IGCC
(Integrated Gasification Combined Cycle)
Technology Overview

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Presentation Outline

- **Brief Introduction of Nexant**
- **IGCC Technology Background**
- **Comparison of Performance, Cost, and Emission with Other Generation Technologies**
- **Potential Technical Advancements for IGCC Plants**
- **Expansion of IGCC for Poly-Generation**
- **Barriers of Using IGCC in India and China**
- **Conclusions**

Brief Introduction of Nexant

Dr. Tan-Ping Chen
Nexant, Inc.

What is Nexant?

- **Used to be Bechtel Technology & Consulting, spun off in Jan. 2000; Bechtel has US$17 billion annual sale**
- **Bechtel is the majority owner; other investors include Morgan Stanley, Mitsubishi Capital, IBM, First Technology**
- **Headquarter in San Francisco with offices in London, DC, and White Plains (NY), Mesa (AZ), Denver, Houston, LA**
- **Started with 150 people, grew to 250 by acquisition**
- **Main business: consulting & technology development services in energy area**
- **7 business lines: Energy Technology, Energy Management, Electric Power, Oil and Gas, Chemicals, ChemSystems Online, Energy Solutions**

Energy Technology Business Line

Type of Work

- Project feasibility/planning studies
- Engineering & construction of pilot units and demonstration plants
- Owner's engineer for commercial plants
- Technology survey
- Technology investment due diligence
- Market study
- Lender's engineer
- Arbitration
- Technology Development

Technologies

- Gasification to make power, SNG, hydrogen, methanol, ethanol, DME, MTO, ammonia, and other chemicals
- Direct and indirect coal liquefaction
- Biomass and garbage conversion
- Gas turbine, combined cycle, reciprocating engines
- PC, FBC, cogeneration
- Emission controls
- CO2 capture from syngas and flue gas
- Hydrogen, fuel cells, distributed power generation
- Solar power
- Oil shale, tar sands
- Waste coal utilization

Clients

- UNDP, UNIDO, GEF
- ADB
- USAID
- USTDA
- USDOE
- NEDO
- EPRI
- Private electric/gas utilities (Virginia Power, Baltimore G&E, Tokyo Electric, SCE, etc)
- Private oil/gas/chemical companies (Shell, Chevron, BP, DuPont, etc)
- Technology developers (Alstom, GE, RTI, etc)
- Investors, IPP

Gasification Experience

- Built 100 MW Cool Water IGCC demonstration plant
- Built 1300 tpd coal to chemicals (methanol, acetic acid, and acid anhydride) plant for Eastman
- Built 250 MW IGCC plant at Tampa Electric in Florida
- Built LuNan 500 tpd coal to ammonia plant
- Conducted Shanghai Wujing tri-generation feasibility study under USTDA funding
- Owner's engineer for US$650 million clean coal project for USDOE and WMPI to co-produce FT liquid and electricity
- Owner's engineer to Reliance for a $2 billion coke gasification plant in India
- Conducting $2 million India IGCC study for NTPC under USAID funding
- Conducting $0.55 million polygeneration feasibility study for HITS in Shenyang under USTDA funding
- Conducting a coal-to-liquid study in Mongolia for QGX
- Conducted more than 130 other gasification feasibility studies

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IGCC Technology Background

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Why IGCC?

- High efficiency: due to CC; GT steadily increases efficiency
- Young Technology: amply room for advancements & improveme
- GHG reduction:
  - by high efficiency
  - Low syngas volume (15-20% of PC flue gas) to facilitate CO_2 capture
- Low SOx and NOx :
  - H_2S is much easier to remove than SO_2
  - Pollution control is easier for gas firing: lean burner, steam injection, SCR
- Low water consumption: 2/3 power from GT

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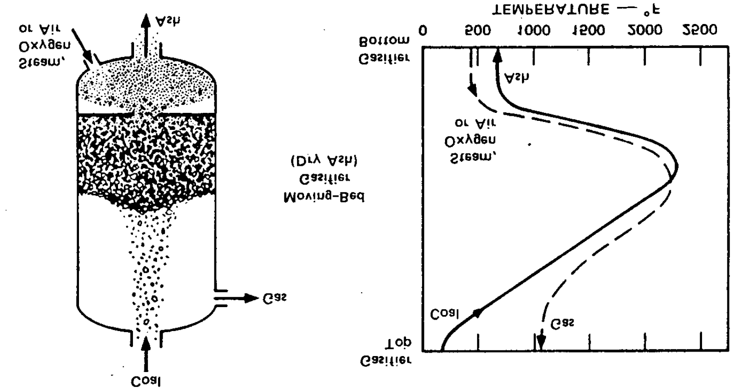
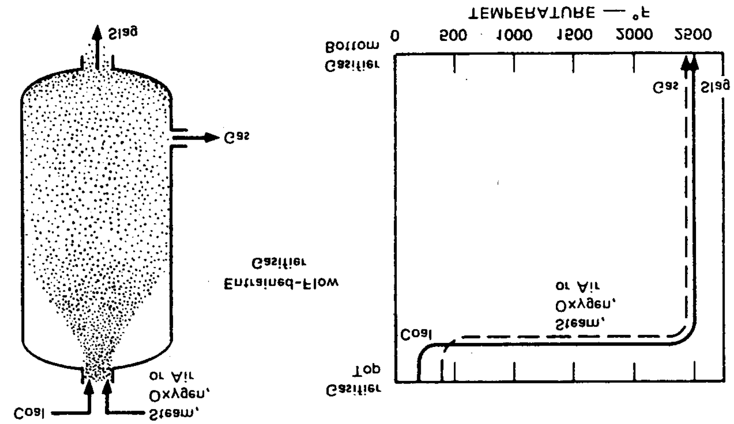
Major Types of Coal Gasifiers

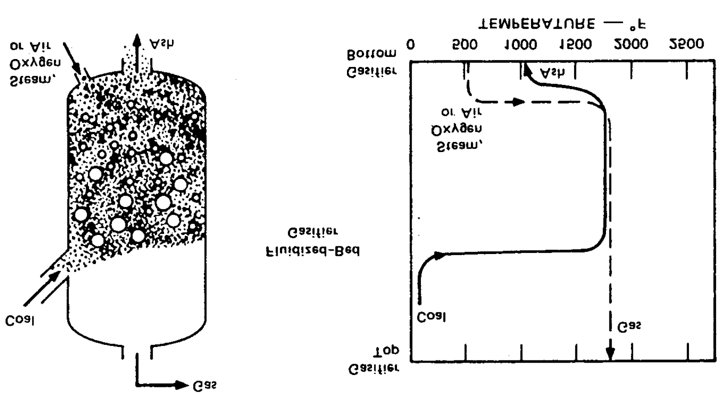
Moving Bed
(1st Generation)



Entrained Bed
(3rd Generation)



Fluidized Bed
(2nd Generation)



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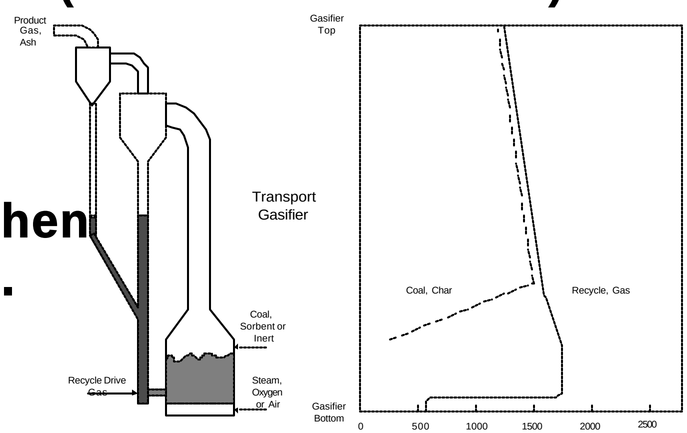
Transport
(variation of fluid bed)



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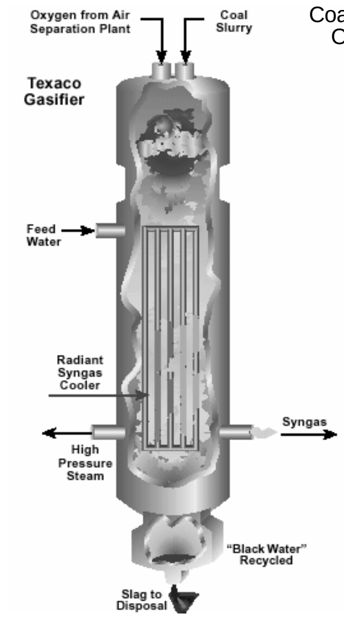
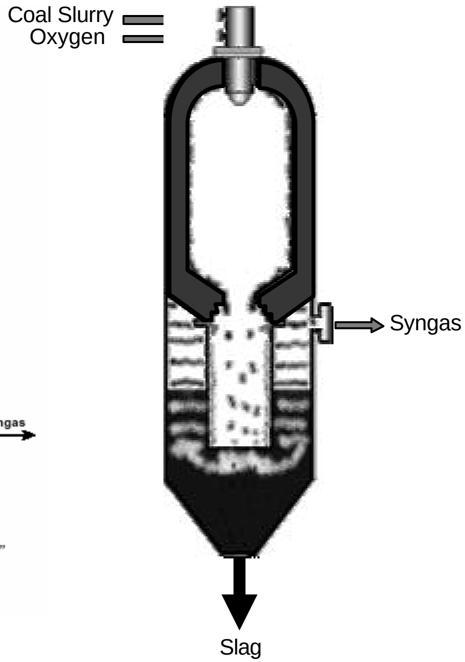
Entrained Bed Gasifier

- Most commercial gasifiers are this type
- Very high temperature to provide good carbon conversion for any grade of coal
- Heavy metals in ash can be encapsulated in glass-like slag
- Slurry feed type (GE, E-Gas) and dry feed type (Shell, Prenflow, Noell)
- Hot syngas from GE gasifier can be cooled not only by WHB but also water quench

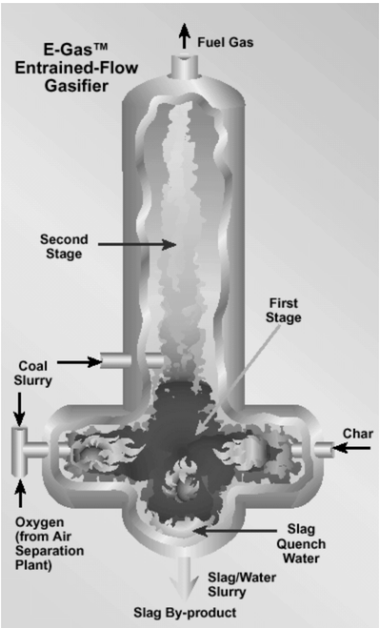
GE gasifier (WHB)



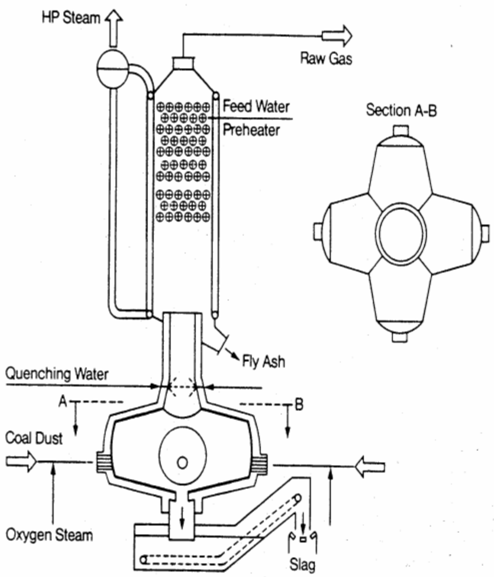
GE gasifier (quench)



E-Gas gasifier



Shell/Prenflow/Noell gasifier



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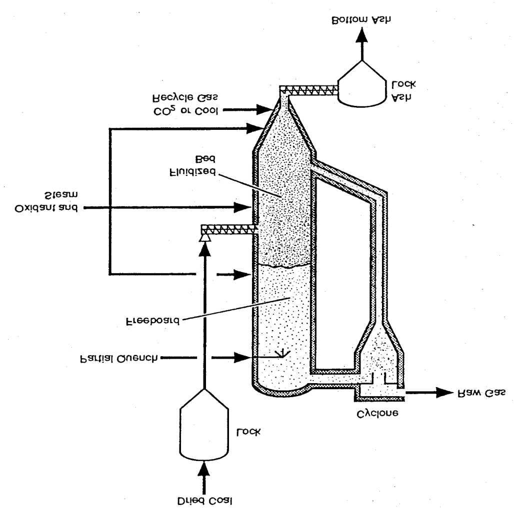
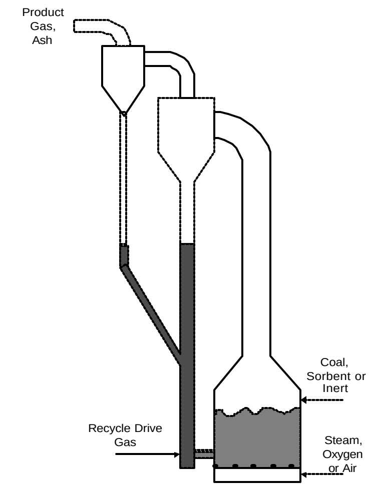
Other Types of Gasifiers

Fluidized Bed



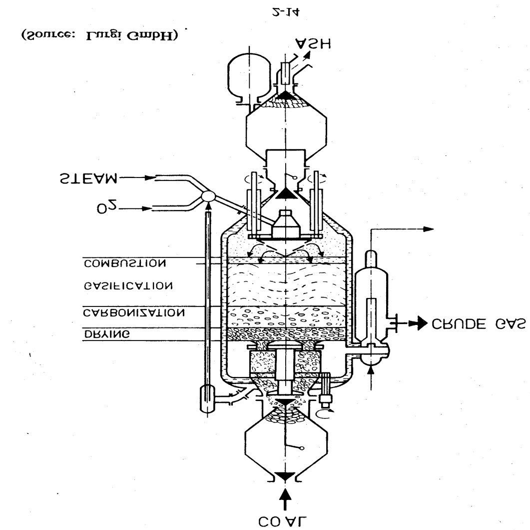
- U-Gas gasifier (developing)
- HT Winkler gasifier (commercial, RWE idle)
- No slagging
- Medium oxidant use
- Medium cold gas efficiency
- Good for high ash, high reactivity coals

Transport



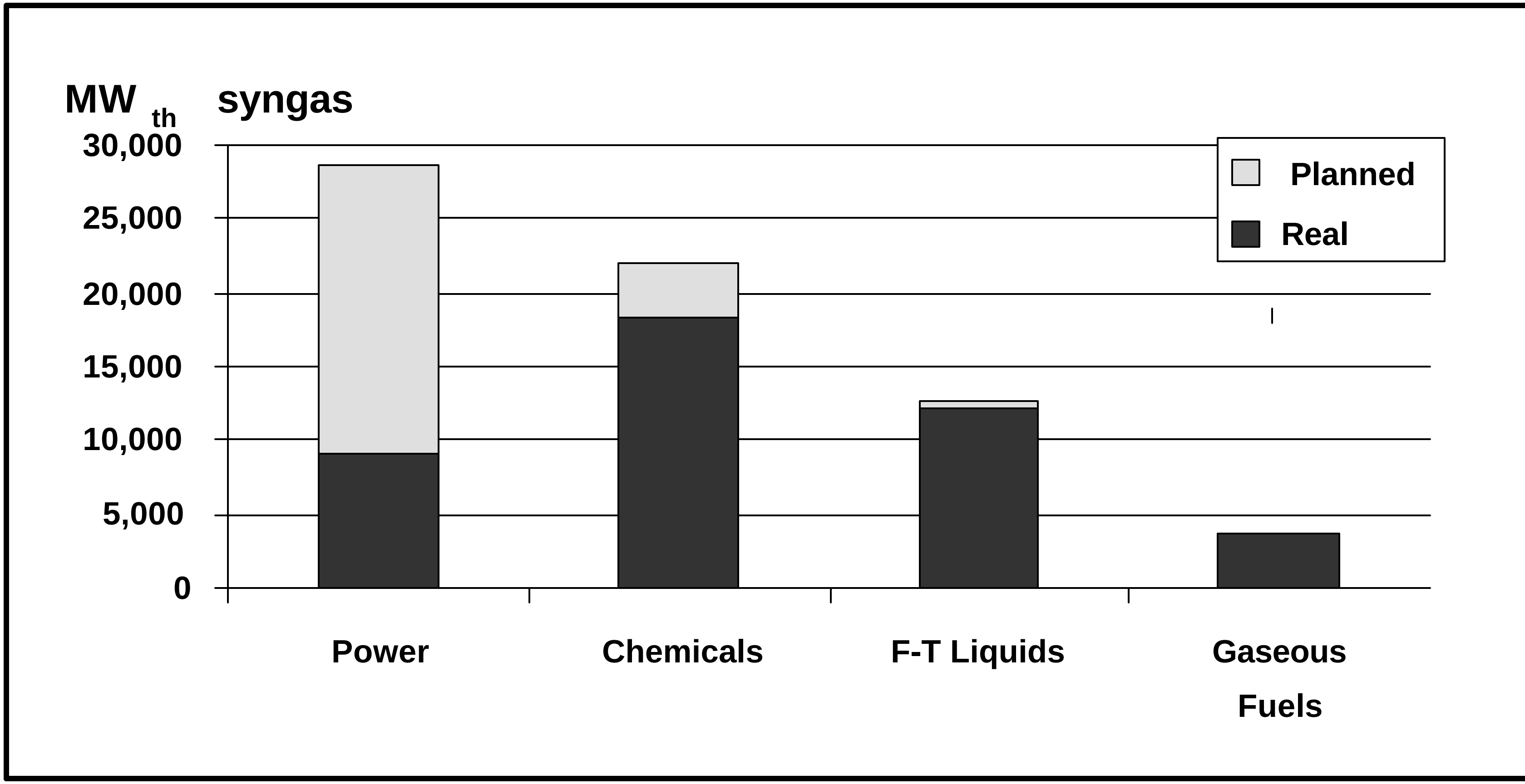
- KBR gasifier (developing)
- No slagging
- Medium oxidant use
- Medium cold gas efficiency
- High throughput
- Good for high ash, high reactivity coal

Moving Bed



- Lurgi gasifier (commercial)
- No slagging
- Low oxidant use
- High cold gas efficiency
- Require lump coal
- Require non-caking coal, high steam use
- Liquid products Issues

Gasification Capacity by Applications



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Tampa Electric 250 MW IGCC Plant

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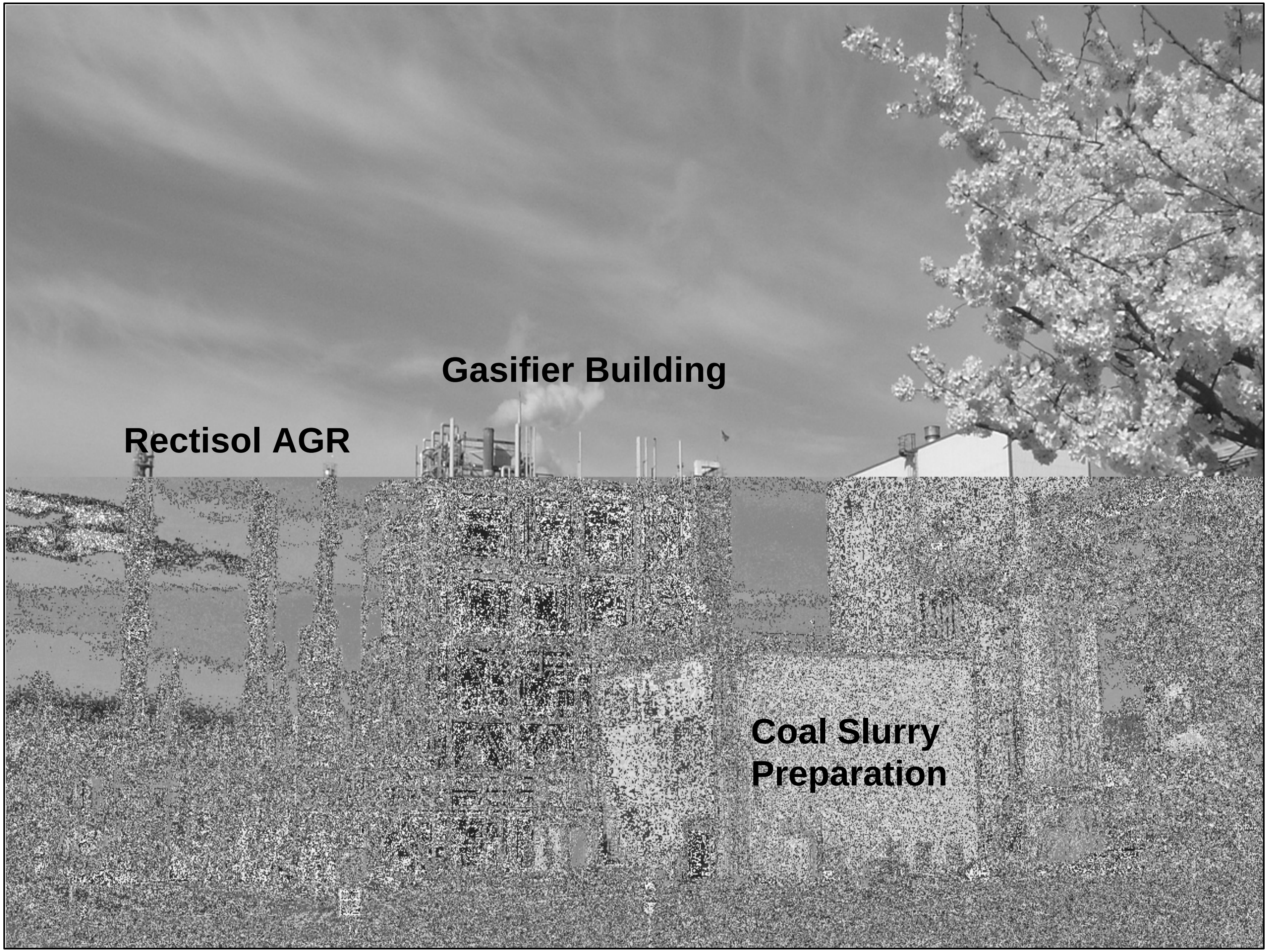
Eastman Coal to Chemicals Plant



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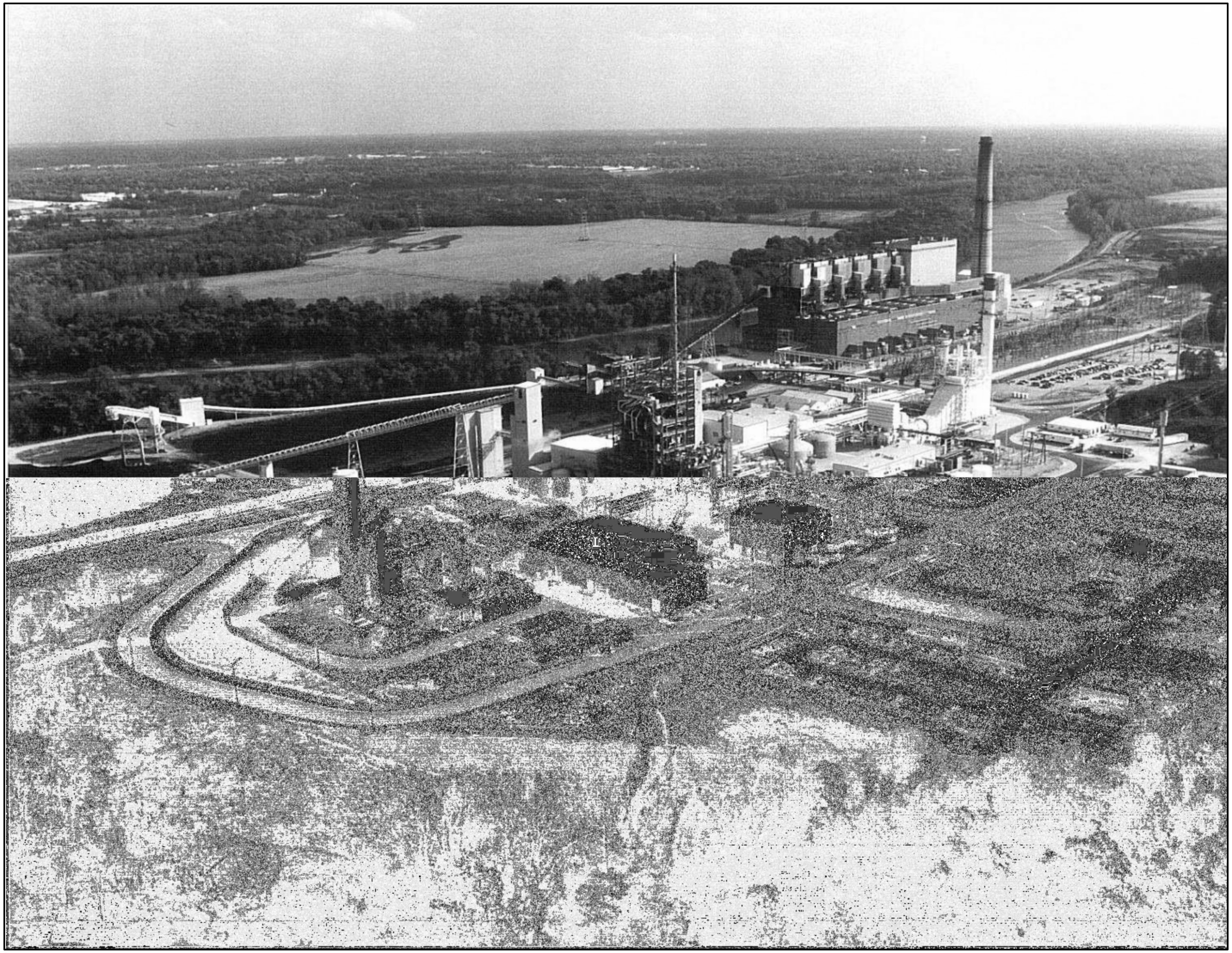
Wabash 250 MW IGCC Plant



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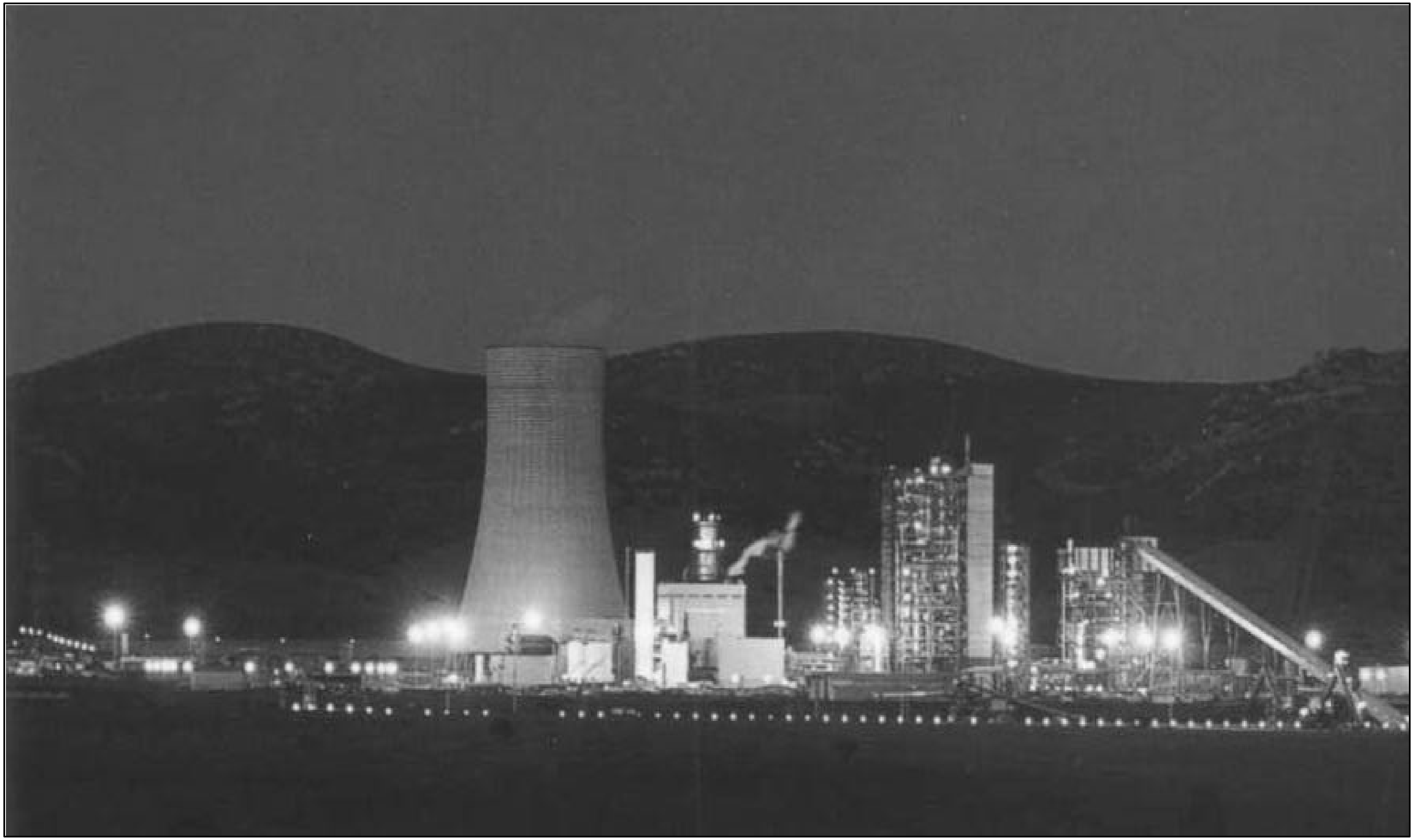
Puertollano 310 MW IGCC Plant



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Coal Based IGCC Plants

Project/ Location	Combustion Turbine	Gasification Technology	Net Output MW	Start-Up Date
Wabash River, IN	**GE 7 FA**	**Global Egas** (formerly Destec)	**262**	**Oct 1995**
Tampa Electric, FL	**GE 7 F**	**GE** (formerly Texaco)	**250**	**Sept 1996**
Demkolec (now Nuon), Buggenum Netherlands	**Siemens V 94.2**	**Shell**	**253**	**Jan 1994**
ELCOGAS Puertollano Spain	**Siemens V 94.3**	**Krupp-Uhde Prenflo** :	**310**	**Dec 1997**

Many Gasification Projects in Planning in North America

- American Electric Power
  Agrium/Blue Sky AK
- Baard Generation OH
- BP/Edison Mission CA
- Cash Creek Generation KY
- Clean Coal Power IL
- DKRW WY
- Duke/Cinergy IN
- Energy Northwest WA
- Erora Group IL
- Excelsior Energy MN
- First Energy/Consol OH
- Leucadia National LA
- Madison Power IL
- Madison Power IL
- Mountain Energy ID
- NRG Energy DL
- Orlando Util/Southern FL
- Otter Creek MT
- Power Holdings IL
- Rentech MS
- Royster Clark/Rentech IL
- Southeast Idaho ID
- Steelhead Energy IL
- Synfuel OK
- Tampa Electric
- WMPI PA
- Xcel Energy CO

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Most projects are for power, but also SNG and liquid fuels; Many also use petcoke; Many projects also in other countries

Comparison of Performance, Cost, and Emissions with Other Generation Technologies

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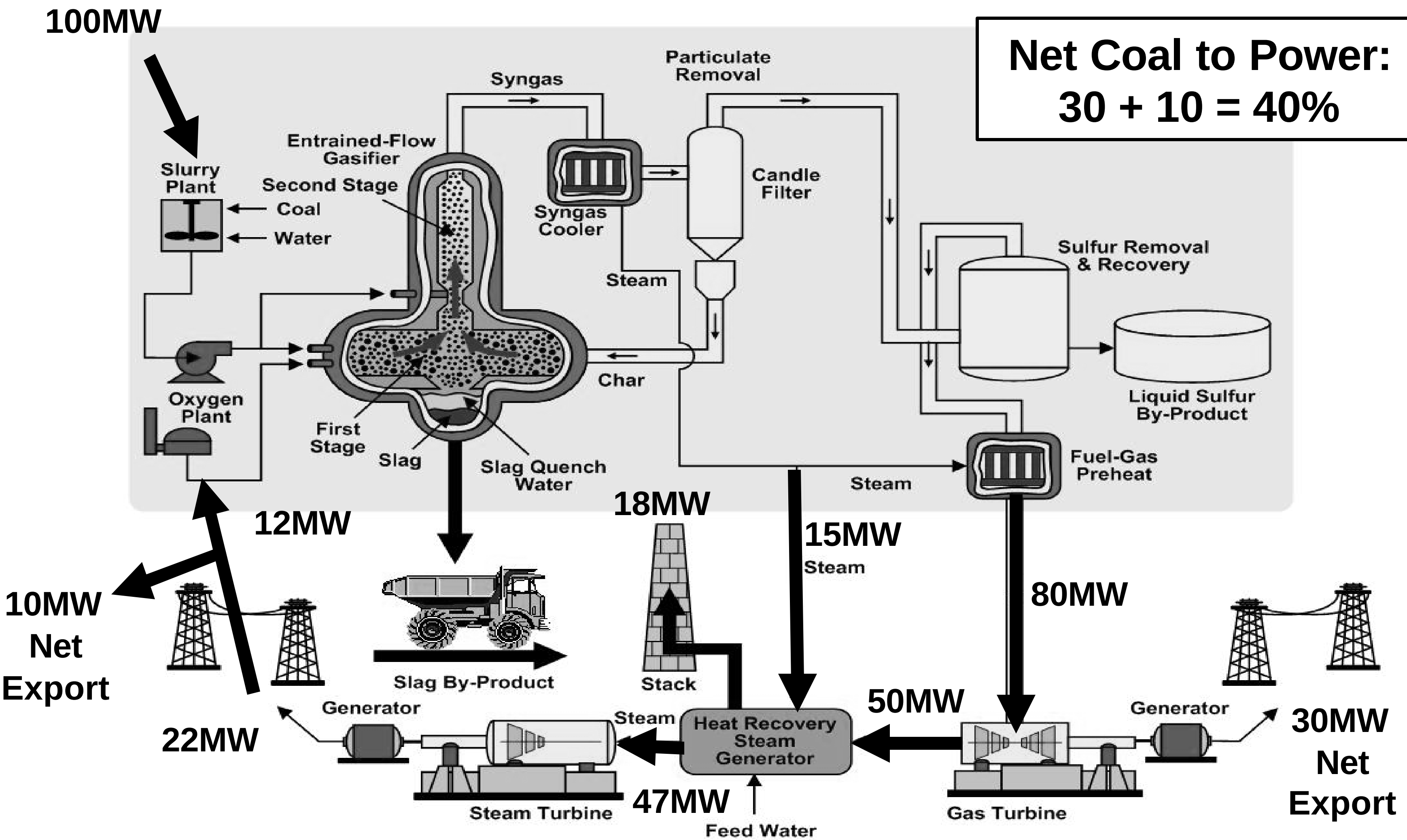
IGCC Plant Energy Flow & Efficiency

Net Coal to Power:
30 + 10 = 40%



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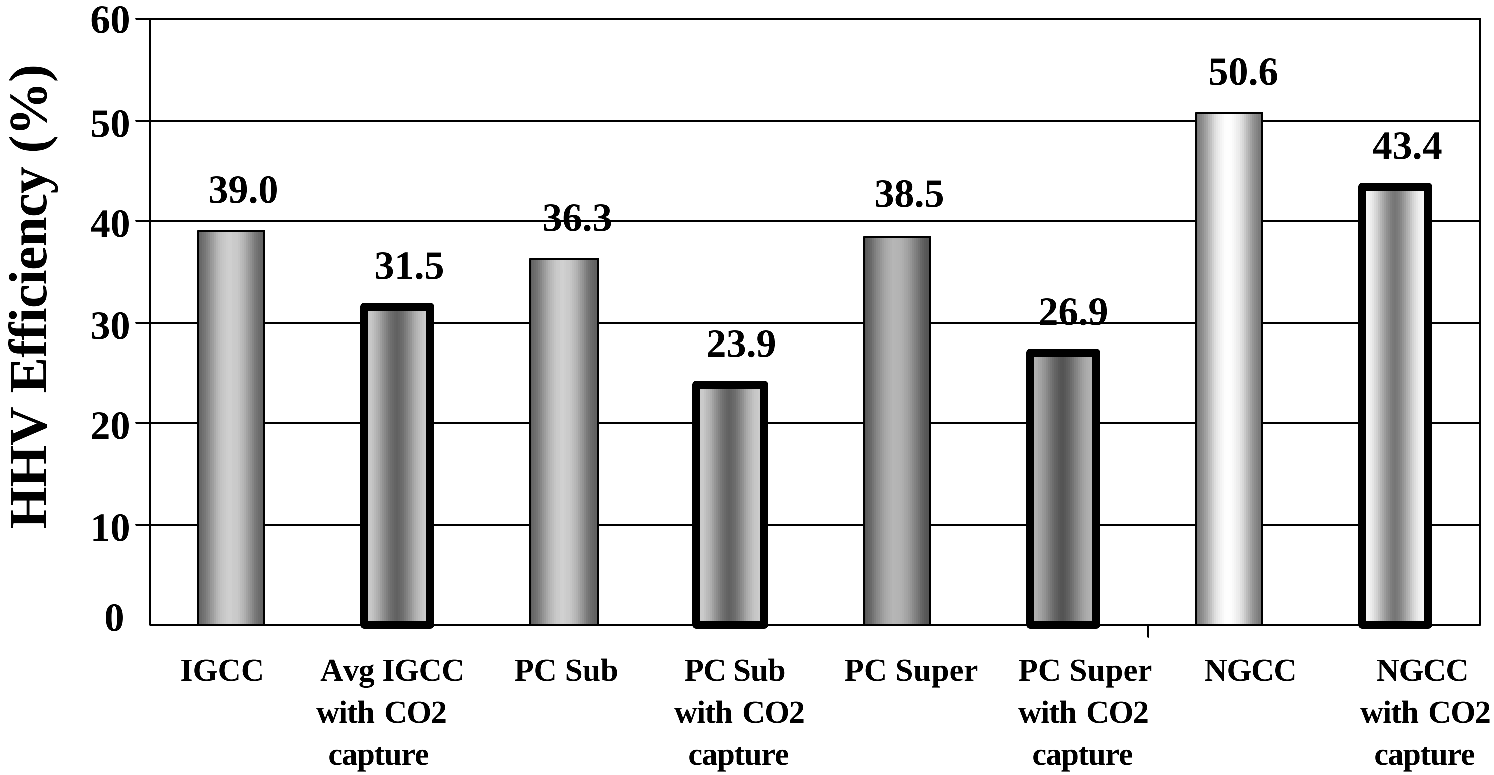
COMPARISON OF EFFICIENCY



Impacts of CO2 Capture:

- 20% hit on IGCC
- 30% hit on PC

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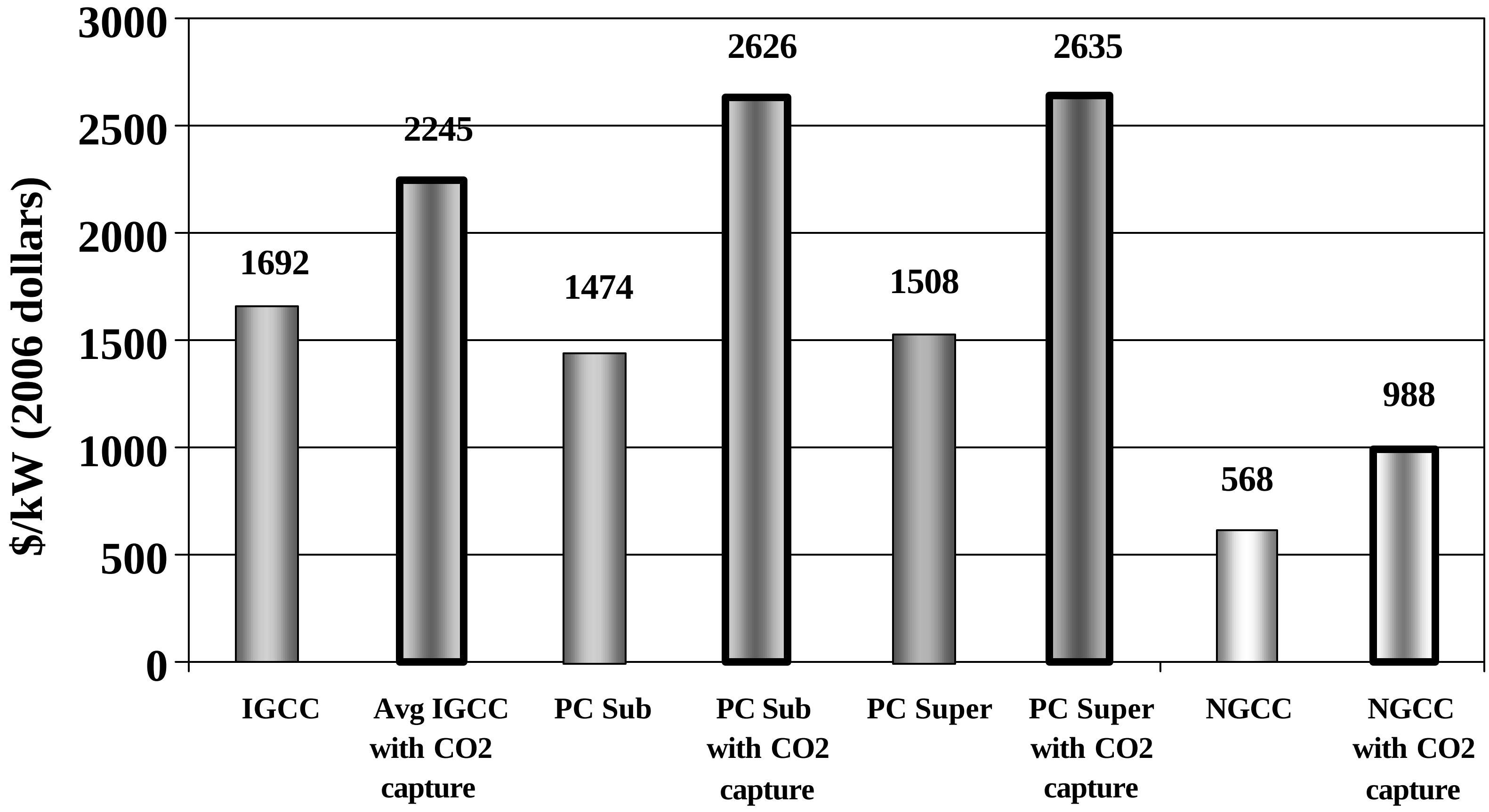
COMPARISON OF CAPITAL COST



Impacts of CO2 Capture:

- 33% hit on IGCC
- 75% hit on PC

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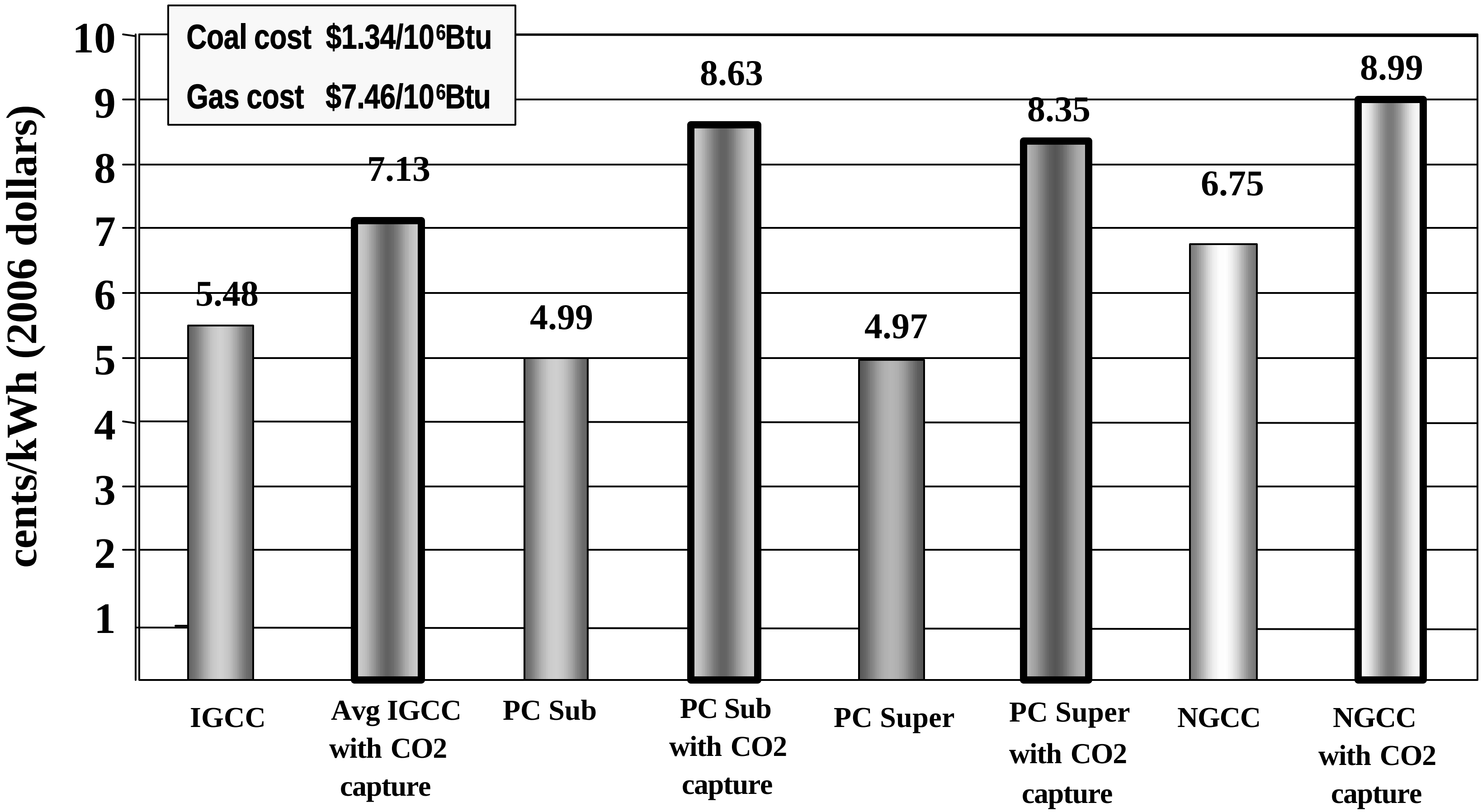
COMPARISON OF GENERATION COST



Impacts of CO2 Capture:

- 30% hit on IGCC
- 70% hit on PC

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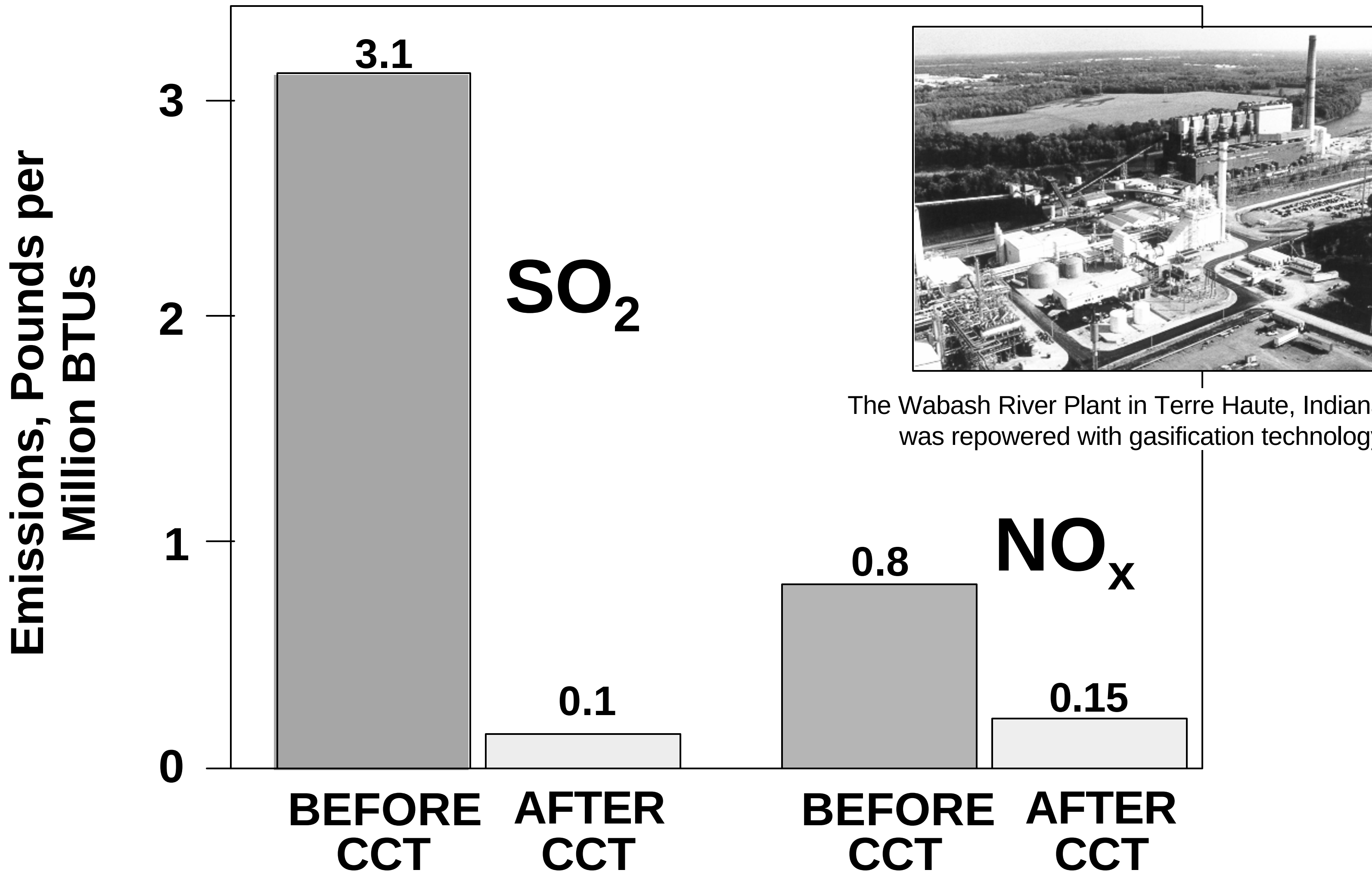
Wabash River Clean Coal Project
A Case Study for Cleaner Air



The Wabash River Plant in Terre Haute, Indiana, was repowered with gasification technology

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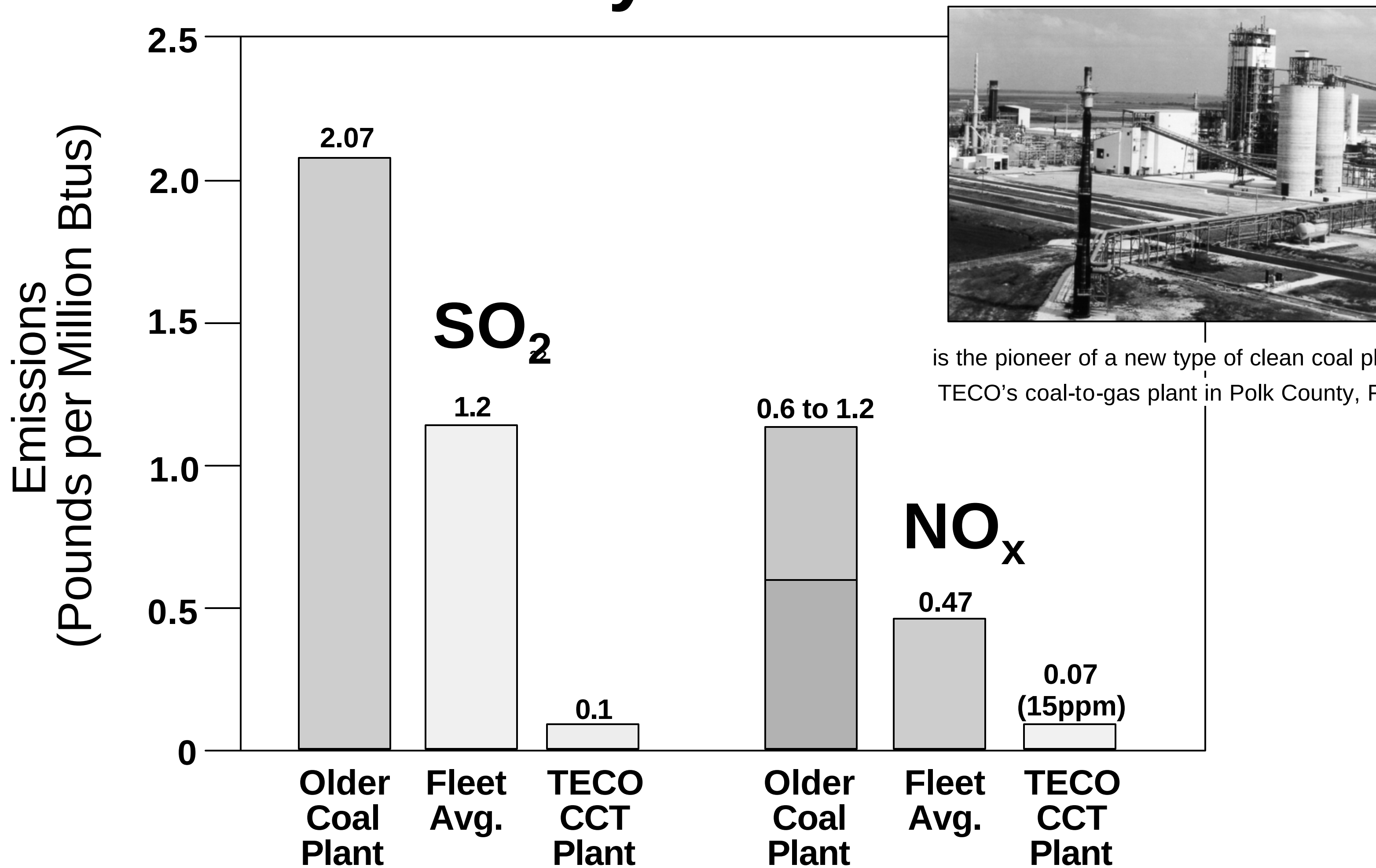
Tampa Electric (TECO) Clean Coal Project
A Case Study for Cleaner Air



TECO's coal-to-gas plant in Polk County, FL, is the pioneer of a new type of clean coal plant.

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Plant Availability

- PC (commercial record):
  - 90-95%
- IGCC (maximum achieved):
  - Tampa Electric: 81%
  - Wabash: 85%
  - Puertollano: 75%
  - Buggenum: 86%

Potential Technical Advancements for IGCC Plants

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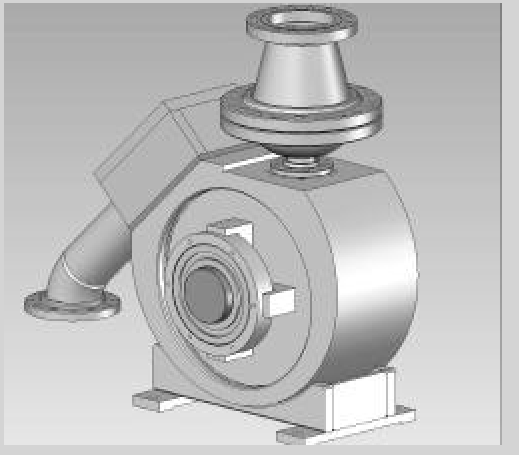
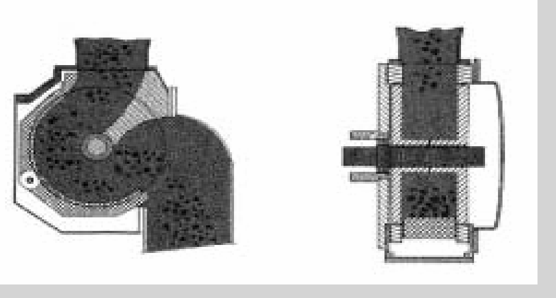
Dry Solids Pump for High Pressure Coal Feed to Gasifier

- Principle:
  - Uses pulverized coal under mechanical pressure to maintain high pressure seal to gasifier
- Benefit:
  - Reduce heat penalties with slurry feed and high-moisture (western) low-rank coals
  - 0.2-1% plant efficiency increase
  - $20-100/kW capital cost reduction

Stamet
Posimetric® Feeder System





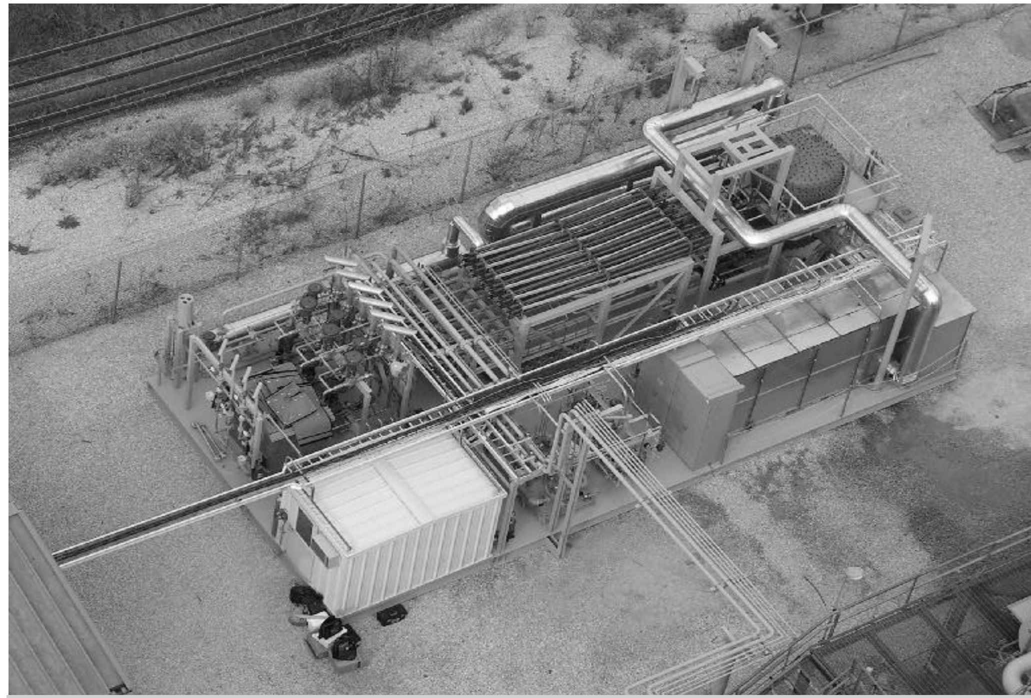
RTI Warm Gas Cleanup

- Sulfur removal @ 800-900 ^{o}F by attrition-free solid sorbent
- PDU tests at Eastman confirmed sulfur removal down to 5 ppmv
- Comparison with cold gas cleanup:

		MDEA	Rectisol	WGC
Gasification		67.6	67.6	67.6
Low Temp Gas Cooling		12.3	12.3	0
Sulfur Removal and Recovery		48.2	77.3	43.1
Balance of Plant		246.1	260.6	234.5
Total Cost ($ MM)		374.2	417.8	345.2
Savings	$MM	(29.0)	(72.6)	reference
	$/kW	$114	$279	reference
COS Hydrolysis Needed		Yes	No	No
Residual Sulfur, ppmv		50-100	<1	<5

ITM (Ionic Transport Membrane) Air Separation

- Oxygen ionized to transport through ceramic membrane at 1800 ^{o}F for separation from air stream
- Tested at Sparrows Point in January 2006 produced >95% purity oxygen
- Oxygen plant cost and power consumption are reduced more than 35%
- IGCC plant efficiency is reduced by 2% and cost reduced by 7%



Subscale engineering prototype ITM test unit at APCI's Sparrows Point gas plant

FY06 – 5 TPD test module
FY08 – 150 TPD test module
FY09 - Offer commercial modules

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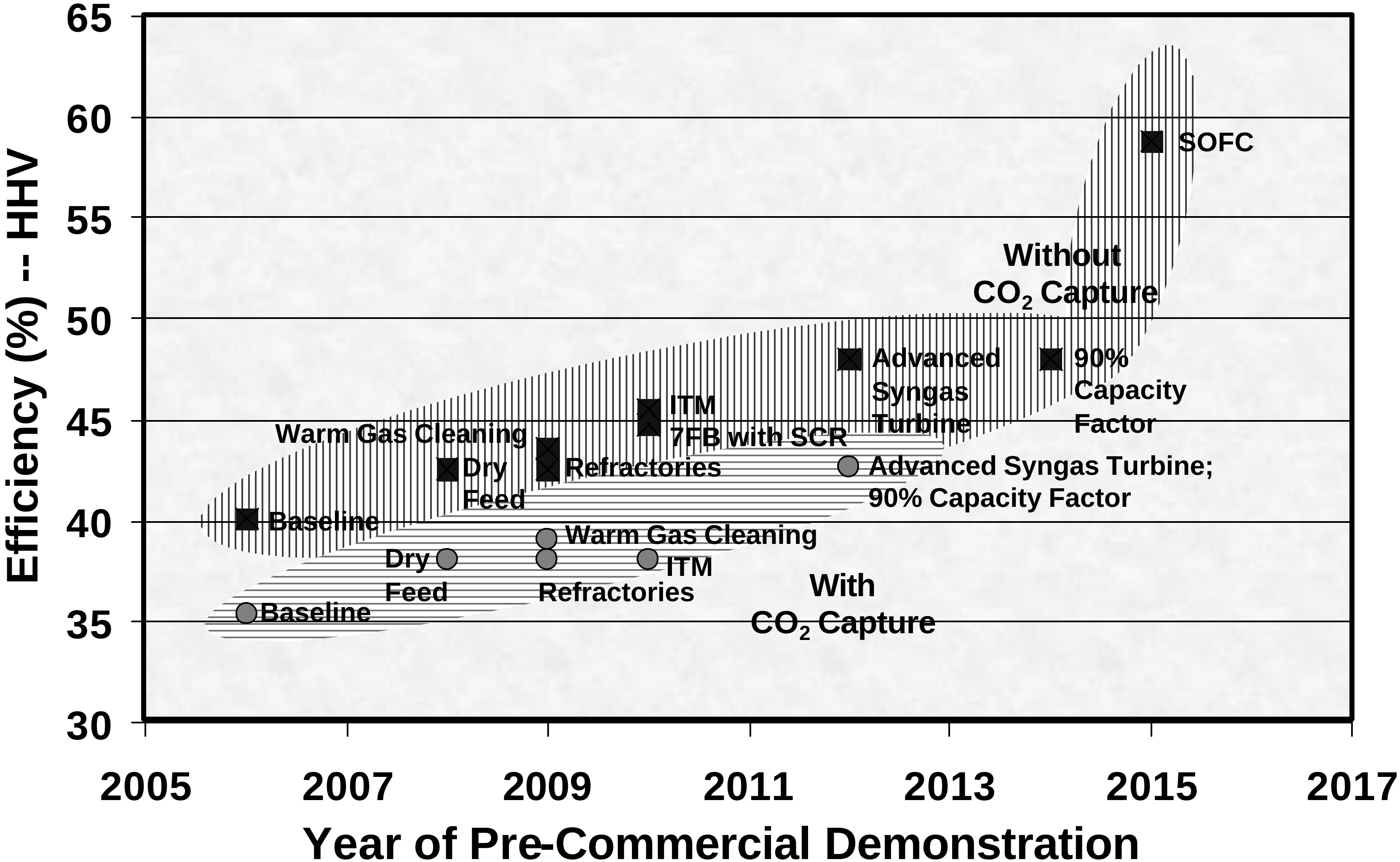
Efficiency Timeline



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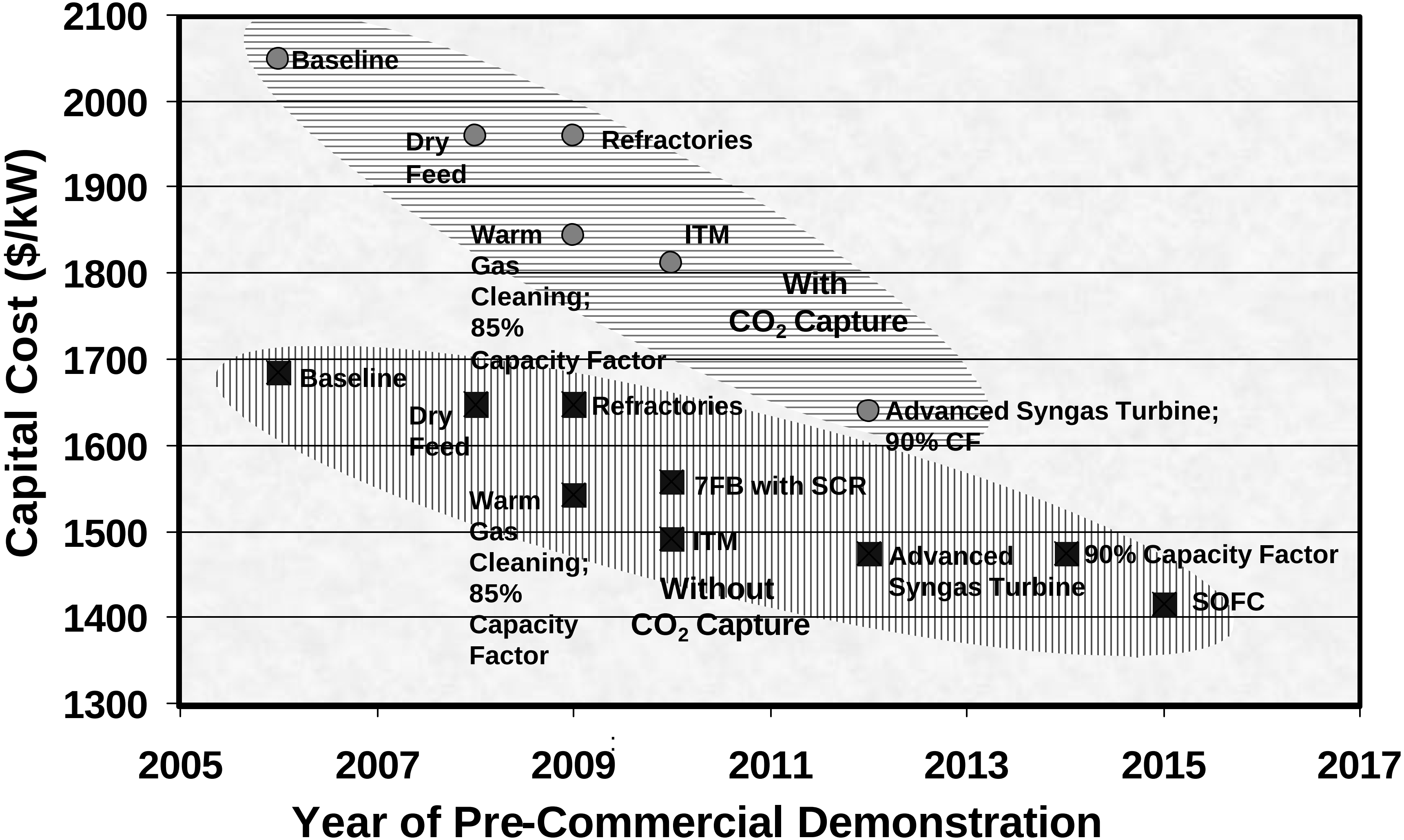
Capital Cost Timeline



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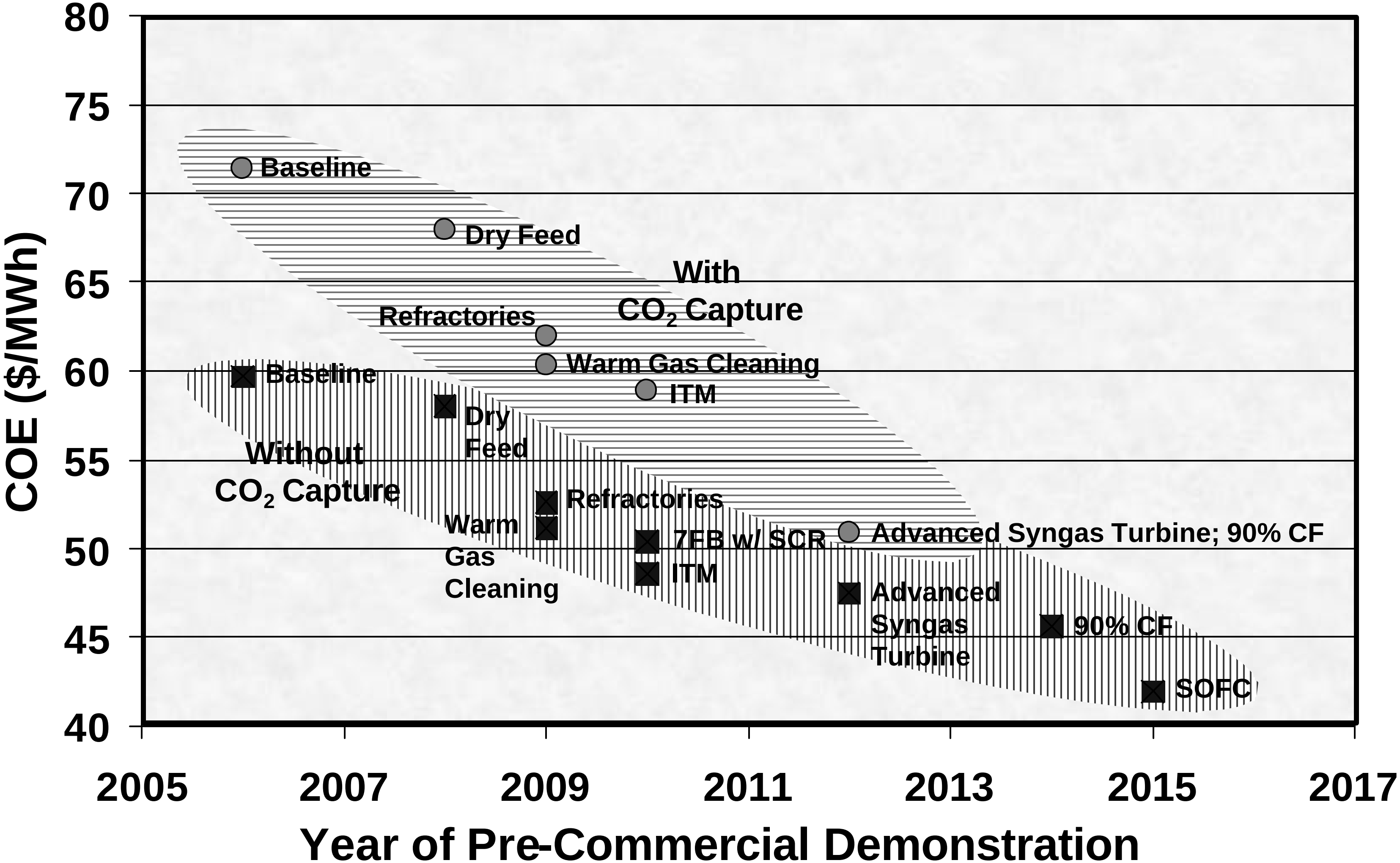
Cost Of Electricity (COE) Timeline



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Expansion of IGCC
to
Polygeneration

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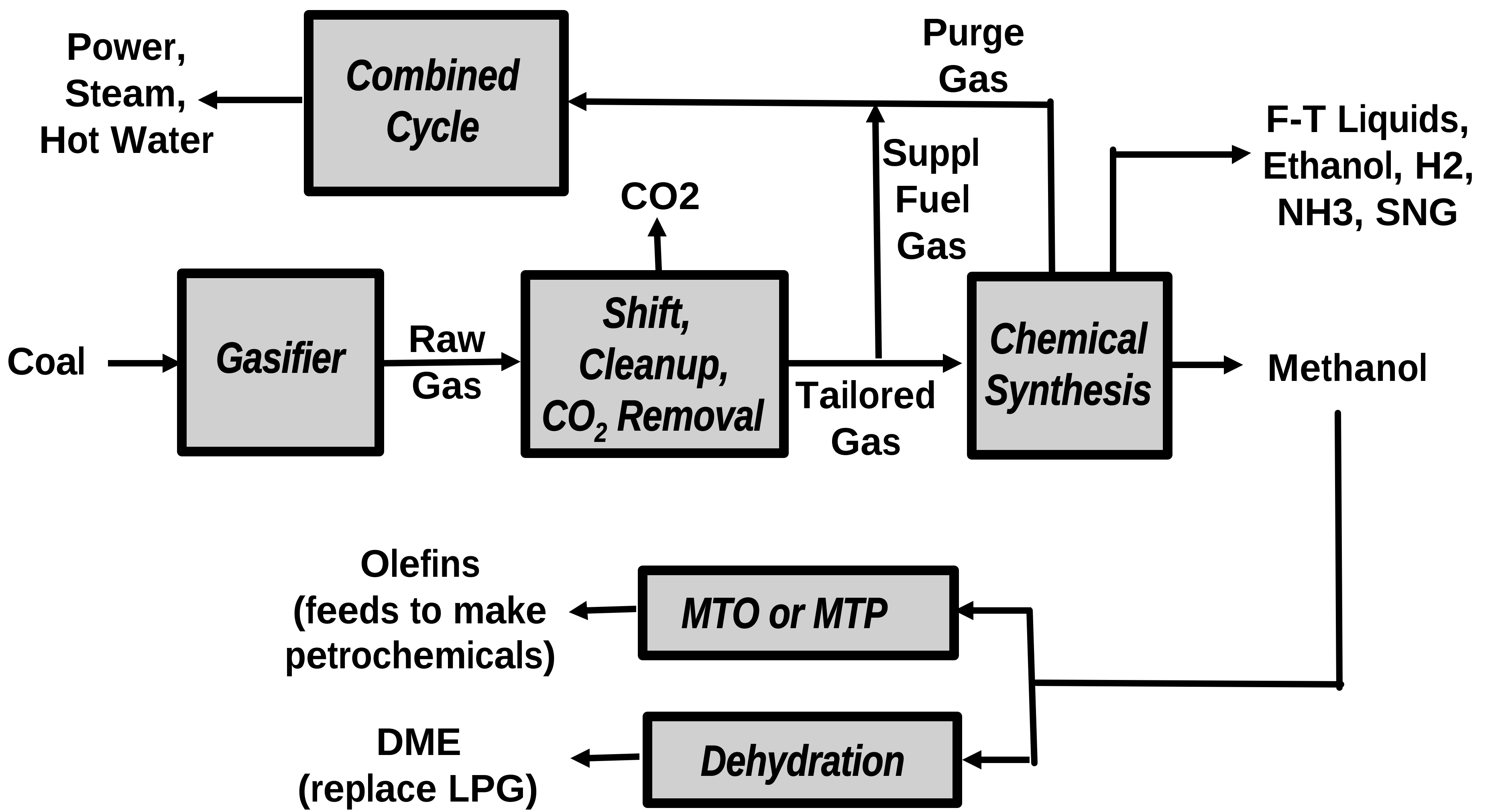
Poly-Generation



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Reasons for Poly-Generation

- Too many ways to produce power from coal & other energy sources (PC, CFBC, nuclear, hydro, wind, etc.)
- IGCC is too expensive now to compete for power generation; needs environmental benefits as the driver
- Power produced as byproduct; cheaper and very clean
- Coal is hydrocarbon sources; liquid fuels for transportation & petrochemicals are deal as replacement for the every more expensive petroleum
- Liquid fuels & chemicals are much higher value products than coal; solve shipping cost issue of coals in remote areas
- Has partial benefit of GHG reduction

Comparison of Methanol with Gasoline for Transportation

	Gasoline	Methanol
Molecular Formula	C_7H_{15}	CH_3OH
Molecular Weight	99	32
Density	0.74	0.795
Lower Heating Value, MJ/kg	42.5	19.7
Octane Number (RON)	100	108.7
Cruise Range, km	600	450
Vehicle Exhaust Emissions, g/km		
CO	0.86-2.08	0.2-1.43
CH	0.08-0.19	0.03-0.06
NO_x	0.2-0.43	0.04-0.19
1,3 Butadiene	0.6	<0.5
Benzene	4.7	1.5
Aldehydes	2.5	5.8
Methanol	---	79

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Methanol for Transportation Market

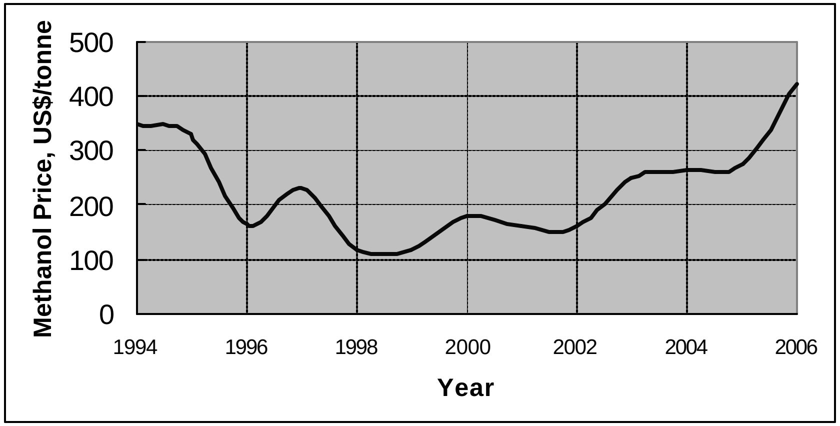
- Can replace both gasoline and diesel
- Vehicle engines prefer oxygenated fuels
  - Engines are more efficient due to less air intake - methanol has half gasoline HHV but engines require only 30% more
  - Build-in oxygen reduces emissions over entire driving cycle
- Technical issues
  - Toxicity, Poor miscibility with gasoline, Hard to startup during cool weather, Too high a vapor pressure during the hot weather, Engine gasket corrosion
- Using additives can solve the technical issues above
- Need 1,200 million tonnes/year even at 15% blending with gasoline/diesel

Other Market Potential for Methanol

- Can cheaply dehydrate to DME for replacing LPG
- Methanol provides missing link to production of coal-based petrochemicals
  - Olefins are the basic feedstocks to produce polymers and many other petrochemicals
  - Old way is to convert coal into carbide, which then reacts with water to produce olefins (acetylene) – polluting & expensive process
  - New & economic way is to convert coal-based methanol into olefins (UOP’s MTO process or Lurgi’s MTP process)

Methanol Market Size and Price

- Consumption: 32 million tonnes in 2005
- Methanol produced in NG rich regions @ $60/tonne
- Very volatile market price; causes:
  - Overbuild in NG rich regions
  - Limited market for making chemicals



- Much larger market for transportation fuel, household fuel, and petrochemicals; price should stabilize & key to gasoline/diesel price
- Price expected to stabilize @ $340/tonne, corresponding to $85/bbl gasoline/diesel (or $60/barrel crude) adjusted by HHV difference
- China consumes 7 million tonnes methanol in 2005; new production plants being built (2/3 from coal) have capacity of 10 million tonnes

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DME & Olefin Market Sizes and Prices

- DME
  - LPG sale in 2005: 205 million tonnes; $580/tonne ; $ 120 billion
  - DME HHV: 68% of LPG
  - No need to change burner to switch from LPG to DME
  - DME price: $400/tonne after adjusting for HHV difference from LPG
- Olefins
  - Ethylene sale in 2005: 133 million tonnes; $750/tonne; 100 billion
  - Propylene sale in 2005: 80 million tonnes; $800/tonne; 65 billion
- Large market for methanol to grab

Barriers of Using IGCC In India and China

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Characteristics of India Coals

- High ash content (35-45%)
  - Detrimental to entrained bed gasifier
  - Penalize IGCC more than PC
- High ash fusion temperature
  - Detrimental to entrained bed gasifier
  - Fluid bed gasifier is ideal, but no vendor support
- High reactivity
  - Entrained bed gasifier is overkill
  - Fluid bed gasifier is ideal, but no vendor support
- Low sulfur content (<0.5%)
  - Less environmental driving force to use IGCC

Applications of IGCC in India

- Operated several coal gasification plants in the past
- Coal is not very ideal for IGCC
- Suited fluid bed gasifier needs development
  - Tests in US/India showed Indian coal converted well in this type of gasifier despite the high ash content
- Emission standards are not stringent in India
  - FGD is still not required for PC
- Large cost differential over PC
  - PC costs only $700/kW
- India still plans to support a 100 MW IGCC demo
  - Potential to be competitive with technical advancements
  - Environmental & GHG reduction pressures

Applications of IGCC in China

- China is leading in using coal gasification; but all for chemical production; no IGCC yet
- Emission standards are not very stringent in China
  - FGD is required for PC but not well enforced
  - Emission limits of sulfur and NOx are still higher than those in developed countries
  - Emission control on mercury, arsenic, and trace pollutants are not considered at all
- Large cost differential over PC ($700/kW)
- Power generation over built; detrimental to build IGCC
- Going the direction of polygeneration

Summary

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Conclusions

- IGCC currently cannot compete with PC
  - Cost of generation is 10-15% more
  - Availability is lower (75-85% vs. 90-95%)
  - PC using super-critical steam cycle catches up in efficiency
- IGCC, however, has great commercial potential
  - Ample rooms for technical advancements, performance enhancements, and cost reduction
  - More cost effective to comply with stringent emission control
  - More cost effective for carbon capture
  - Fuel flexible - can use low cost petroleum coke
  - Can co-produce transportation fuels/chemicals by polygeneration
- WB financing for IGCC projects can promote clean and carbon-free use of coal and petcoke

GE Gasifier Projects in China

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? ? ?	F 2.8m 3? 1?	6.5	3×750	? ?	? ? ? ?

Other Coal/Coke Based Gasification Plants

Gasifier	Feedstock	Project
Texaco	Coal	1,300 tpd Tennessee Eastman coal to chemicals
		1,000 tpd Lunan coal to ammonia in China
		1,000 tpd Ube coal to ammonia in Japan
		900 tpd Hefi City coal to ammonia/urea in China
	Coke	120 MW Motiva Refinery IGCC in Delaware
		600 MW Citgo Refinery IGCC in Louisiana (in engineering)
Shell	Coal	900 tpd coal to chemicals at Yingcheng, China (2004 startup)
		2,000 tpd coal for ammonia/urea at Donting, China (2004 startup)
		1,200 tpd coal for chemical at Liuzhou, China (2005 startup)
		2,000 tpd coal for chemical at Heibei, China (2005 startup)
	Coke	2,300 tpd IGCC with H2 coproduction at Paradip, India (2005 startu
		5,000 tpd IGCC at Sardinia, Italy (2006 startup)
Lurgi	Coal	16,800 tpd lignite to SNG in North Dakota
		100,000 tpd coal to liquid fuels and chemicals in South Africa
U-Gas	Coal	800 tpd Wujing trigeneration plant in Shanghai
BGL	Coal	540 MW IGCC in Kentucky (2007 startup)
		541 MW IGCC in Ohio (2007 startup)

Nexant