Coal Gasification:

The Technology and Its Viability as a Future Energy Source

Edward S. Rubin
Department of Engineering and Public Policy
Carnegie Mellon University
Pittsburgh, Pennsylvania

Presentation to the

Group Against Smog and Pollution (GASP)
Pittsburgh, Pennsylvania

April 6, 2006

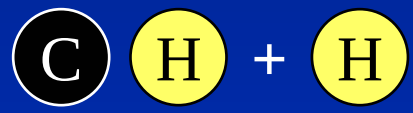
Outline of Talk

- What is coal gasification?
- How does it work?
- Why the interest?
- Where does it stand?
- Where is it headed?

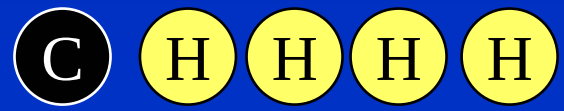
What is Coal?

	Bituminous (Ill.#6)	Subbituminous (PRB)
Carbon (wt%)	61.2	47.9
Hydrogen	4.20	3.40
Oxygen	6.02	10.8
Sulfur	3.25	0.48
Nitrogen	1.16	0.62
Chlorine	0.17	0.03
Ash	11.0	6.40
Moisture	13.0	30.4
Mercury (ppm,dry)	0.12	0.10
HHV (Btu/lb)	*10,900*	*8,335*

Coal vs. Other Fossil Fuels

COAL C:H ~ 1:1 

PETROLEUM C:H ~ 1:2 

NATURAL GAS C:H ~ 1:4 

What Is Gasification?

- Gasification is a process that converts carbonaceous materials, such as fossil fuels and biomass, into a mixture of mostly hydrogen and carbon monoxide (called synthesis gas, or syngas)
- Other gaseous species (including some potential air pollutants) also are formed; amounts depend on the fuel composition and process conditions
- The syngas can be burned as a fuel, or processed to produce chemicals and other fuels

Not a New Technology

- Coal gas was first used in London in 1790 for gas lights
- Later used for fuel gas in Europe and North America in the 19th and early 20th century
- Used to produce coal-derived transportation fuels in Germany during WWII
- Many different gasification processes have been proposed, employing different schemes for fuel feed, reactor design, etc.
- Current generation of gasifiers are much cleaner and more efficient than earlier designs

Gasification Basics

- Coal gasification is carried out at high temperature (and pressure, usually) to decompose the coal and create new products via addition of hydrogen
- The source of heat for these reactions is the *partial oxidation* (combustion) of the coal, which requires some addition of oxygen
- The source of hydrogen is water (H_2O), added either as a liquid or vapor (steam)
- The source of oxygen is either air, or nearly-pure oxygen (supplied by an air separation unit)

Gasification Chemistry

Gasification processes use one or more common reactions:

- Thermal decomposition

  $HC + heat = H_2 + C + organics$

- Reaction with oxygen (partial oxidation)

  $HC + O = H_2 + CO + heat$

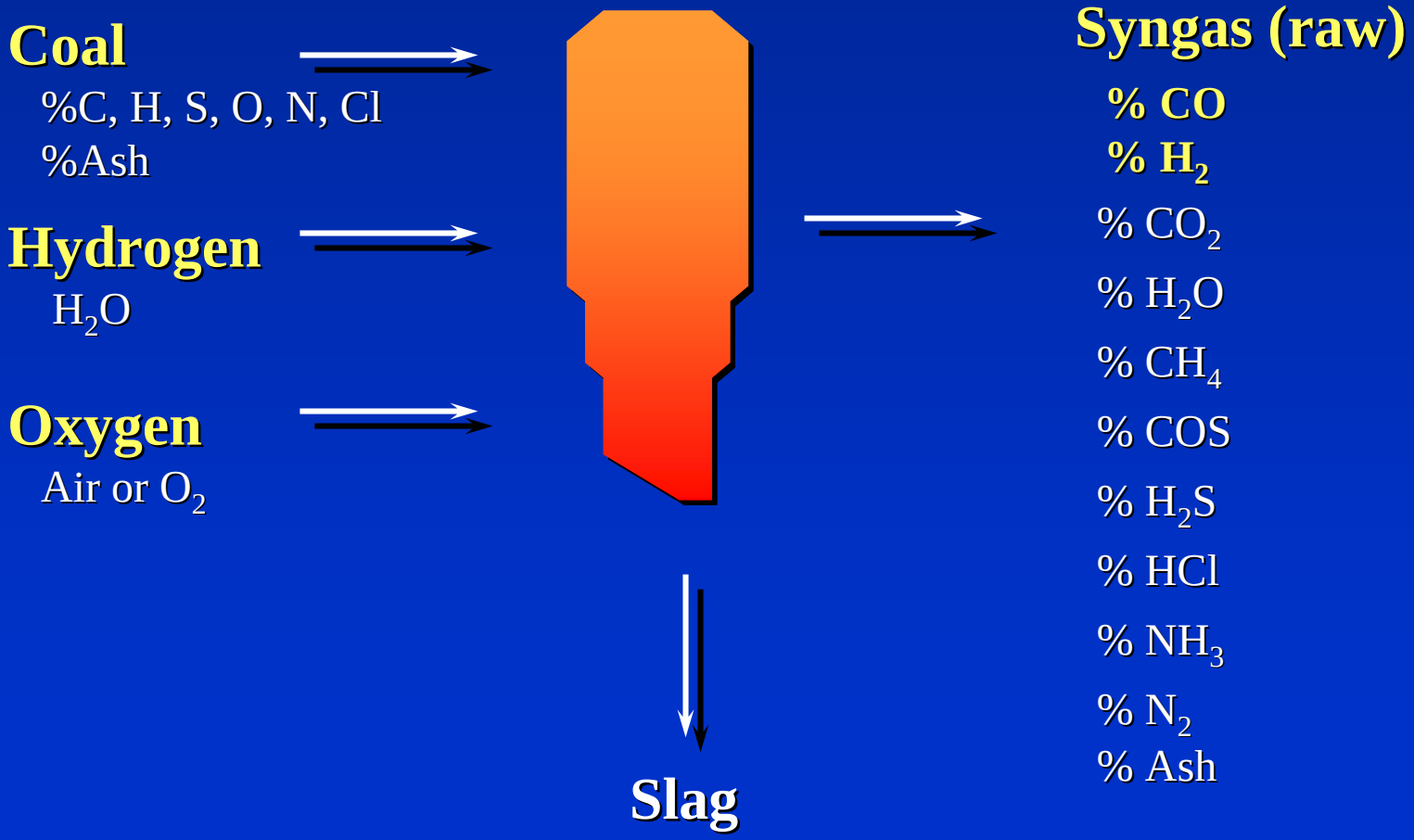
- Reaction with steam (reforming)

  $HC + H_2O + heat = 3/2H_2 + CO$

- Reaction with hydrogen (hydrogasification)

  $HC + H_2 = CH_4 + heat$

A Typical Coal Gasifier

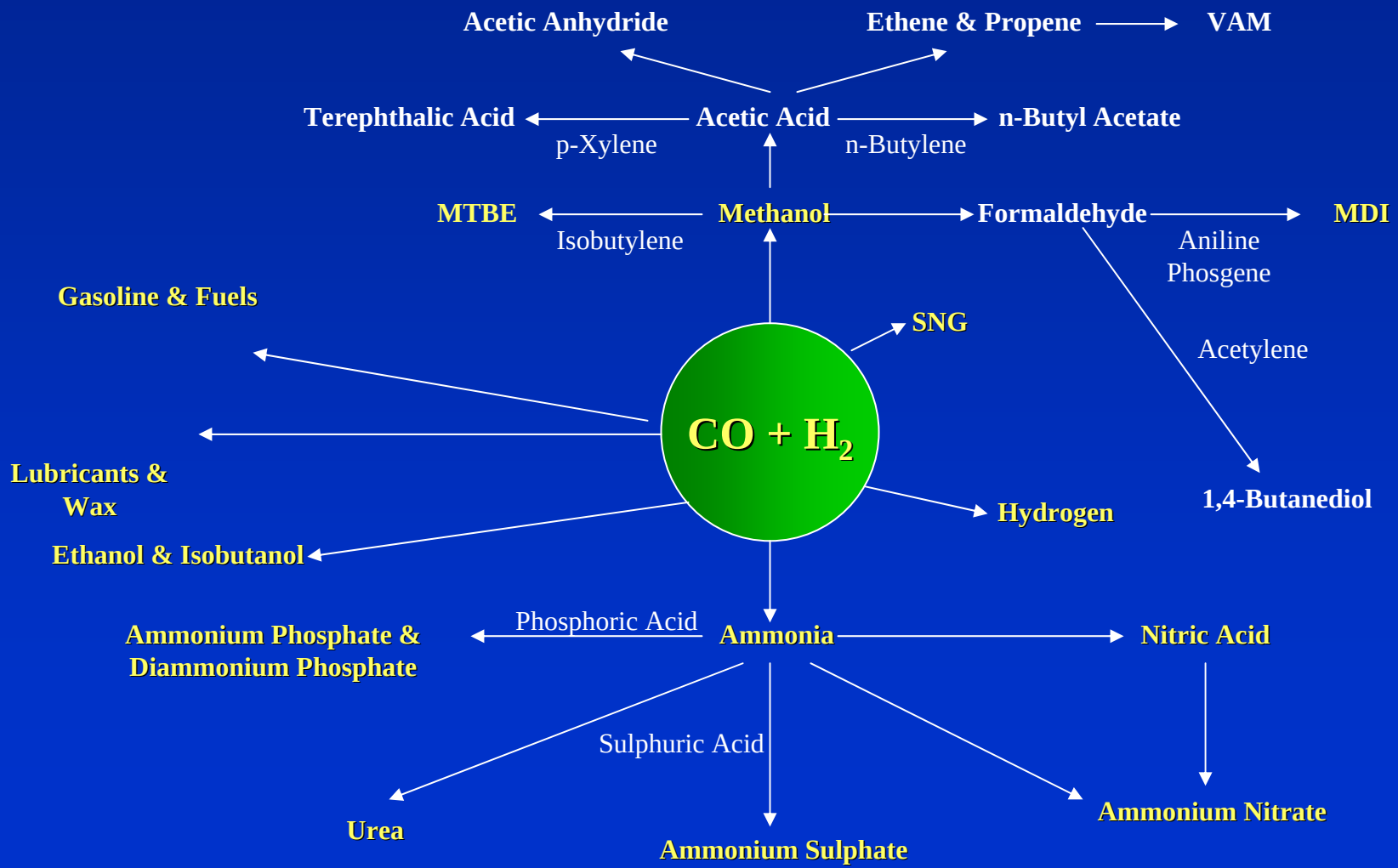


Uses of Syngas

After cleanup for removal of impurities, syngas can be used for:

- Electric power generation
- Steam generation
- Process heat
- Chemicals production
- Liquid fuels production
- All of the above

Chemicals and Fuels from Syngas



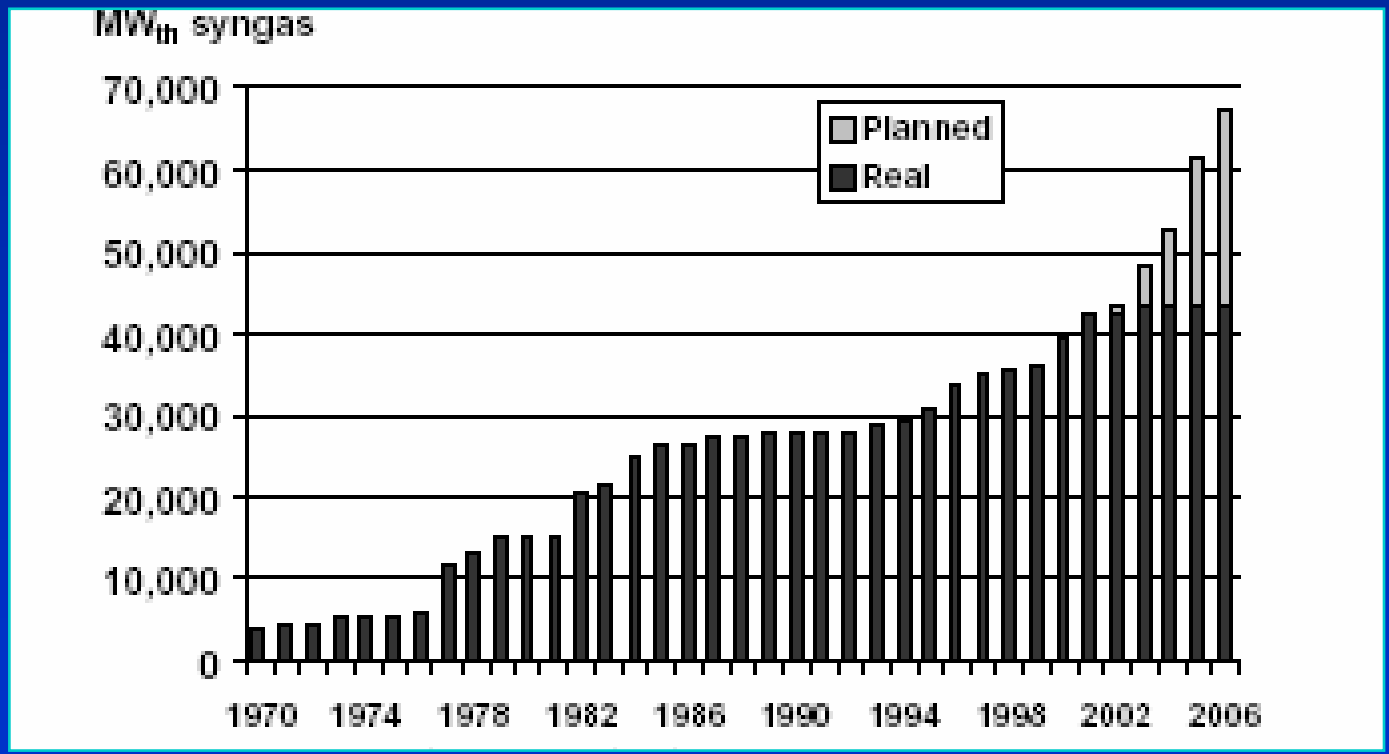
Source: Gunal-Akgol, U.Waterloo

Why the Current Interest?

Process Considerations

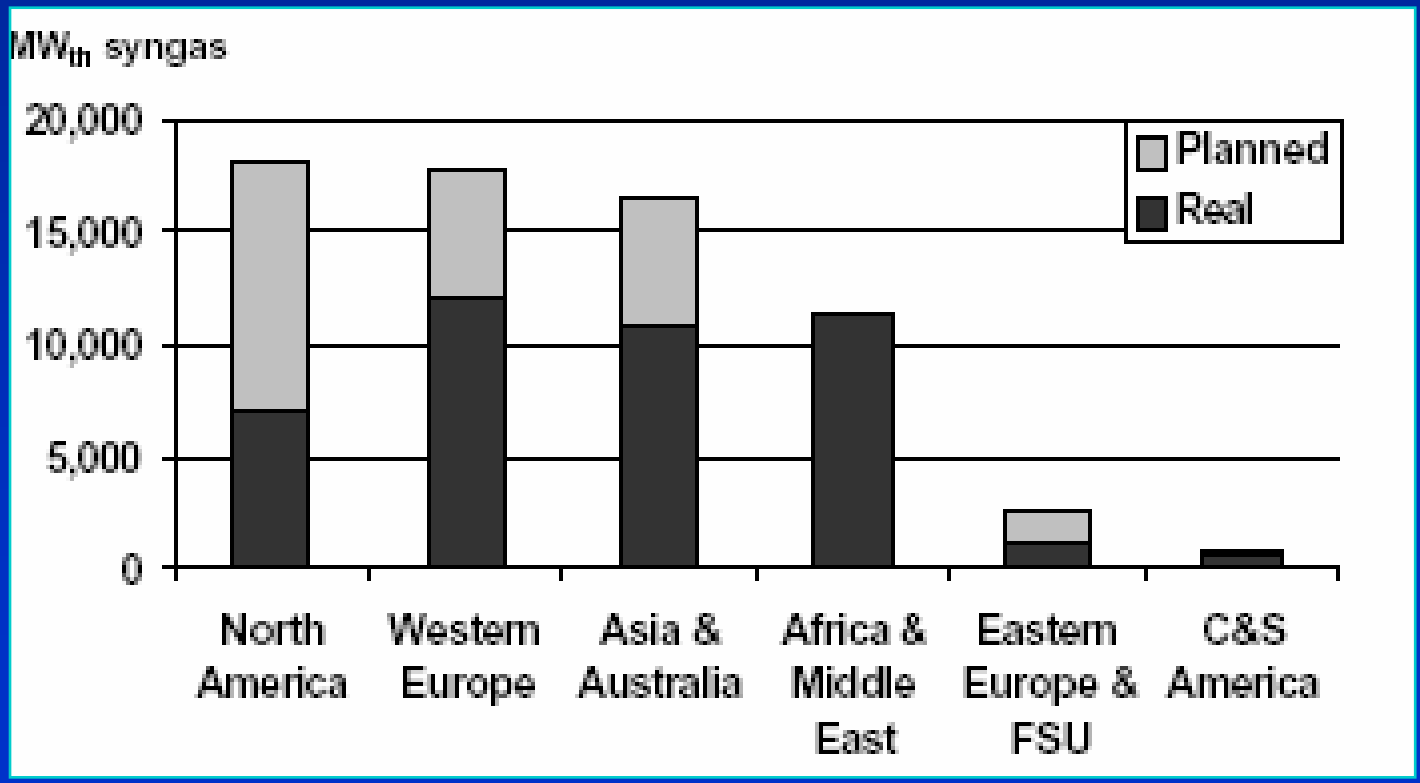
- Offers a way to utilize low-value feedstocks or wastes (such as petroleum coke) in a variety of refinery and petrochemical processes
- Can produce multiple products (polygeneration)
- Growing interest for industrial application in the face of high natural prices in recent years

Worldwide Gasification Capacity



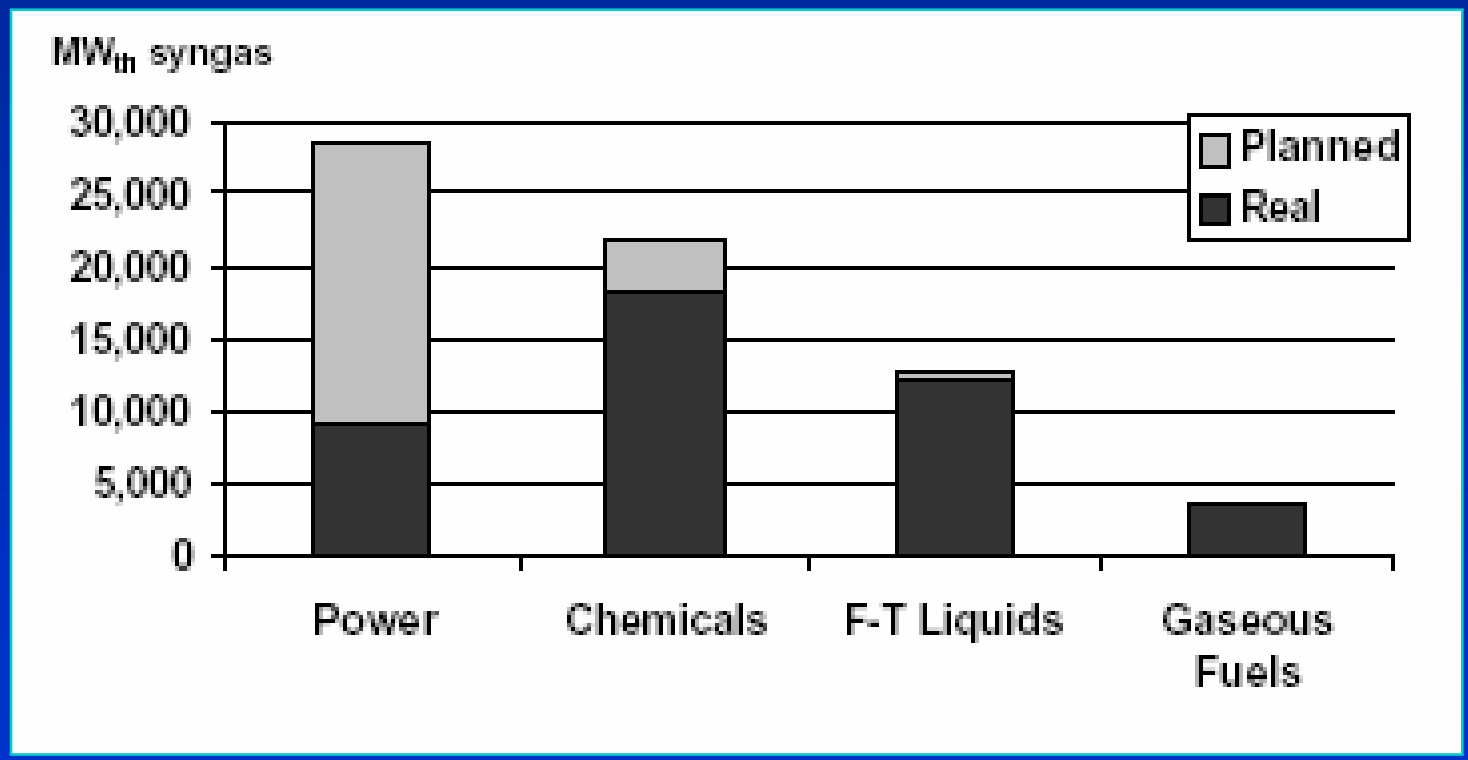
Source: SFA Pacific /DOE, 2001

Gasification by Global Region



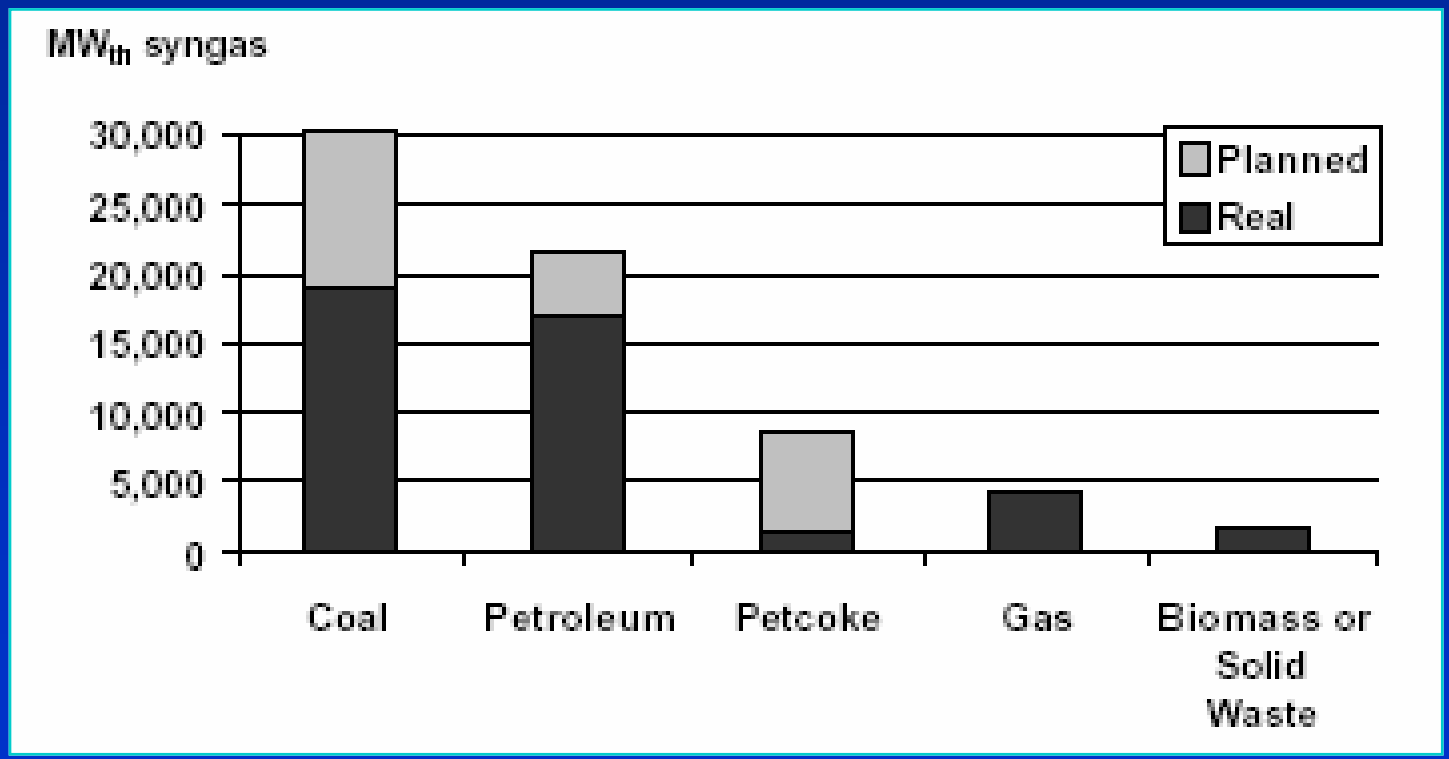
Source: SFA Pacific /DOE, 2001

Gasification Applications



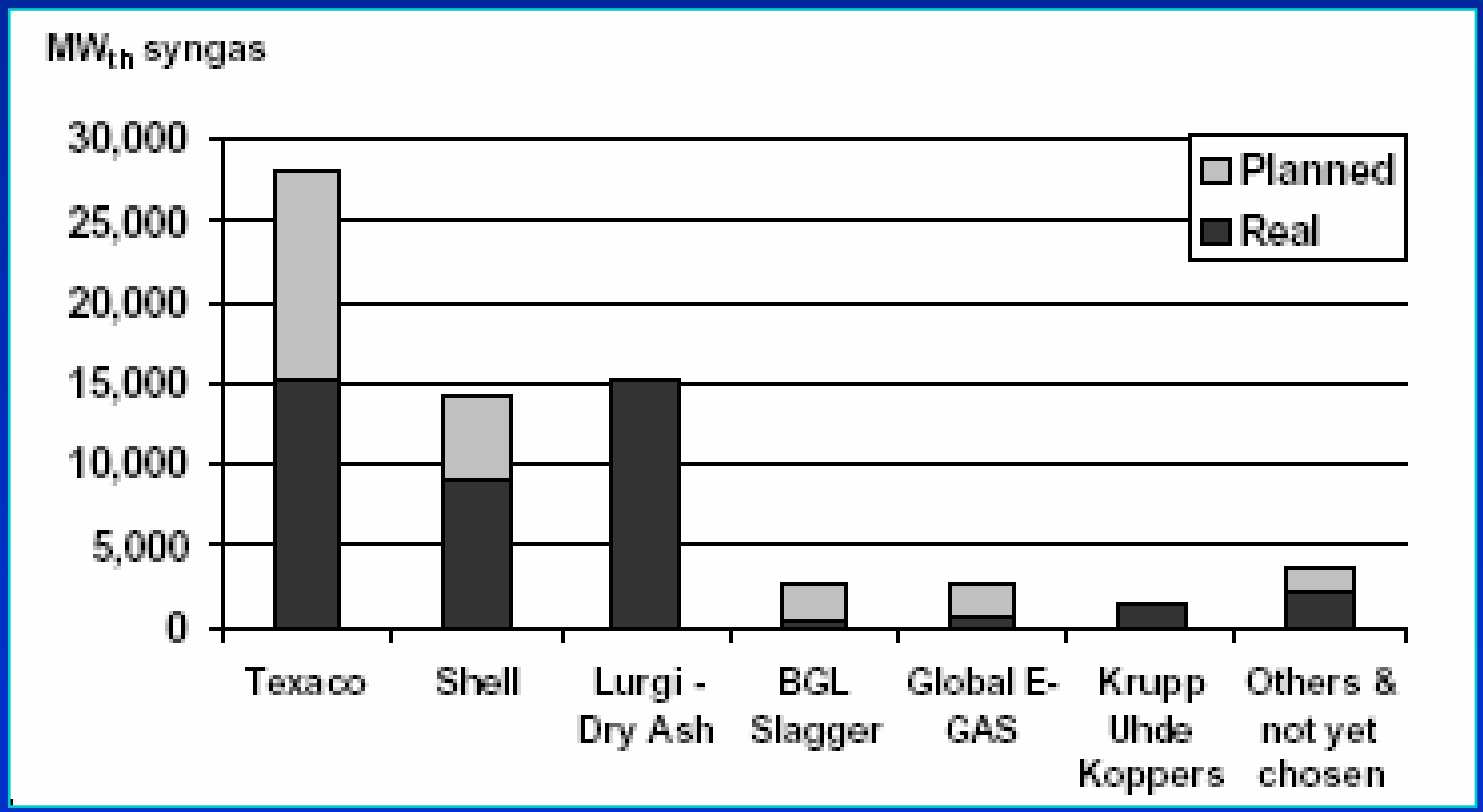
Source: SFA Pacific /DOE, 2001

Primary Gasification Feedstock



Source: SFA Pacific /DOE, 2001

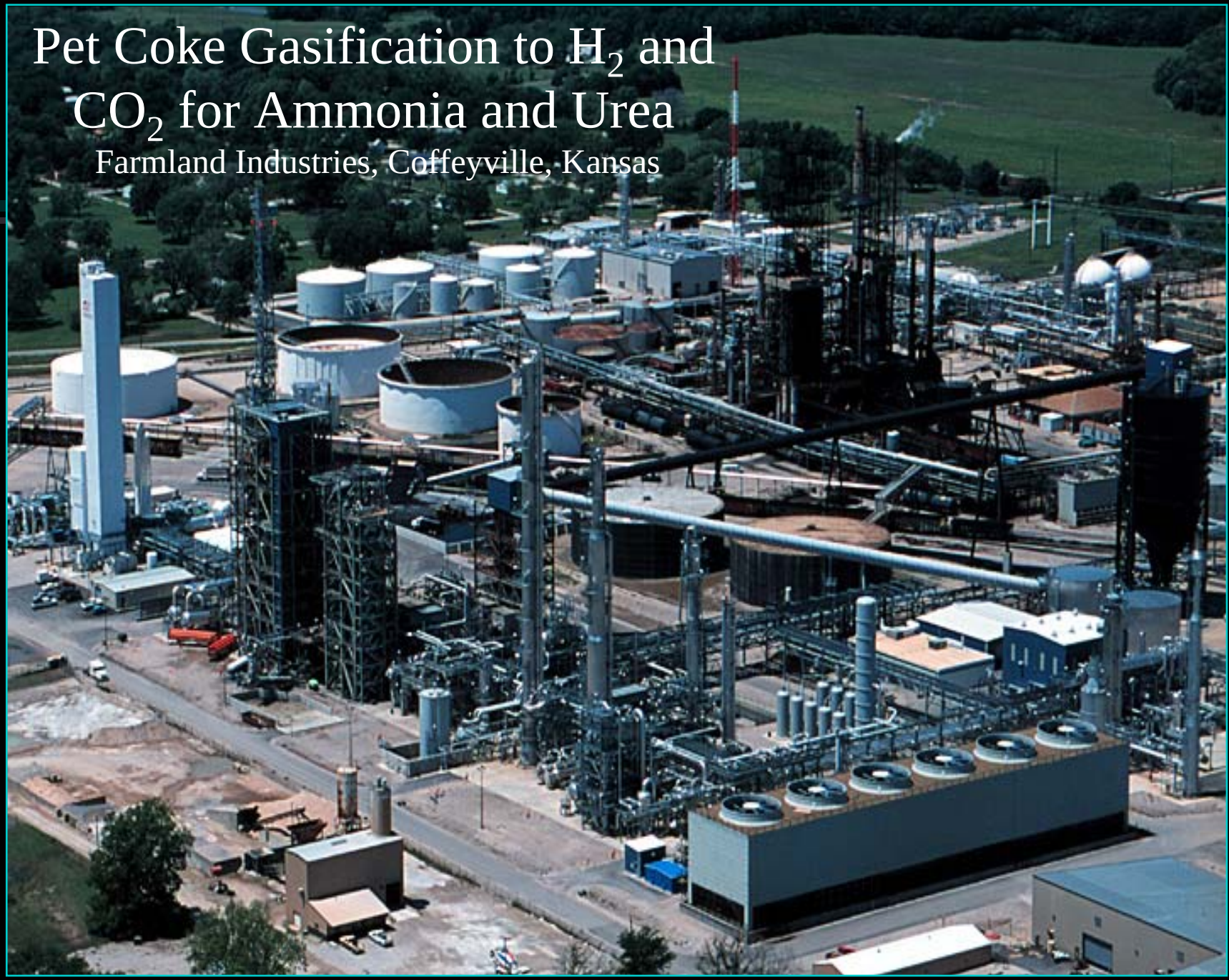
Gasifier Technologies



Source: SFA Pacific /DOE, 2001

Pet Coke Gasification to H_2 and CO_2 for Ammonia and Urea

Farmland Industries, Coffeyville, Kansas



Why the Current Interest?

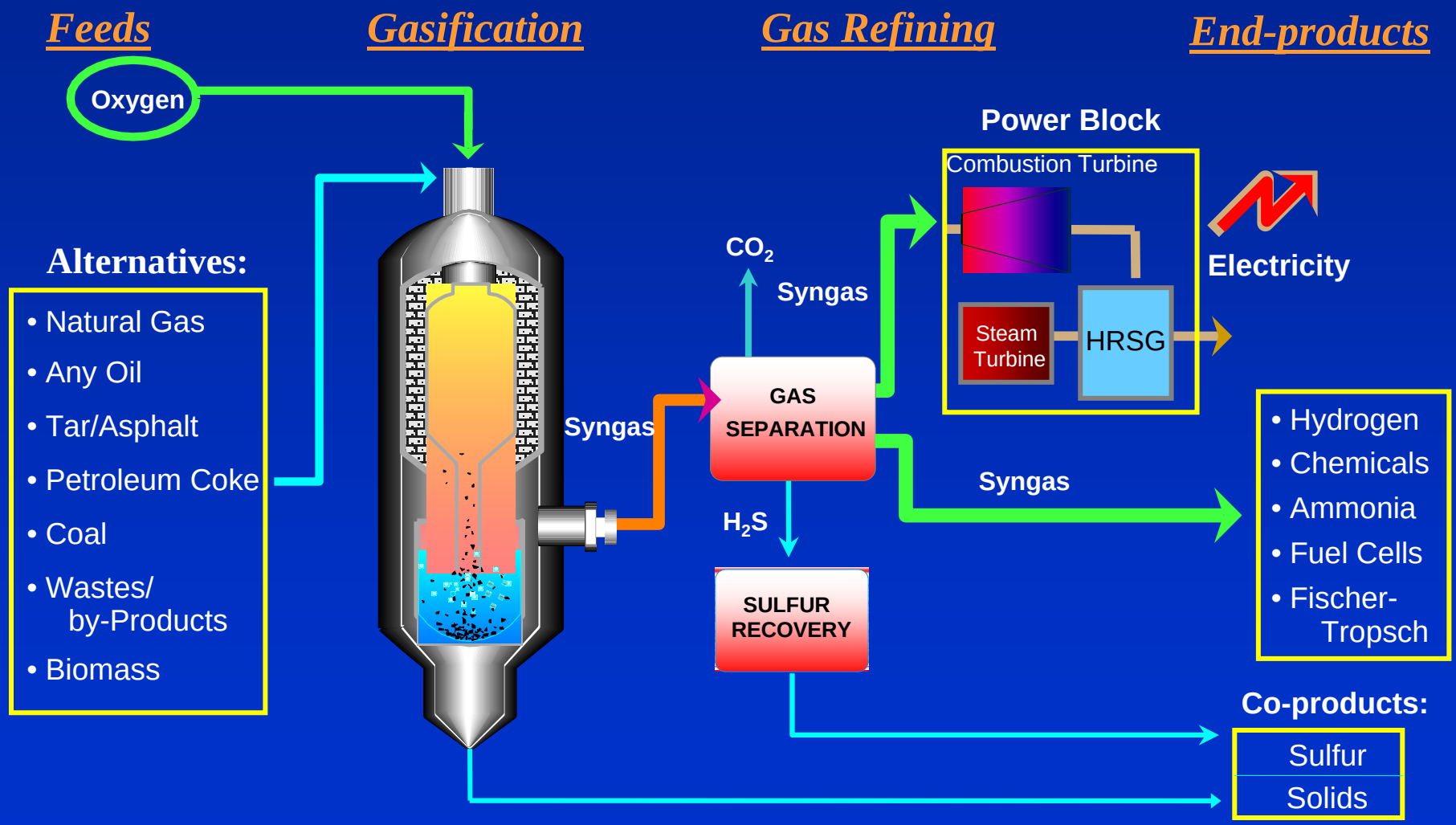
Process Considerations

- Offers a way to utilize low-value products or wastes (such as petroleum coke) in a variety of refinery and petrochemical processes
- Can produce multiple products (polygeneration)
- Growing interest for industrial application in the face of high natural prices in recent years

Environmental Considerations

- Lower emission rates than current coal-fired plants
- Lower cost of carbon capture as climate change mitigation option

An Integrated Gasification Combined Cycle (IGCC) Power Plant

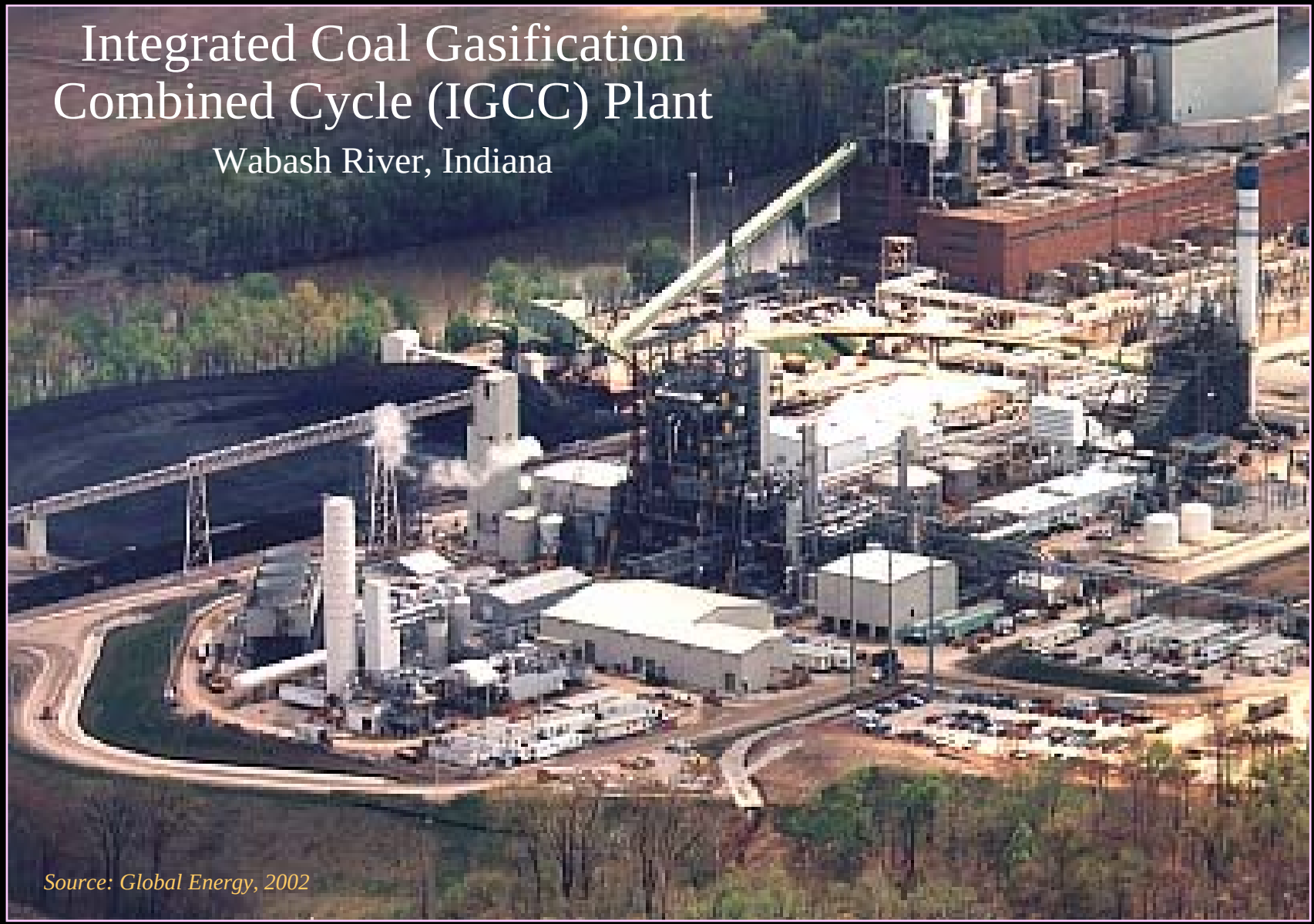


Source: Adapted from Chevron-Texaco, 2003

Polk Power Station
IGCC Plant
(Tampa Electric, 250 MW)

Integrated Coal Gasification Combined Cycle (IGCC) Plant

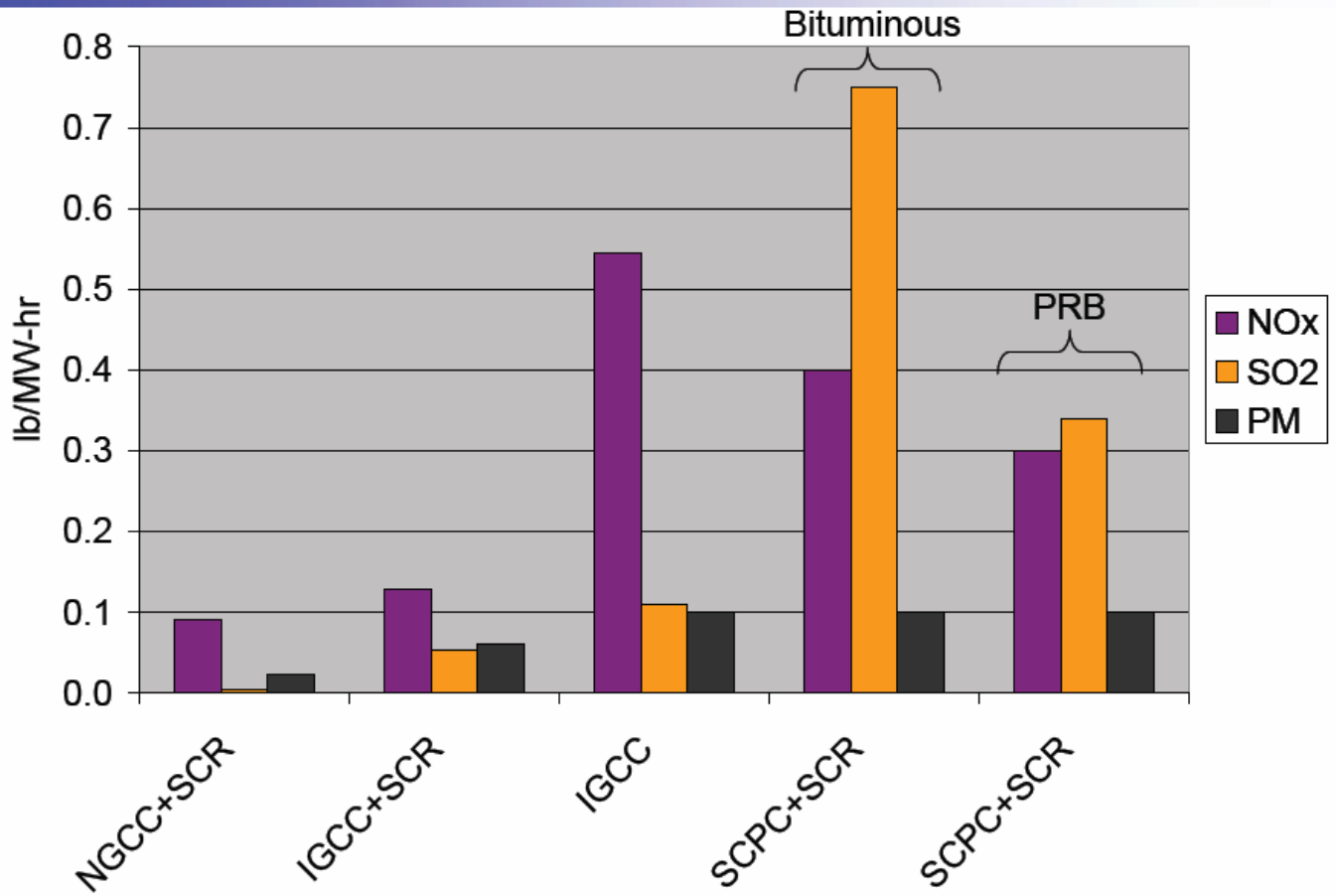
Wabash River, Indiana



Source: Global Energy, 2002

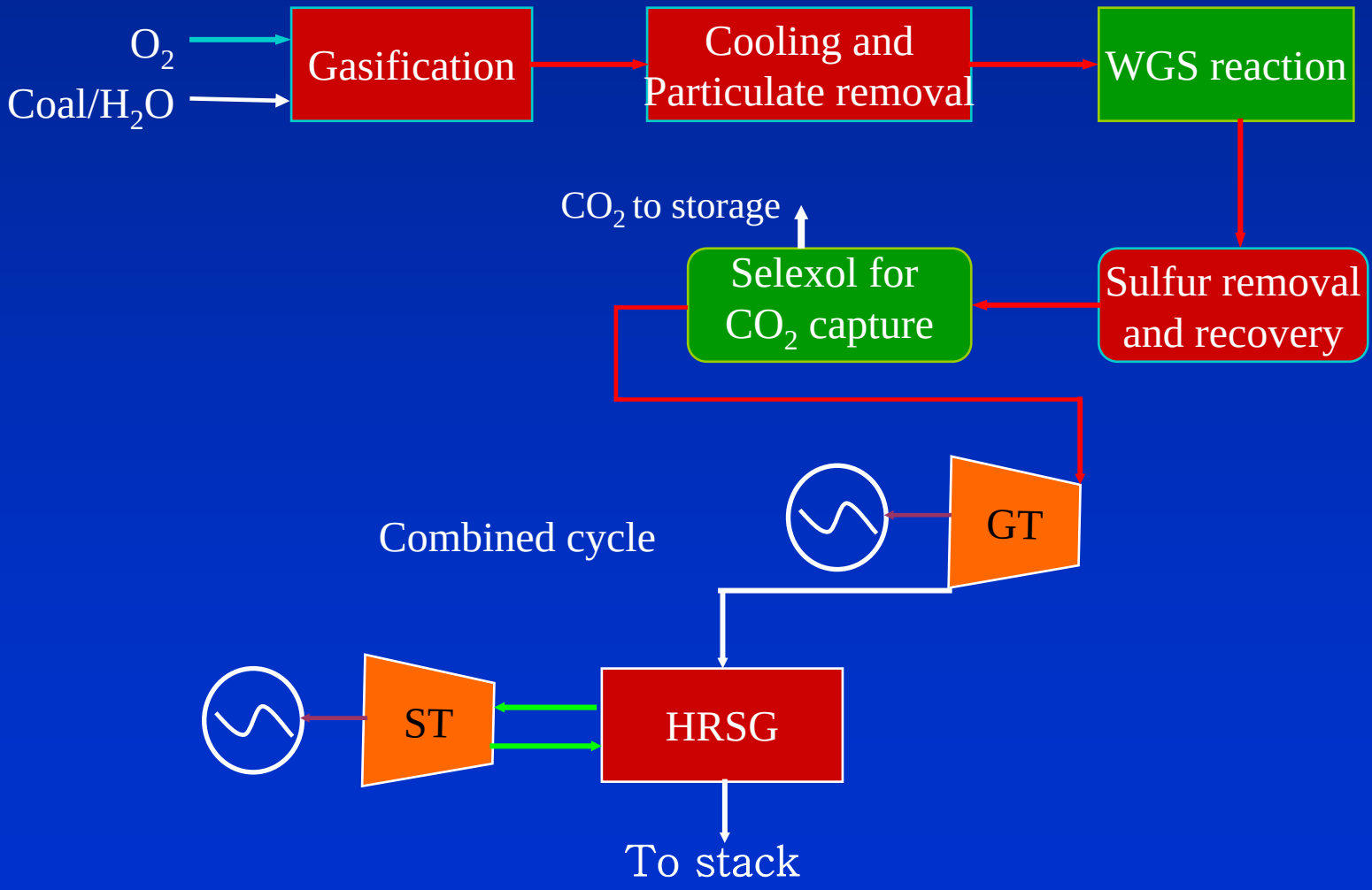
Emissions Comparison – State-of-the-Art Coal Combustion, IGCC, and NGCC

Values represent technology capability, not permit levels



Source: EPRI, 2005

IGCC w/ CO_2 Capture



Industrial CO_2 Capture Systems

(Source: Mitsubishi Heavy Industries)

Post-Combustion Capture

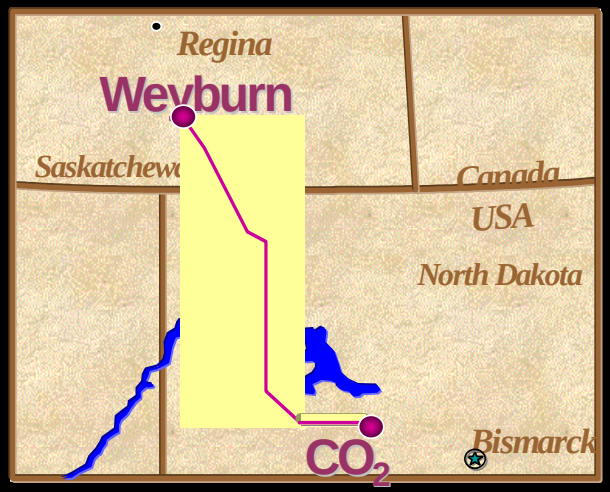
(gas-fired power plant, Malaysia)

(Source: Dakota Gasification

Pre-Combustion Capture

(coal gasification plant, USA)

Coal-to-Gas Plant Supplying CO_2 for Enhanced Oil Recovery (EOR) and CO_2 Sequestration

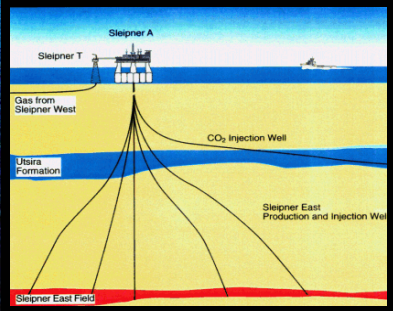


Sources: USDOE; NRDC

Geological Storage Projects

Source: Statoil

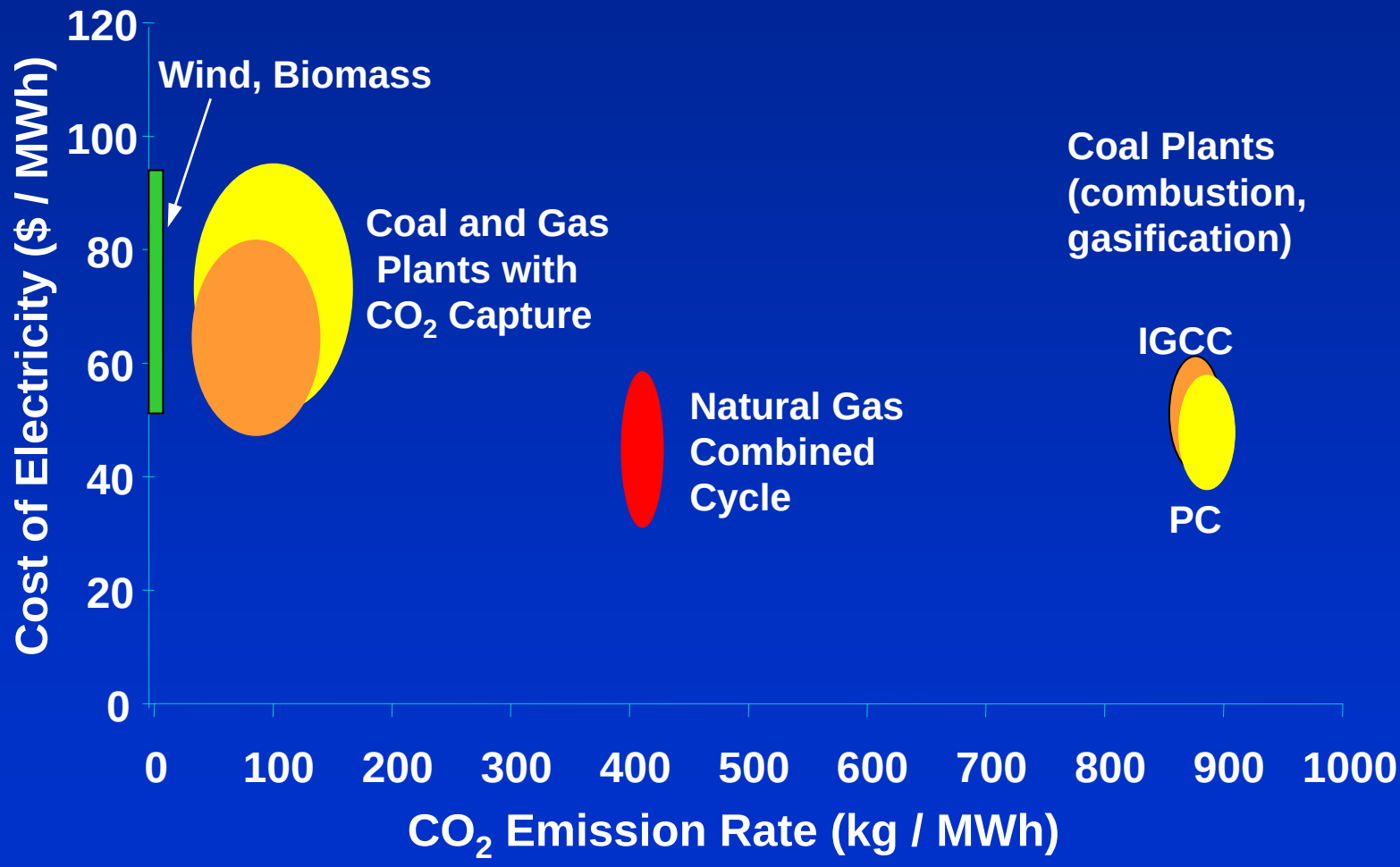
Sleipner *(Norway)*



In Salah /Krechba *(Algeria)*

Source: BP

Cost of Alternative Options



Conclusion

- Growing interest in IGCC for power generation, and in gasification to produce liquids and natural gas
- Several proposed new power plants in the U.S.
- Cost and reliability are the main issues
- Potential for lower cost of CO_2 capture wrt PC plants
- DOE “FutureGen” project moving ahead to demonstrate and improve IGCC with CCS