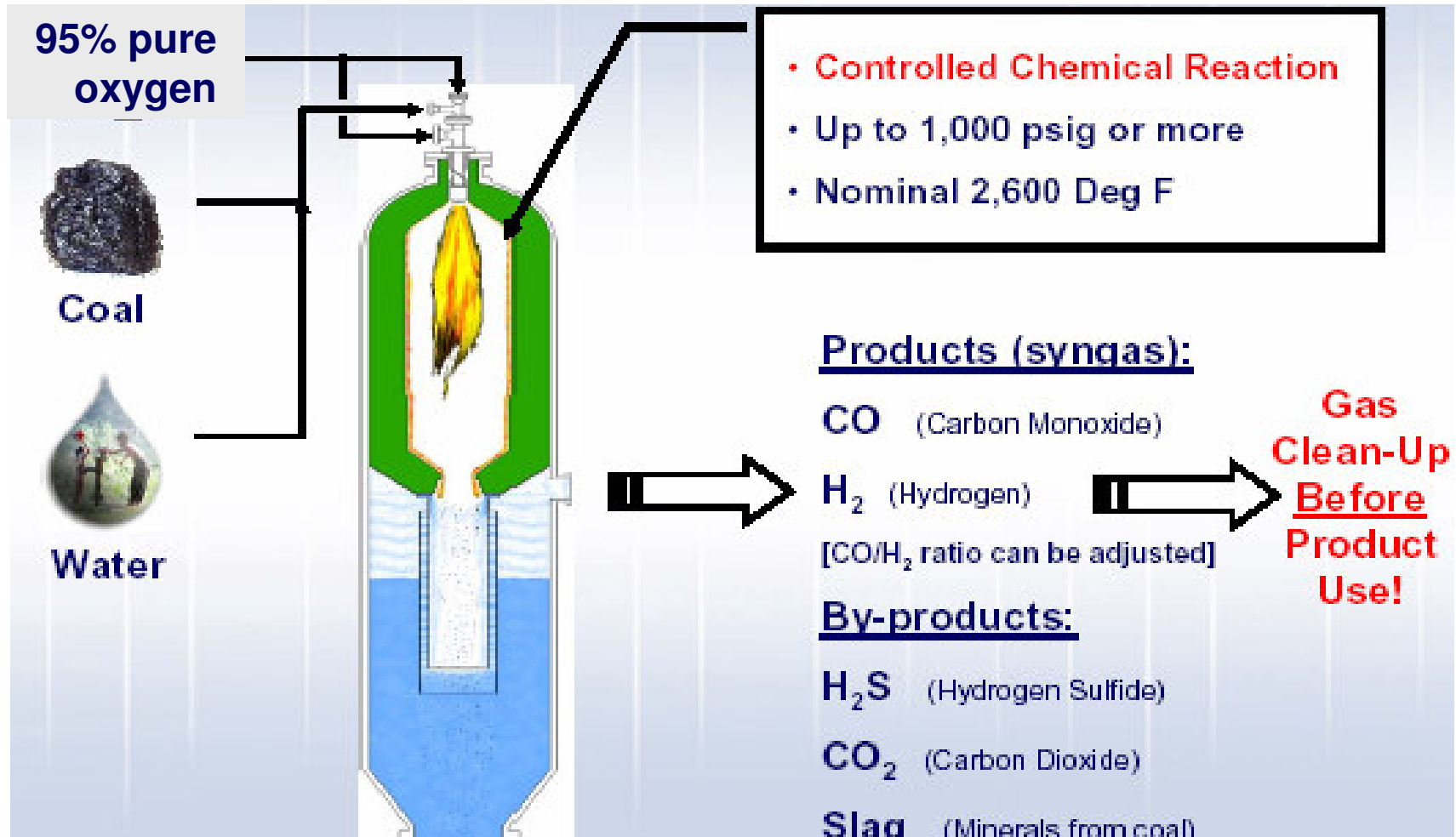
- Making “town gas” from coal (1792)



- Manufactured gas plants – prior to discovery and use of natural gas

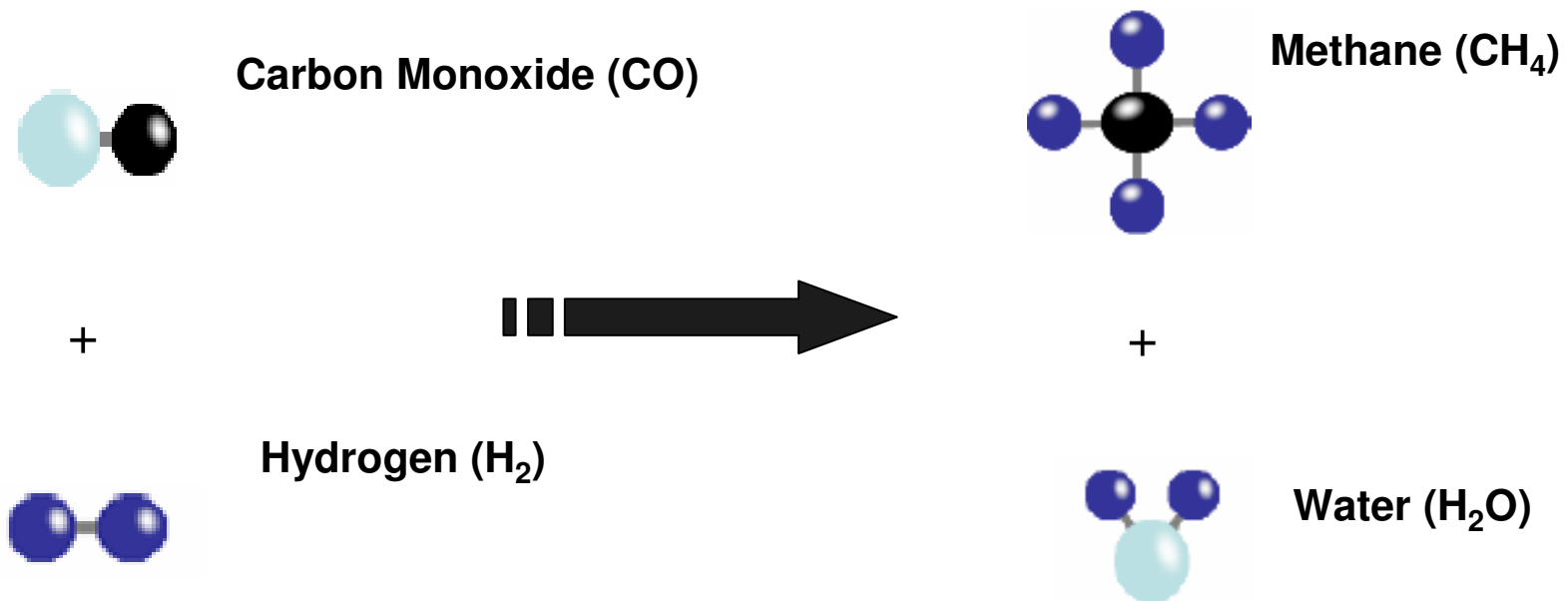


Modern Coal Gasification

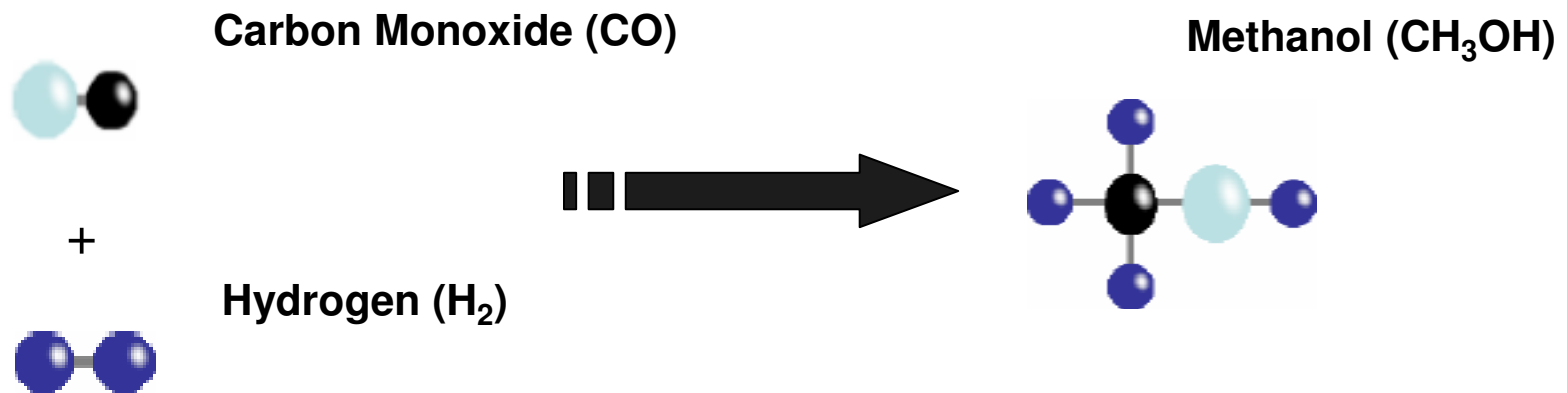


Products from Syngas

- CO and H₂ are basic building blocks for a wide range of organic chemicals and fuels



Products from Syngas

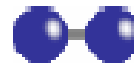


Products from Syngas



Carbon Monoxide (CO)

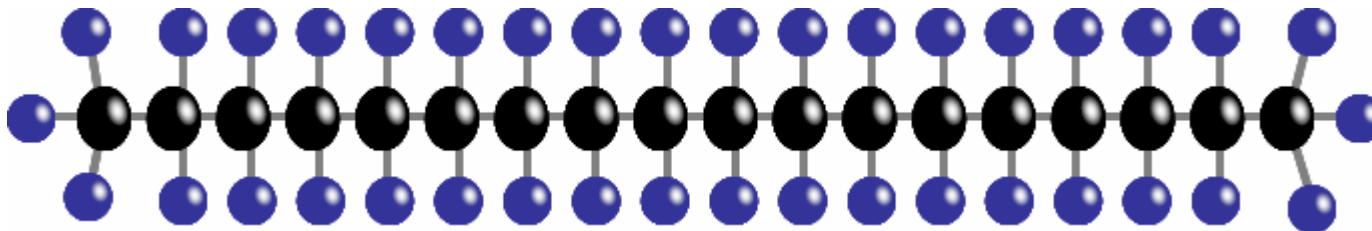
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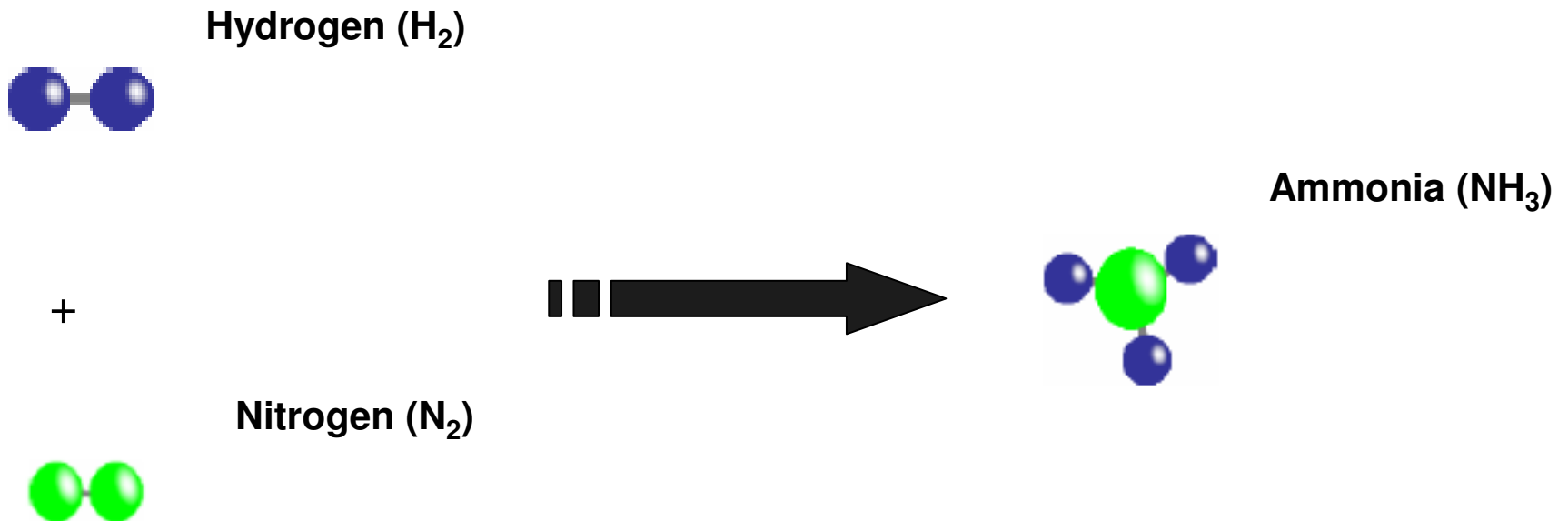
Hydrogen (H₂)



Diesel (C₁₈H₃₈)



Products from Syngas



How has Gasification been Used?

- Fuels

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



wood gasifier

Source: www.fischer-tropsch.org

Modern Coal Gasification

SASOL – Coal to Liquid Fuels

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



Source: Sasol

Eastman Chemical - Kingsport, Tennessee

Coal to Chemicals

- Started up in 1983
- Two GE Energy gasifiers
- 1,300 tons/day Central Appalachian medium sulfur coal
- Sulfur compounds and ash are removed from the syngas
- Syngas is used to make chemicals which are made into consumer products....



Source: Eastman

Consumer Products



Dakota Gasification Company Great Plains Synfuels Plant

- Started up in 1984
- Beulah, North Dakota
- Part of Basin Electric Power Cooperative
- Converts 16,000 tons/day of North Dakota lignite into substitute natural gas (SNG)
- SNG is sold into local gas pipeline



Source: Dakota Gasification

Coffeyville Resources

Coal to Fertilizer

- Ammonia/fertilizer plant in Coffeyville, Kansas
- Used high-cost natural gas to make ammonia
- Added pet coke gasification system
 - GE Energy gasifier
 - H₂ from syngas is used to make ammonia
 - Significant production cost savings and increased profitability

Gasification Plants

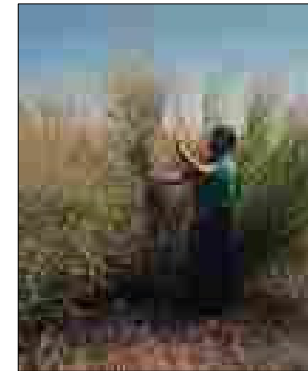
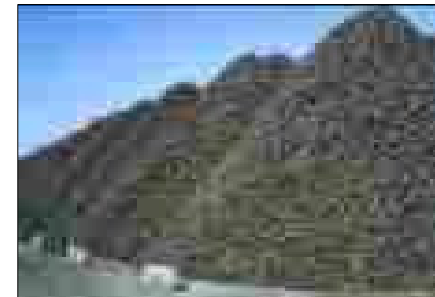
- There are 142 operating gasification plants with a total of 420 gasifiers in operation worldwide
- They are used primarily for gasifying coal, pet coke, natural gas and refinery wastes
- They produce syngas for use in making chemicals, SNG, hydrogen for ammonia, Fischer-Tropsch transportation fuels, and some power
- Only 5 coal-based IGCC plants

Proposed Gasification Plants in North America

- 25-35 projects
- Economic Drivers
 - High cost of natural gas where it is the feedstock for downstream products
 - SNG to replace high-cost natural gas
 - Production of lower cost transportation fuels
 - Low-cost, available feedstocks
 - Federal and state incentives
 - Energy Policy Act of 2005

Feedstocks

- Coal
- Pet coke
- Refinery wastes
- Biomass
- Blends



Products from Gasification Plants

- Ammonia
- Ethanol
- Fischer-Tropsch fuels (diesel)
- Hydrogen
- Methanol
- Methyl acetate
- SNG
- Urea
- Urea ammonium nitrate

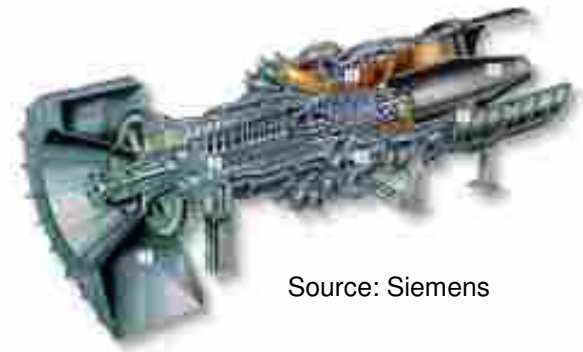
Proposed Gasification Plants in the U.S. (Examples)



Combined Cycle Power Generation

What is Simple Cycle Power Generation?

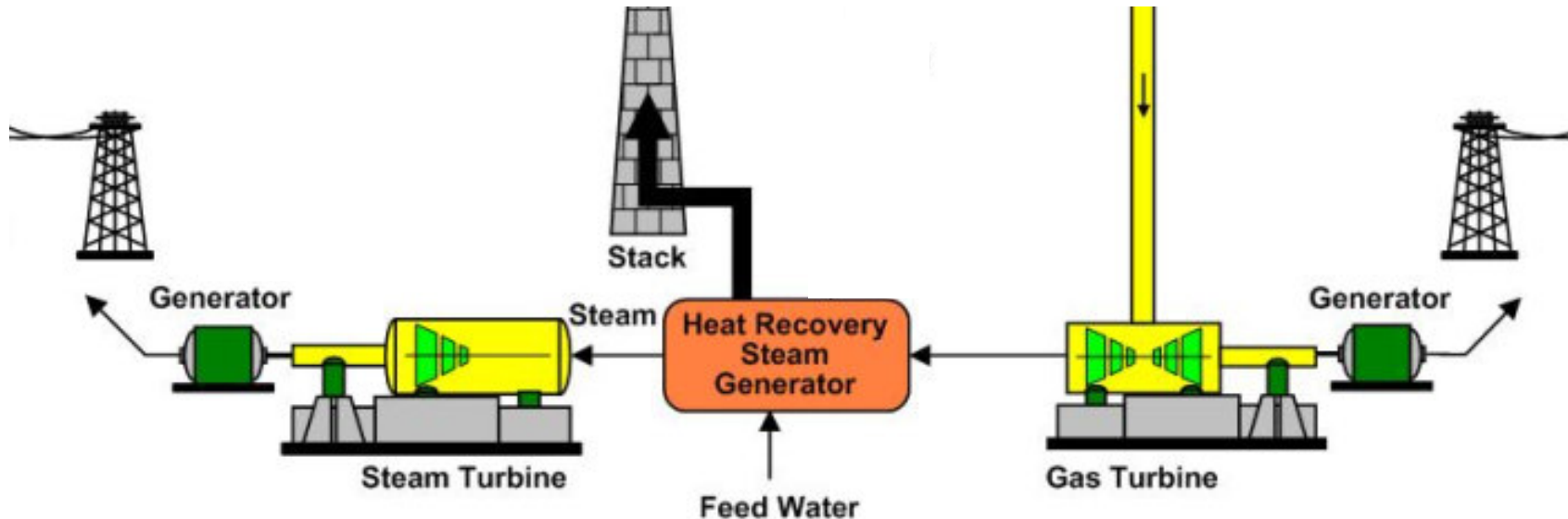
- Simple cycle combustion turbine burns a fuel
 - Fuel oil
 - Natural gas
 - Biogas
 - Jet fuel
- Combustion turbine turns a generator, producing electricity
- Hot exhaust gas ($>1,000$ °F) exits through a stack
- Efficiency = 35%



Source: Siemens



What is Combined Cycle Power Generation?



- Hot exhaust gas from gas turbine is ducted through a boiler, where steam is produced
- Steam is piped to a conventional steam turbine-generator, producing more electricity
- Combined cycle plant efficiency = 55-60%
- Commercially proven at hundreds of installations

Combined Cycle – 2 Gas Turbines and 1 Steam Turbine

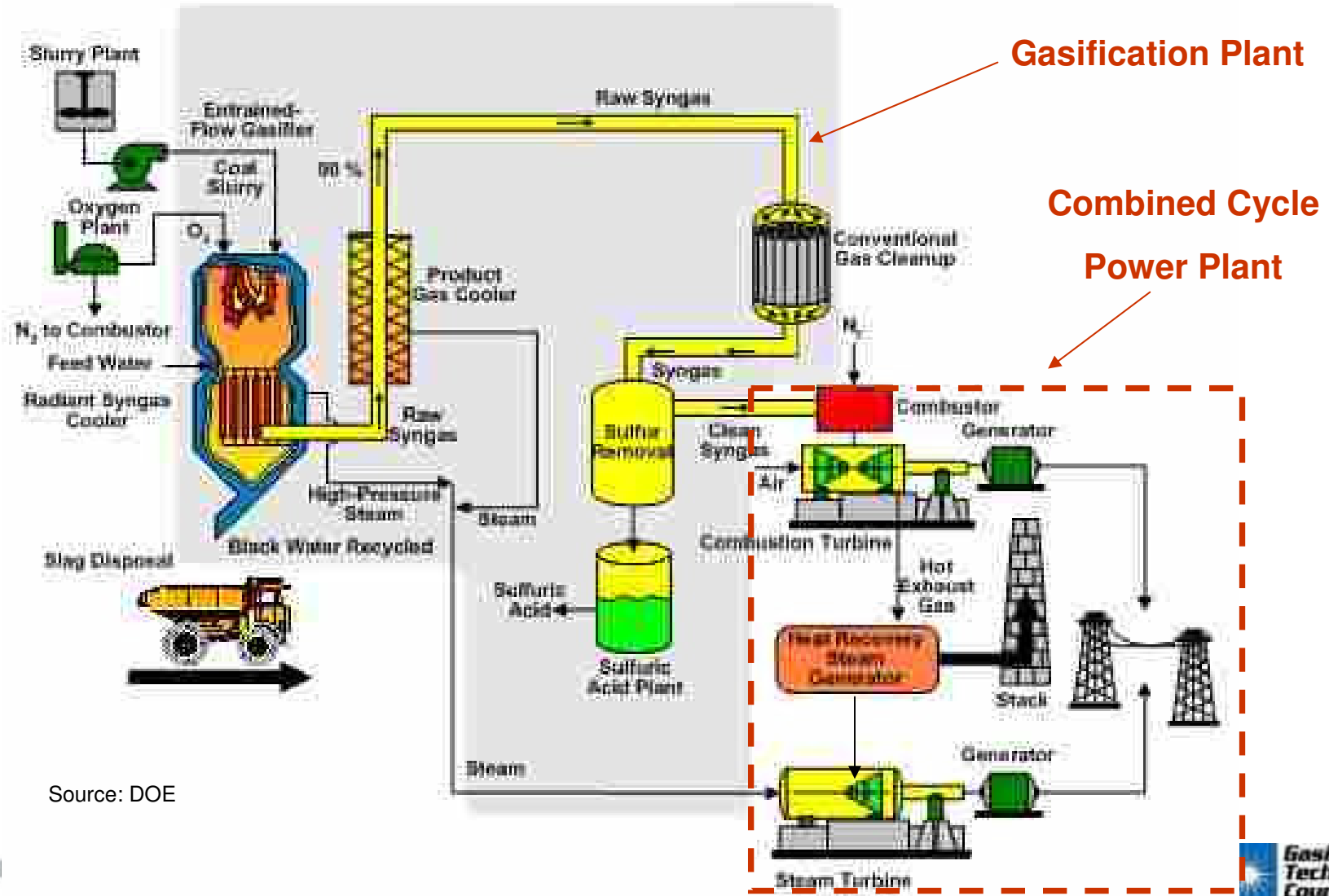


Source: Calpine

How Does IGCC Work?

- Integrate the coal gasification process with a combined cycle power plant
- Instead of using natural gas, convert coal to a clean-burning syngas and use it as the fuel for the gas turbines
- Advantages of IGCC
 - Takes advantage of high efficiency combined cycle power generation technology
 - Has low emissions and saleable byproducts

IGCC



Source: DOE

Where is IGCC Being Demonstrated?

Only 5 Plants Worldwide

Company	Facility	Location	Feedstock	Gasifier Technology
Nuon	Willem Alexander Centrale	Buggenum, Netherlands	coal/biomass	Shell
SG Solutions/ Duke Energy Indiana	Wabash River	W. Terre Haute, IN	coal/coke	ConocoPhillips
Tampa Electric	Polk Power Station	Mulberry, FL	coal/coke	GE Energy
ELCOGAS	Puertollano	Puertollano, Spain	coal/coke	Prenflo
Japanese utilities, MITI, CRIEPI	Clean Coal Power R&D Co.	Nakoso, Japan	coal	MHI

Nuon Willem-Alexander Centrale Buggenum, The Netherlands

- Start-up in 1993
- Shell technology
- 2,000 tons/day coal
- Blends with up to 30% biomass (wood chips)
- 253 MW net



Source: Nuon

SG Solutions

Wabash River Generating Station

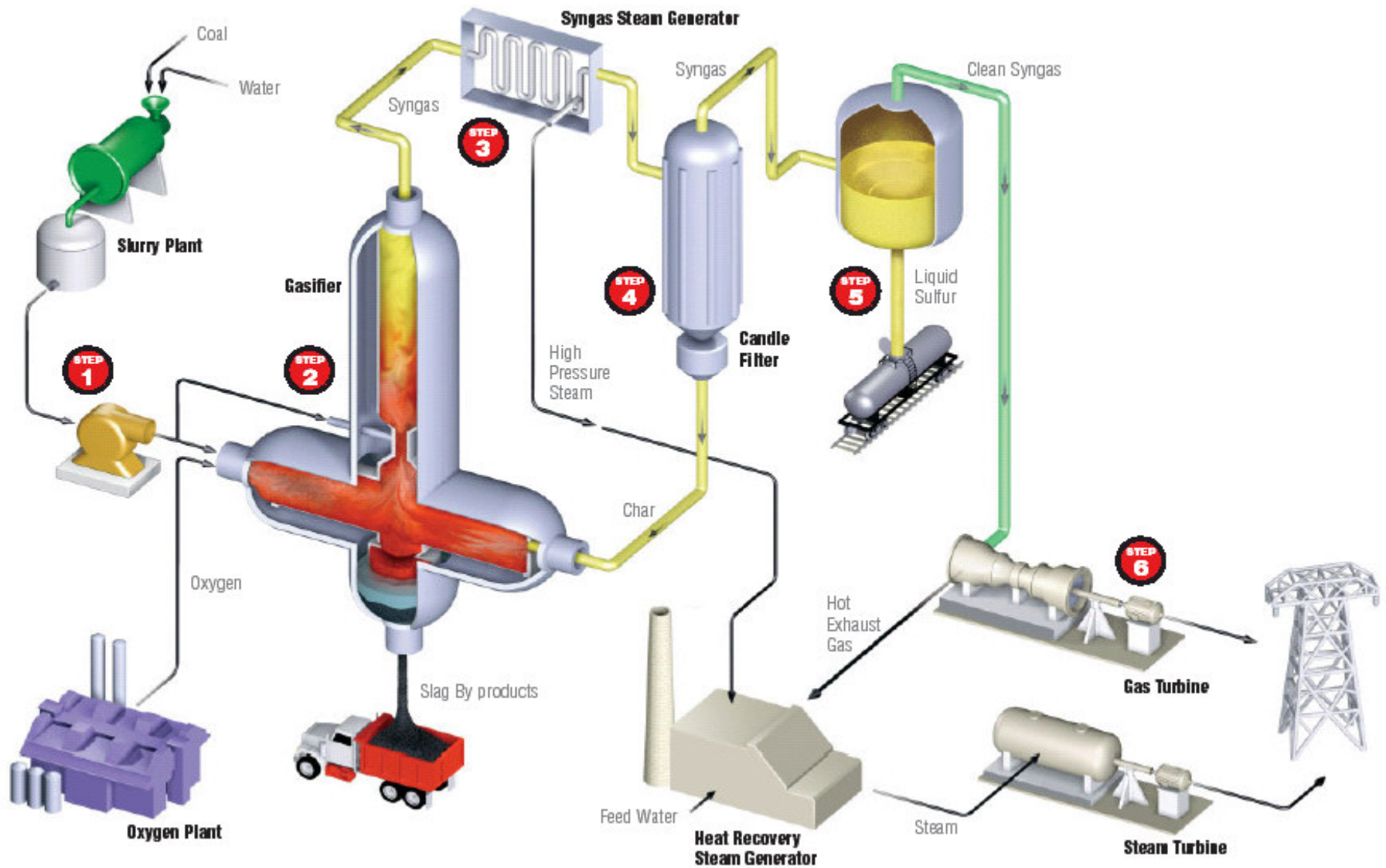
W. Terre Haute, IN

- Started up July 1995
- ConocoPhillips E-Gas™
- 2,000 tons/day coal, pet coke, blends
- Repowered existing unit
- DOE Clean Coal Technology Program
- 262 MW net output



Source: ConocoPhillips

A Look Inside the Process



Polk Power Station

- Started up July 1996
- GE Energy gasifier
- 2,000 tons/day coal and blend with pet coke
- DOE Clean Coal Technology Program
- 252 MW net output



Source: TECO

ELCOGAS

Puertollano, Spain

- Started up in 1998
- Prenflo technology
- 2,000 tons/day of 50/50 blend of local subbituminous coal and pet coke
- 260-280 MW net



Source: Siemens

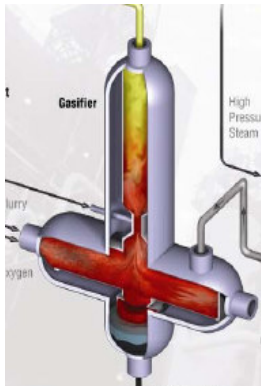
Clean Coal Power R&D Nakoso, Japan

- Started up fall 2007
- MHI technology
- 1,700 tons/day of subbituminous coal
- 250 MW net



Source: MHI

Gasification Technologies for IGCC



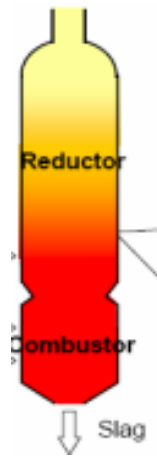
**ConocoPhillips
E-Gas**



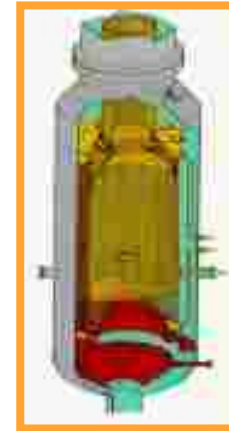
GE



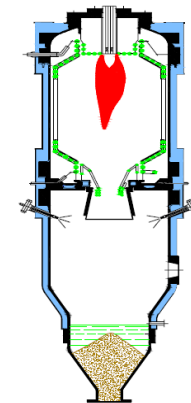
KBR



MHI



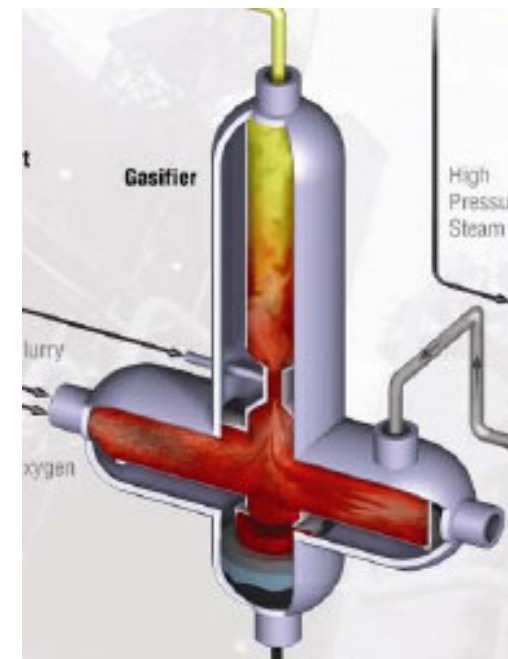
Shell



Siemens

ConocoPhillips (E-Gas process)

- Coal-water slurry feed
- Oxygen-blown
- Refractory-lined gasifier
- Good for a wide range of coals, from pet coke to PRB, and blends



Source: ConocoPhillips

GE Energy

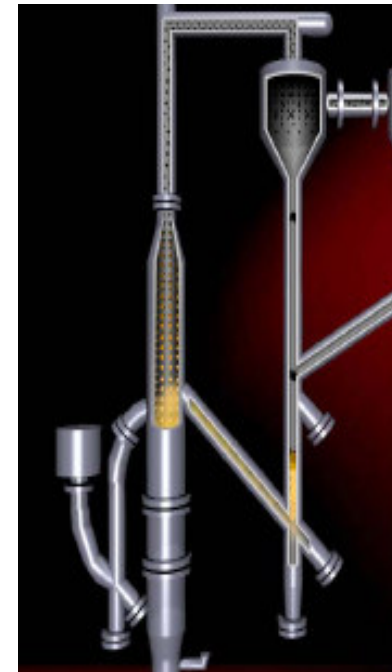
- Coal-water slurry feed
- Oxygen-blown
- Refractory-lined gasifier
- Good for bituminous coal, pet coke, or blends
- Developing dry-feed gasifier for use with low-rank coals



Source: GE

Kellogg Brown & Root (KBR)

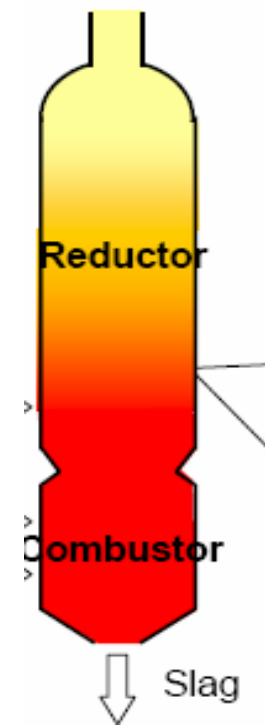
- Dry feed
- Air-blown transport gasifier
- Pilot tested on wide range of coals at Power Systems Development Facility in Alabama
- Targets low-rank coals
- Mississippi Power to develop full-scale 560 MW (net) plant
 - Lignite



Source: KBR

Mitsubishi Heavy Industries (MHI)

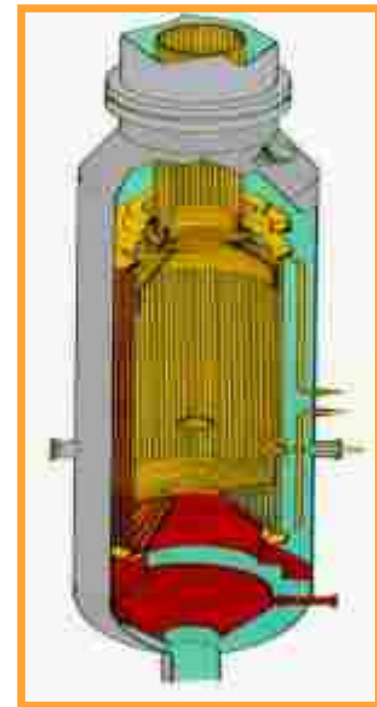
- Dry feed
- Air-blown
- Targets low-rank coals
- 250 MW (net) demonstration plant started up in Japan in late 2007
- Has operated at full load



Source: MHI

Shell

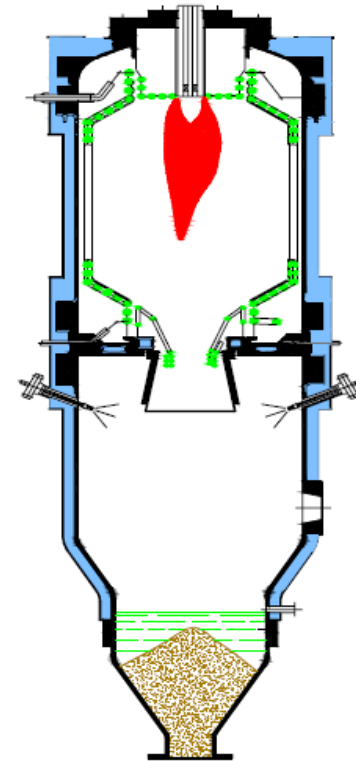
- Dry feed (coal is crushed and dried and then fed into gasifier)
- Oxygen-blown
- Waterwall (no refractory)
- Good for wide variety of feedstocks, from pet coke to PRB



Source: Shell

Siemens Fuel Gas

- Dry feed
- Oxygen-blown
- Waterwall screen in gasifier
- Good for a wide variety of feedstocks, from bituminous to low-rank coals



Source: Siemens

Proposed IGCC Projects – (air permit final or in review)

Company	Facility	Location	Feedstock	Gasification Technology
AEP	Mountaineer	WV	Coal	GE
Duke Energy Indiana	Edwardsport	Edwardsport, IN	Coal	GE
EnergyNorthwest	Pacific Mountain Energy Center	Port of Kalama, WA	PRB/pet coke	ConocoPhillips
Excelsior Energy	Mesaba	Taconite, MN	PRB/Illinois #6/pet coke	ConocoPhillips
Mississippi Power Company	Kemper County	Liberty, MS	Lignite	KBR
Tenaska/MDL Holdings	Taylorville Energy Center	Taylorville, IL	Coal	GE

Energy Northwest plant will go forward as NGCC

Capacity of Proposed IGCC Plants

The IGCC “Reference Plant”

- New IGCC plants based on two gasifiers producing sufficient syngas to fully load two “FB” class gas turbines; designed for eastern bituminous coal and operating at sea level
 - Gross output: 784 MW
 - Internal load: 154 MW (19% of gross output)
 - Net output: 630 MW
- Feedstock requirement
 - 6,000 tons/day bituminous coal
- Efficiency and net output changes with feedstock and elevation

Environmental Issues

Air Emissions

Comparison of Air Emission Controls: PC vs. IGCC

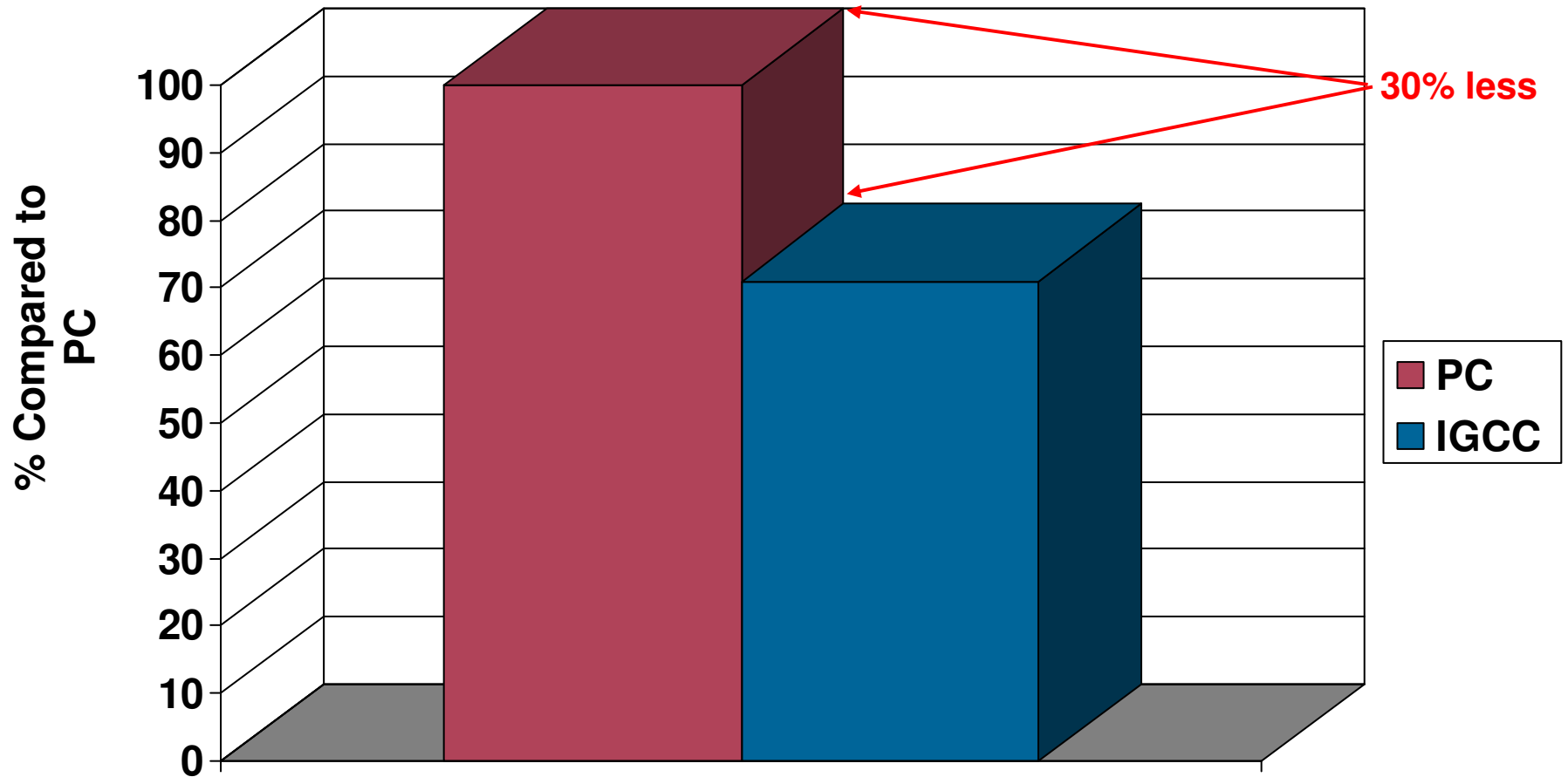
	SO₂	NOx	PM	Mercury
PC	FGD system	Low-NOx burners and SCR	ESP or baghouse	Inject activated carbon
IGCC	Acid gas removal system removes H ₂ S and COS from syngas	Syngas saturation and N ₂ diluent; SCR is an option	Wet scrubber, high temperature cyclone, candle filter	Pre-sulfided activated carbon bed

Water Issues

Water Consumption IGCC vs PC

- For IGCC reference plant:
 - 784 MW (gross) unit, 464 MW is from gas turbines and 320 MW is from the steam turbine
 - Only 40% of total output is from steam turbine, so cooling water make-up needs are decreased by ~60% compared to a PC plant
- No FGD system needed for IGCC, so no water needed to produce limestone slurry
- IGCC requires water for preparing coal slurry and for syngas washing and cooling

Comparison of Water Use

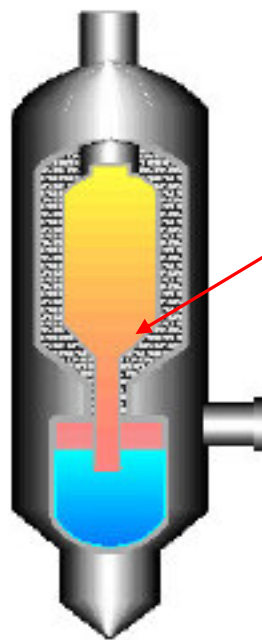


Source: DOE

Solid Byproducts

Solid Byproducts

- Ash is removed in molten form, then quench-cooled to form glassy, inert, saleable slag

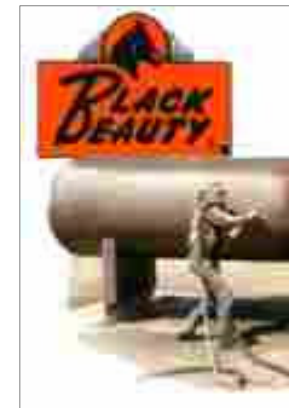


Molten slag



Slag Use

- Used for making
 - Cement
 - Asphalt filler
 - Roofing shingles
 - Sand-blasting grit
 - Aggregate



Other Byproducts

- Sulfur
 - Recovered in molten form
 - Transported by rail or truck
- Sulfuric acid
 - Various concentrations
 - Transported by rail or truck

Sulfur Products



Questions?

Contact Info

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