

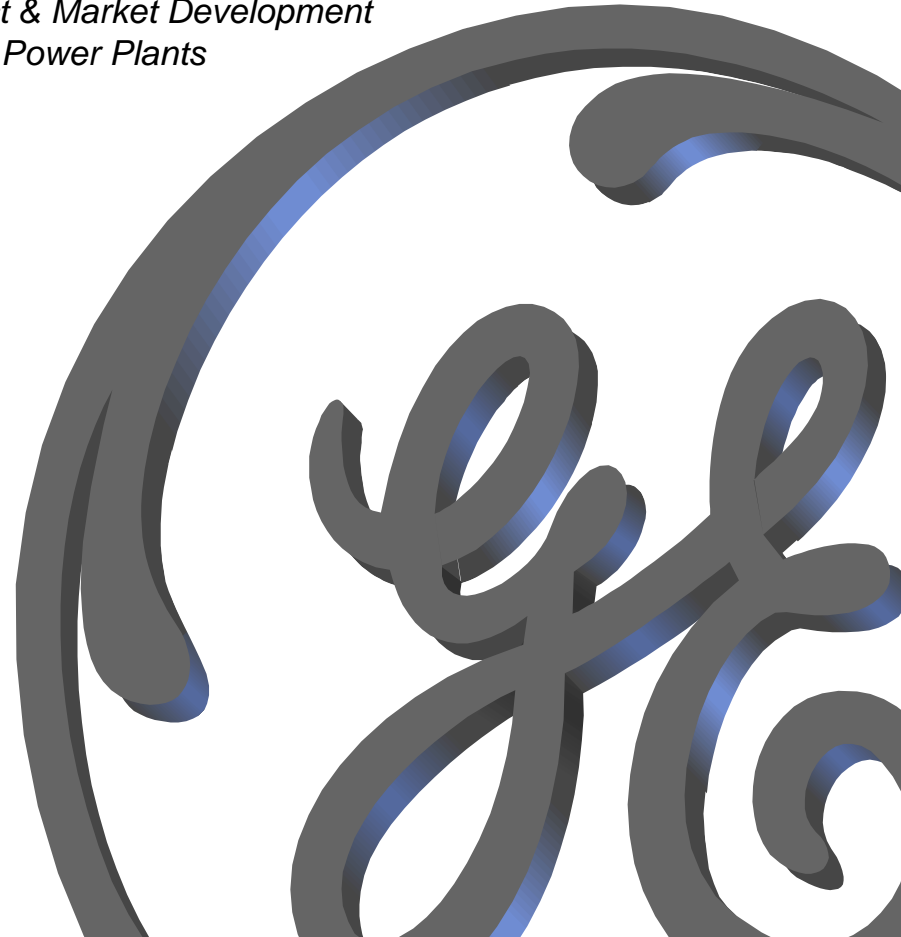
Economic Viability and Experience of IGCC From a Gas Turbine Manufacturers Perspective

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Power Systems
General Electric Company

ASME - IGCC
Turbo Expo
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ABSTRACT

Economic Viability and Experience of IGCC From a Gas Turbine Manufacturers Perspective

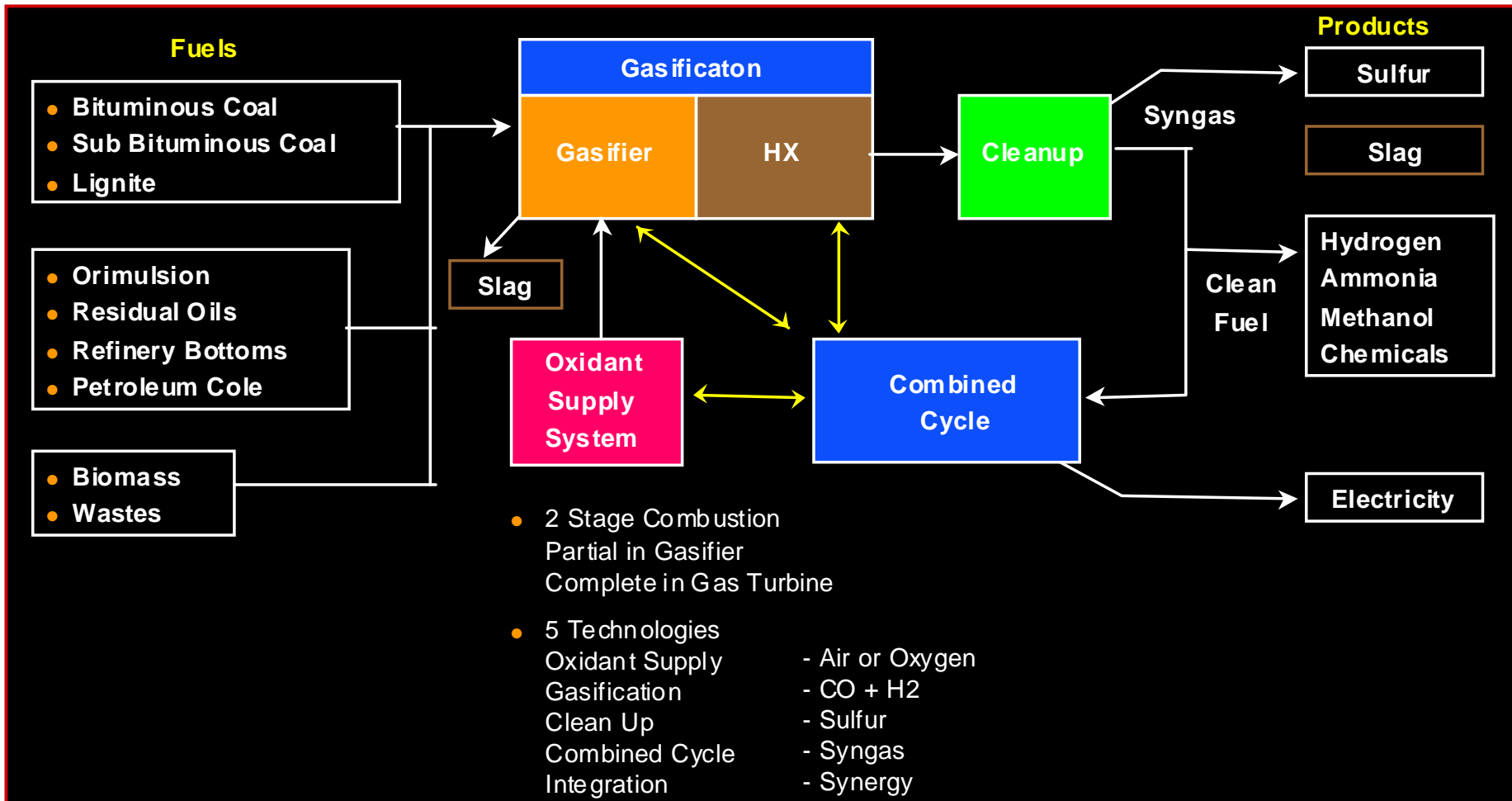
High natural gas fuel gas prices combined with new technology developments have made IGCC a competitive option when compared to conventional combined cycle or coal steam turbine cycles. Although the initial investment costs for an IGCC plant are still comparatively high, the low level and stability of petroleum coke, coal, and oil/tar residue feedstock prices can be shown to easily overcome this disadvantage when a plant's life cycle costs are compared over an extended time period. The ability of new IGCC technology to use a mix of low or negative value opportunity fuels has played a significant role in the commercial introduction of these systems. Co-production of Hydrogen, sulfur, Ammonia, Methanol, etc. and/or using IGCC to upgrade existing refinery products can furthermore enhance the economic viability of IGCC. Finally, a dual- or co-fired IGCC plant with natural gas and Syngas (derived from petroleum coke, coal, or residues) as the fuels can be effectively employed by power producers as a financial hedge against exaggerated fuel market price fluctuations.

General Electric has developed the technology to provide power producers with a range of gas turbines that can be efficiently integrated with IGCC to generate least cost electricity while meeting environmental regulatory requirements. Today there are over five (5) GW of IGCC plants in operation or under design. IGCC gas turbines are a mature product line with a total of 34 General Electric units sold of which 19 have accumulated over 340,000 hours of operation on Syngas. The IGCC technology has reached the point where systems are commercially competitive, technologically low risk, and offer exceptional environmental performance. The introduction of the next generation of advanced gas turbines will propel IGCC systems to a previously unobtainable level of performance while simultaneously realizing a step change improvement in capital cost.

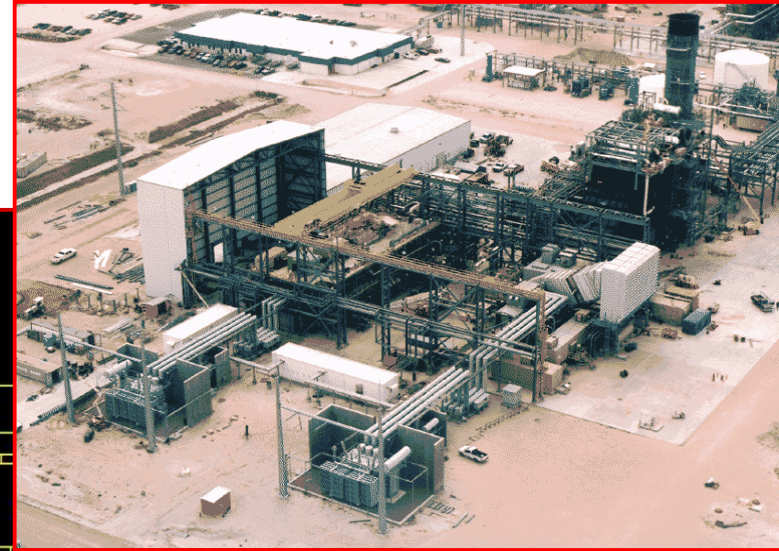


What is IGCC?

Integrated Gasification Combined Cycle

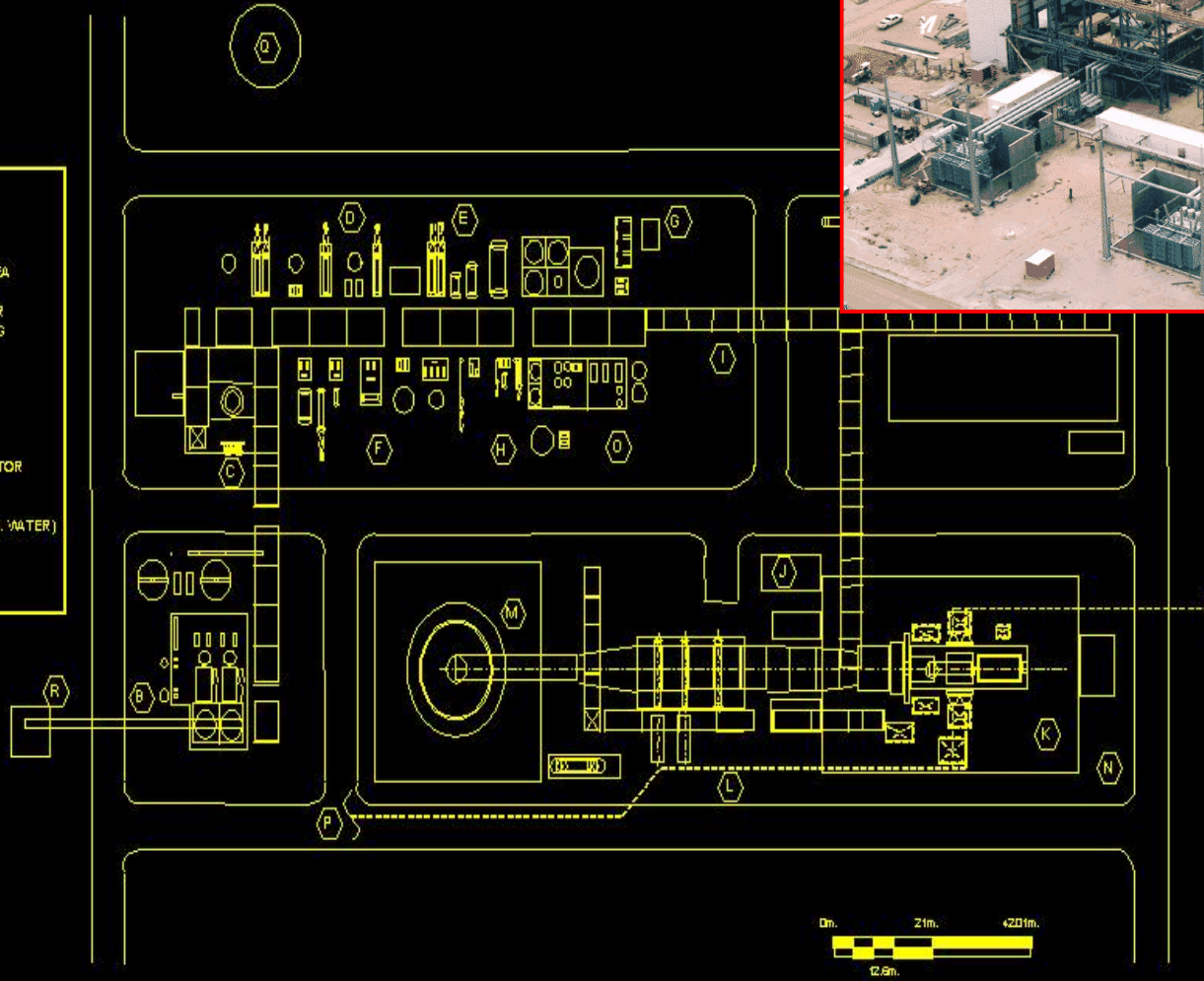


What is IGCC?



LEGEND:

- A AIR SEPARATION
- B COAL SLURRY PREPARATION AREA
- C GASIFICATION STRUCTURE
- D SYNGAS SATURATION / EXPANDER
- E LOW-TEMPERATURE GAS COOLING
- F ACID GAS REMOVAL
- G SULFUR LOADING PAD
- H AMMONIA STRIPPER
- I PIPE RACK
- J CONTROL BUILDING
- K COMBINED CYCLE
- L HEAT RECOVERY STEAM GENERATOR
- M STACK
- N STEP UP TRANSFORMER
- O BALANCE OF PLANT (AIR & DEMIN. WATER)
- P CIRCULATING WATER PIPES
- Q SYNGAS FLARE STACK
- R COAL CONVEYOR



*Typical
Coal
IGCC*

IGCC - A Brief Industry History

- 1878** - Lurgi Gasifier
- 1930** - Coal Gasification
- 1940** - Town Gas Applications
- 1950** - Gasification for Hydrogen Production in the Chemical Process Industry
- 1960** - Coal Tested as Fuel for Gas Turbines (Direct Burning)
- 1970** - IGCC Studies
- 1980** - First Pilot IGCC (Coolwater)
- 1990** - Commercial IGCC Plants
- 2000** - IGCC Accepted Coal Plant Option



General Electric IGCC Technical Leadership

- Over 22 Years Experience Testing Low Btu Fuels
- First IGCC Plant Commissioned in 1984
- 17 Units Currently Operating on Synthetic Gas
- Over 340,000 Operating Hours on Synthetic Gas
- 19 Additional Units Scheduled to Start 2001-2006
- IGCC Units Include GE10, 6B, 7EA, 9E, 9EC, 6FA, 7FA, 9FA



General Electric IGCC Combustion Laboratory

We are Committed to IGCC Gas Turbine Developments

IGCC - Major Technological Milestones

- **Cool Water Demonstration Plant 1984**

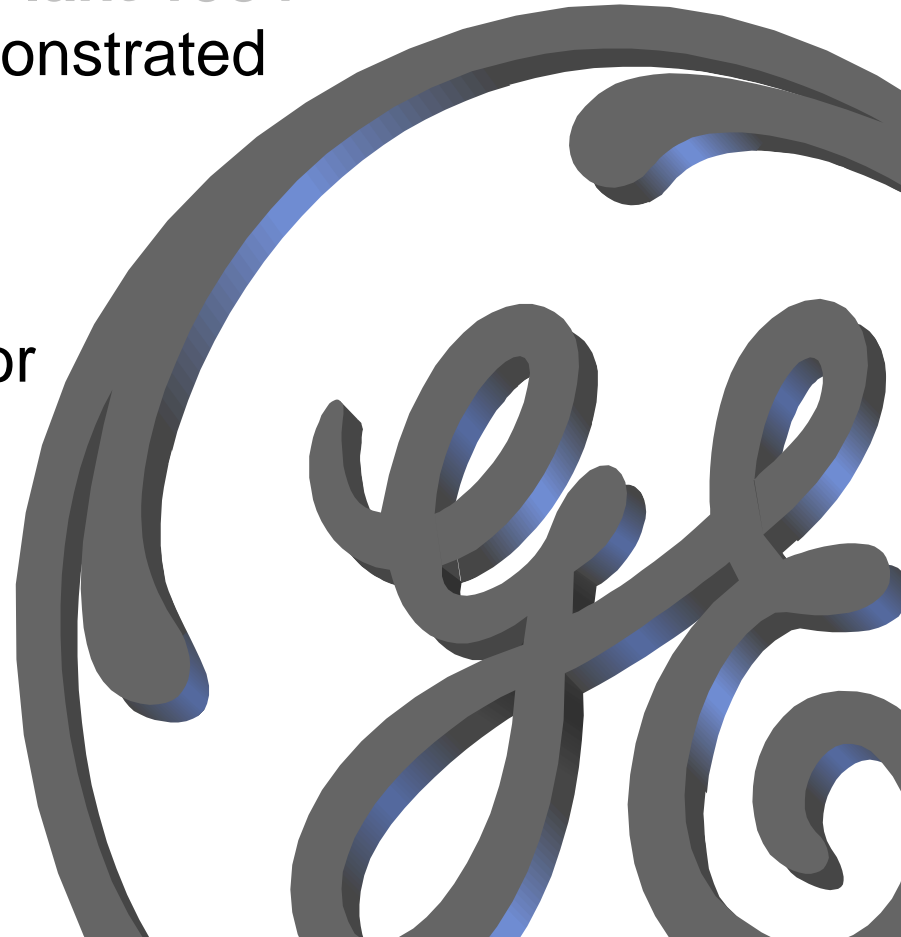
First Large Scale IGCC. Demonstrated IGCC Technical Feasibility.

- **Polk Tampa Electric 1996**

Successful Nitrogen Injection for NO_x Control. Demonstrated IGCC Commercial Feasibility.

- **Exxon Singapore 2000**

Widest Variety of Gas Turbine Fuels.



IGCC - World Experience

<u>Customer</u>	<u>C.O. Date</u>	<u>MW</u>	<u>Application</u>	<u>Gasifier</u>
SCE Cool Water - USA	1984	120	Power/Coal	Texaco - O₂
LGTI - USA	1987	160	Cogen/Coal	Destec - O ₂
Demkolec - Netherlands	1994	250	Power/Coal	Shell - O ₂
PSI/Destec - USA	1995	260	Repower/Coal	Destec - O₂
Tampa Electric - USA	1996	260	Power/Coal	Texaco - O₂
Texaco El Dorado - USA	1996	40	Cogen/Pet Coke	Texaco - O₂
SUV - Czech.	1996	350	Cogen/Coal	ZUV - O₂
Schwarze Pumpe - Germany	1996	40	Power/Methanol/Lignite	Noell - O₂
Shell Pernis - Netherlands	1997	120	Cogen/H₂/Oil	Shell - O₂
Puertollano - Spain	1998	320	Power/Coal/Pet Coke	Prenflow - O ₂
Sierra Pacific - USA	1998	100	Power/Coal	KRW - Air
ISAB - Italy	1999	500	Power/H ₂ /Oil	Texaco - O ₂
API - Italy	2000	250	Power/H ₂ /Oil	Texaco - O ₂
MOTIVA - Delaware	2000	240	Repower/Pet Coke	Texaco - O₂
Sarlux/Enron - Italy	2000	550	Cogen/H₂/Oil	Texaco - O₂
EXXON - Singapore	2000	180	Cogen/H₂/Oil	Texaco - O₂
Bio Electrica - Italy	2001	12	Power/Biomass	Lurgi - Air
FIFE - Scotland	2001	120	Power/Sludge	BGL - O₂
EDF - Total	2003	400	Power/H₂/Cogen/Oil	Texaco - O₂
FIFE Electric - Scotland	2003	400	Power/Coal/RDF	BGL - O₂
Nihon Sekiyu - Japan	2004	350	Power/Oil	Texaco - O ₂
IOC Paradip	2004	180	Power/Pet Coke	Shell O₂
Confidential	2004	750	Power/Coal	Texaco - O₂
PIEMSA	2004	800	Power/H₂/Oil	Texaco - O₂
Confidential	2004	800	Power/Coal	Texaco - O₂
TPS/Lake Charles	2005	700	Power/H₂/Oil	Texaco - O₂

General Electric Gas Turbine Syngas Experience

Syngas Hours of Operation

December 2000

Customer	Type	MW	Syngas Start Date	Hours of Operation		
				Syngas	N.G.	Dist.
Cool Water	107E	120	5/84	27,000	-	1,000
PSI	7FA	262	11/95	21,700	-	3,000
Tampa	107FA	250	9/96	*23,200	-	5300
Texaco El Dorado	6B	40	9/96	22,800	17,100	-
Sierra Pacific	106FA	100	-	0	20,500	-
SUV Vresova	209E	350	12/96	63,700	1,200	-
Schwarze Pumpe	6B	40	9/96	26,700	-	3,400
Shell Pernis	2x6B	120	11/97	40,300	17,900	-
ISE / ILVA	3x109E	540	11/96	98,900	2,200	-
Fife Energy	6FA	80	-	0	5,600	-
Motiva Delaware	2x6FA	240	8/00	***100	-	***1300
Sarlux	3x109E	550	10/00	**4,400	-	10,500
Piombino	109E	150	10/00	0	400	-
Exxon Singapore	2x6FA	180	-	0	0	50

* as of 1/01

** as of 2/01

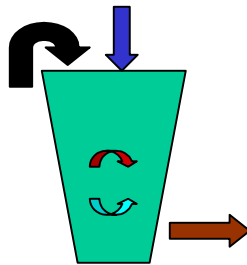
*** as of 3/01

Totals 328,800

Major IGCC Market Players

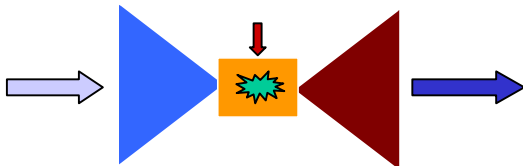
Gasifiers & Clean-Up:

- Texaco
- Shell
- Global / E-Gas
- Lurgi
- Noel



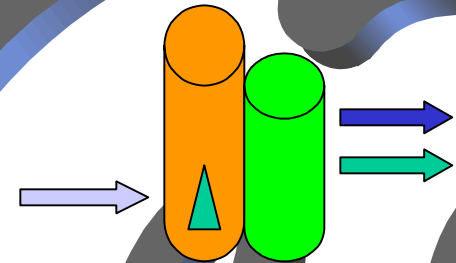
Power Block (GT&ST):

- General Electric
- Siemens-Westinghouse
- MHI
- Alstom



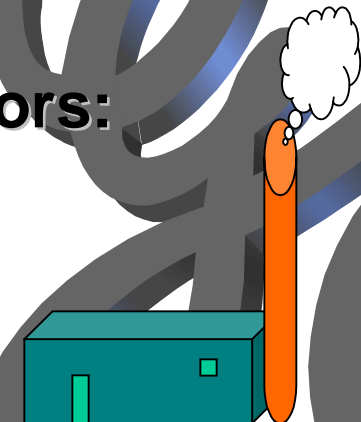
Air Separation Units:

- Air Products International
- BOC Group
- Praxair
- Air Liquide



EPC Contractors:

- Bechtel
- Krupp-Uhde
- Fluor Daniel
- Foster Wheeler
- Snamprogetti

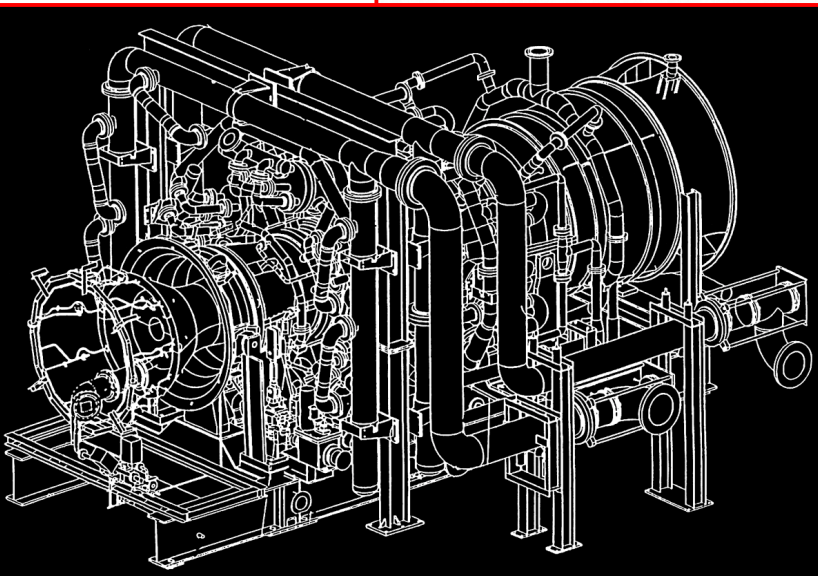
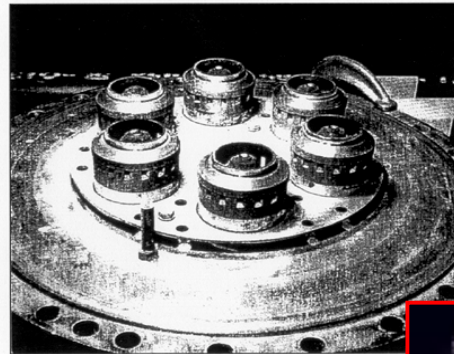
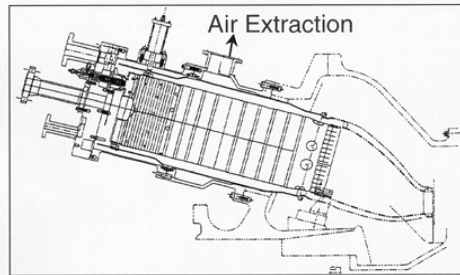


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IGCC Gas Turbine State-of-the-Art

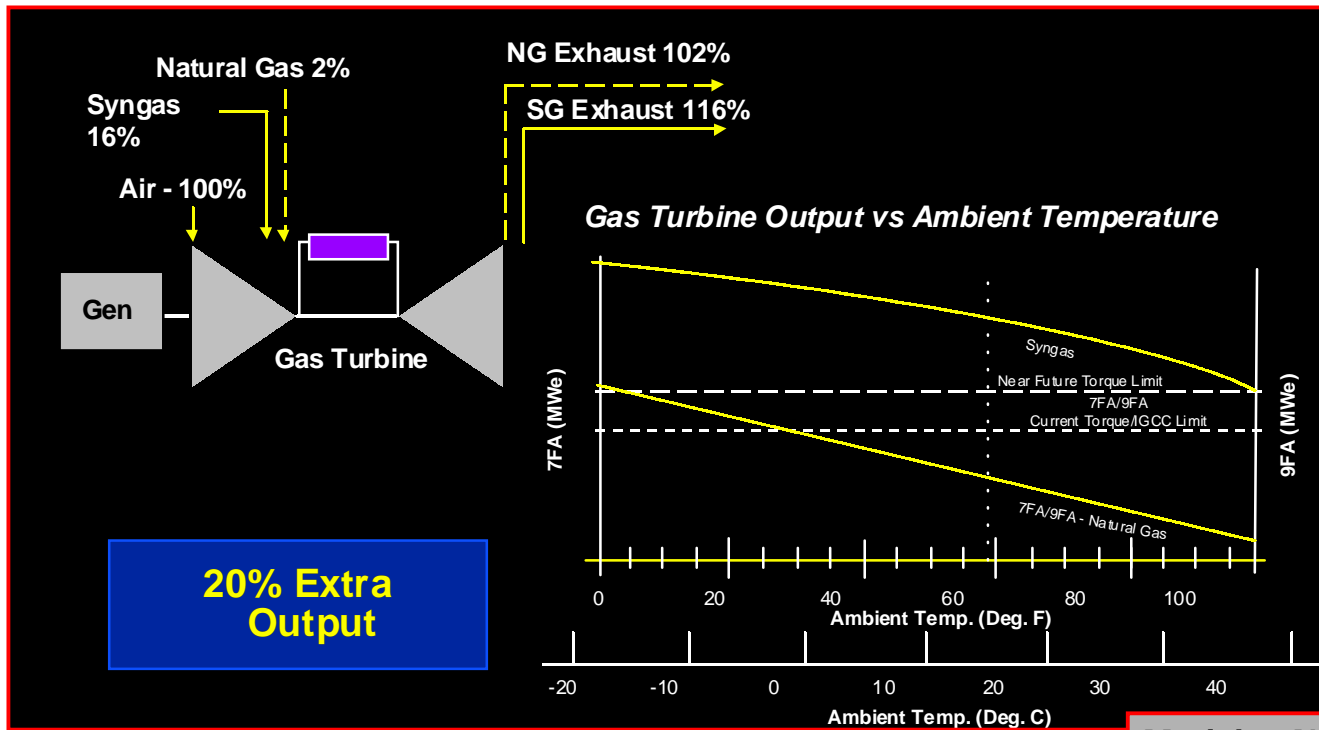
Combustion System Developments

Same IGCC Combustor Design for 6FA, 7FA, 9FA, 9EC



IGCC Gas Turbine State-of-the-Art

IGCC Output Enhancement



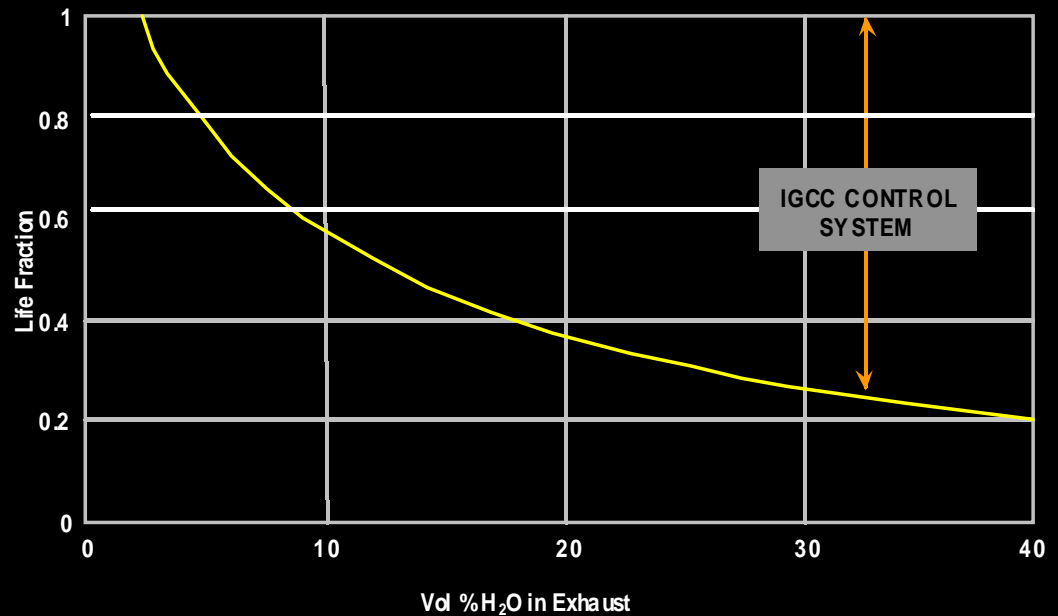
Model	NG-SC	Syngas-SC	Net-IGCC
6FA	70	90	126
7FA	172	197	280
9EC	170	215	300
9FA	256	286	420

All Units MW

IGCC Gas Turbine State-of-the-Art

Reliability - Availability - Maintenance (RAM)

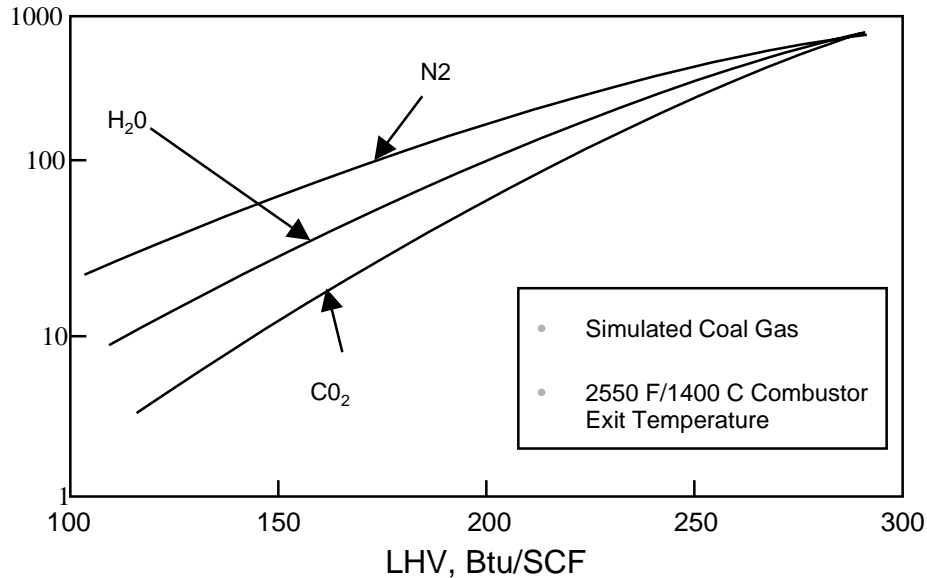
- Need Automatic Fuel Switch/Nitrogen Purge
- Need Clean Syngas
- Reduced Firing Temp to Maintain Design Metal Temp/ 100% Life



Syngas Combined Cycle Can Have Same Performance as Natural Gas Combined Cycle

IGCC Gas Turbine State-of-the-Art

Emissions



Full load NO_x versus Syngas Heating Value

Best Available Control Technology:

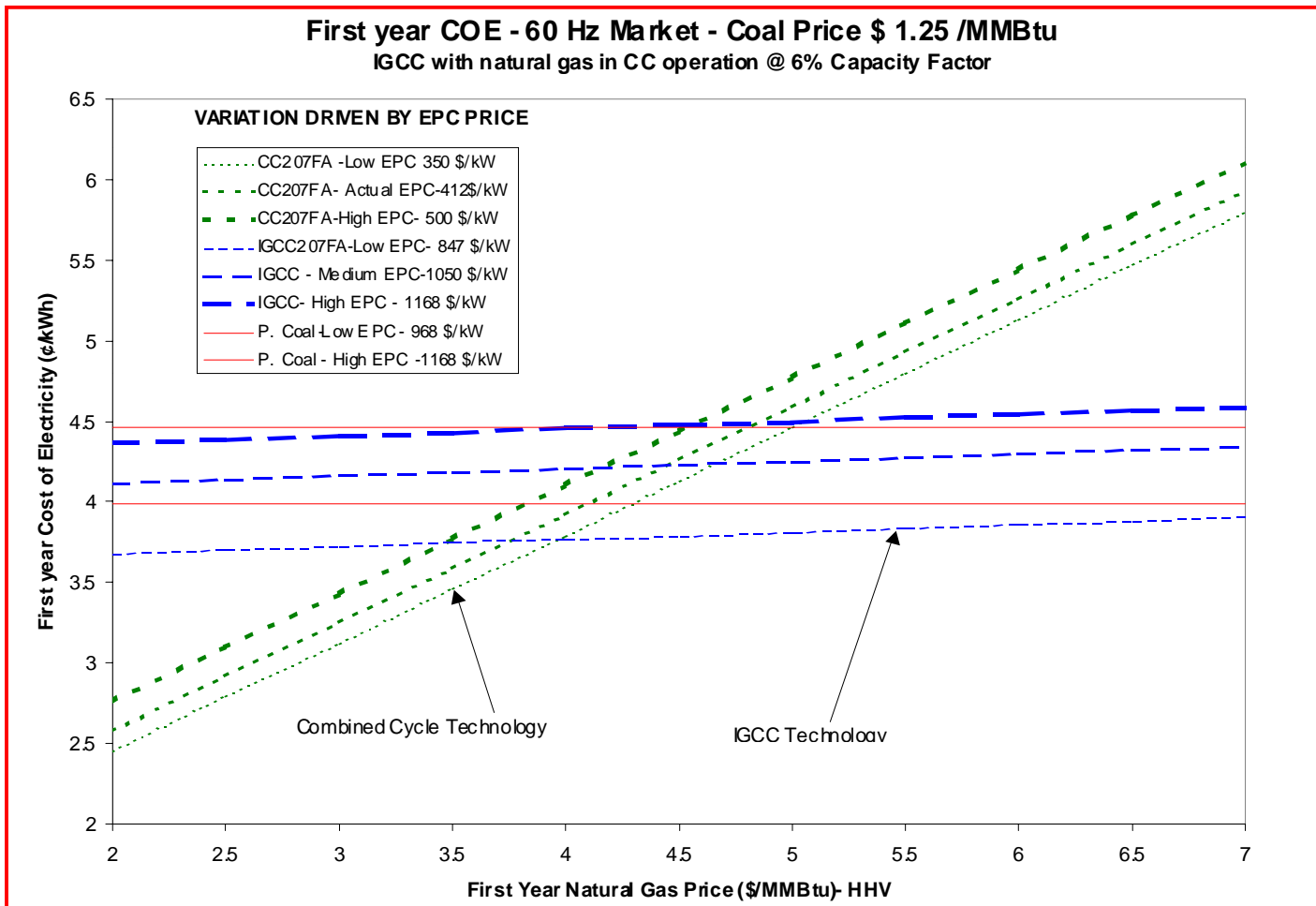
Current IGCC BACT: 15-25 ppm NO_x

Near Future IGCC BACT: 9-15 ppm NO_x

Long Term IGCC BACT: <9 ppm NO_x

IGCC Economics

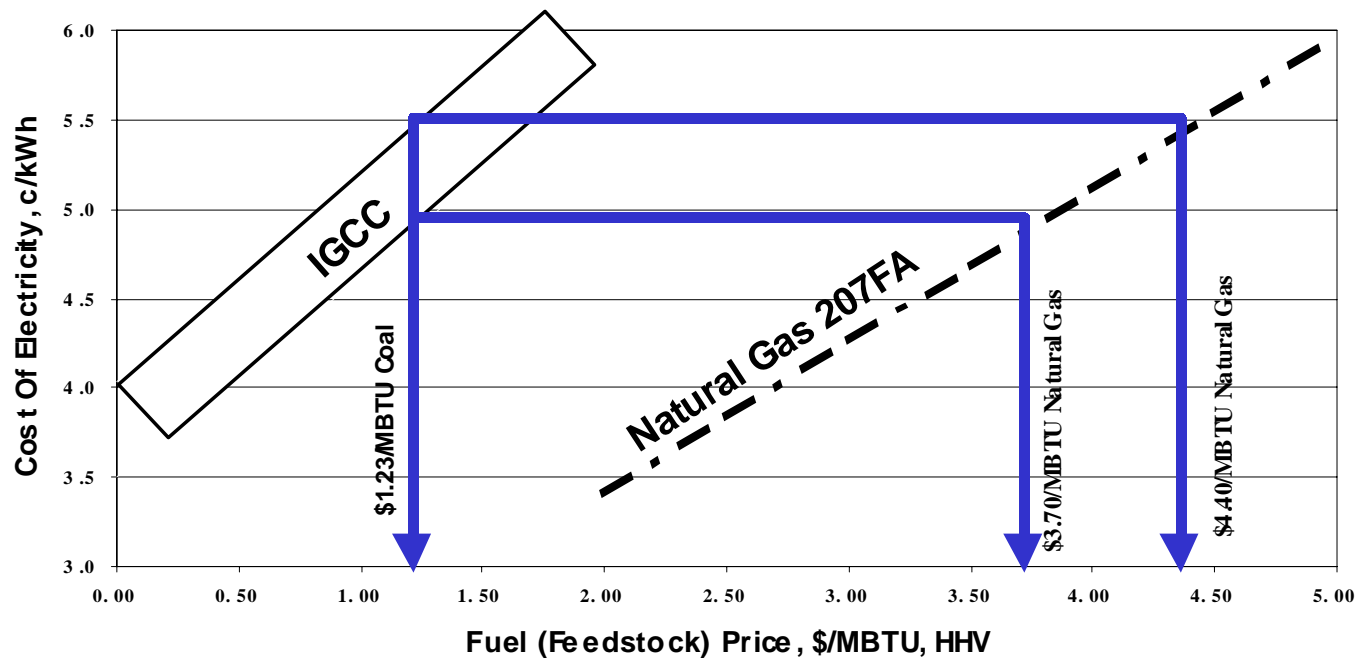
IGCC versus Conventional Natural Gas Combined Cycle



IGCC Economics

IGCC versus Conventional Natural Gas Combined Cycle

20 Year Levelized COE versus Fuel Price

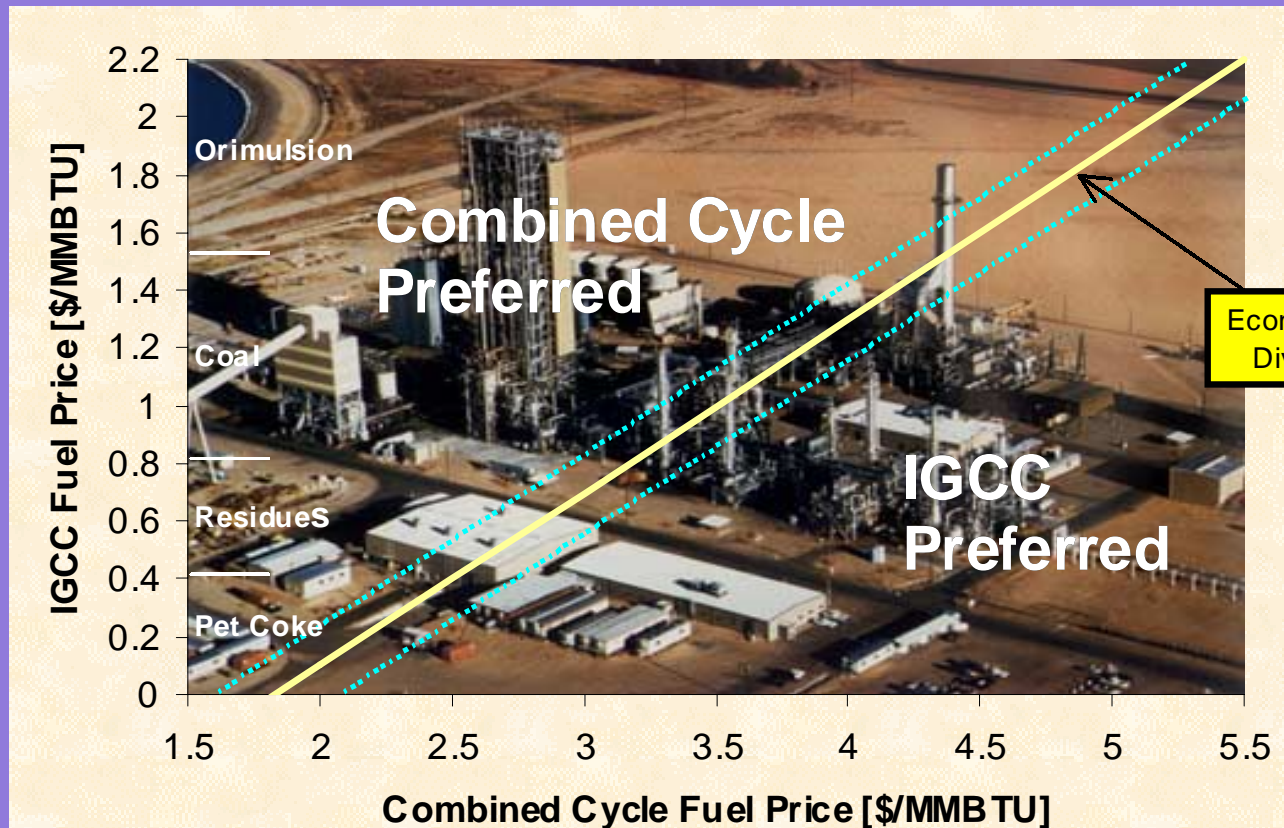


IGCC Economics

IGCC versus Conventional Natural Gas Combined Cycle

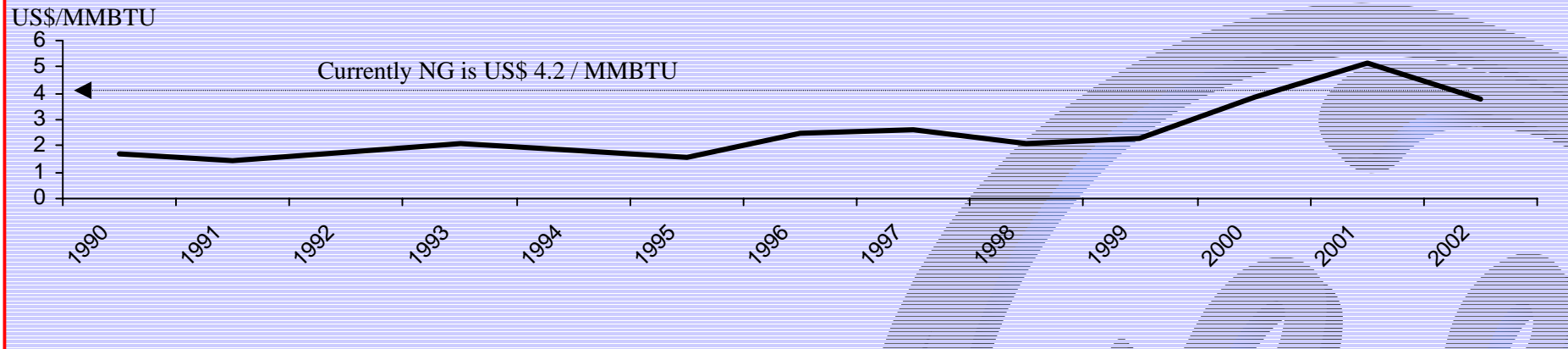
Economic Comparison of IGCC versus Combined Cycle

based on 20 year COE for large power plants



IGCC Economics

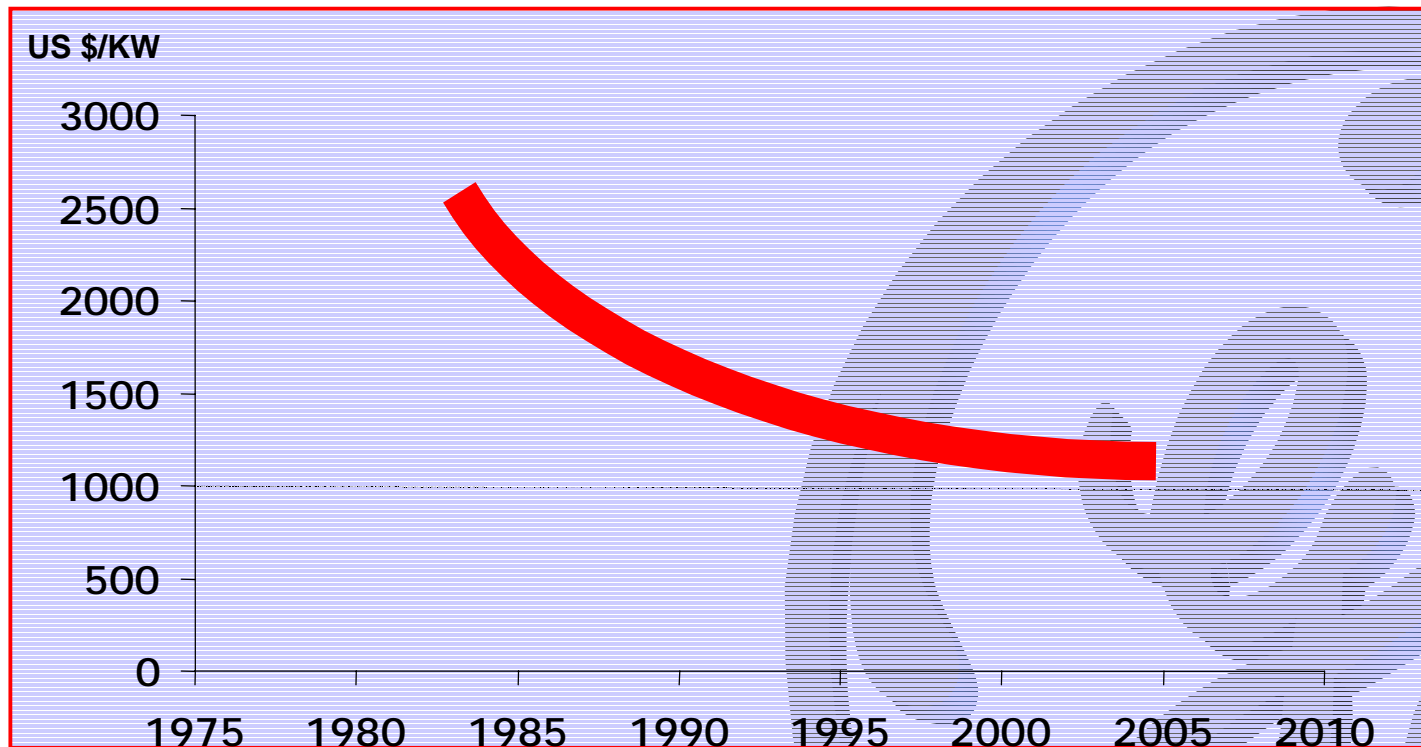
US Natural Gas Prices (Henry Hub)



Cost of Electricity:
**Coal IGCC Beats Natural Gas Combined Cycle when
Natural Gas Prices are Above US\$4.1/MMBTU.**

IGCC Economics

New Power Plant Cost Development



Coal IGCC Currently at US\$ 1050-1250 per kW Installed

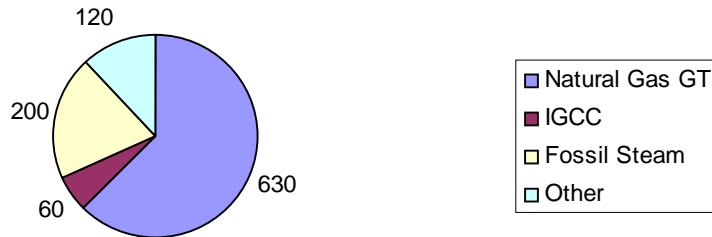
IGCC Economics

IGCC Versus Other Coal Fired Power Plants

g	Power Generation Options						
	Actual 1999	Current 2000			Future 2005		
	PC	PC	IGCC	NGCC	PC	IGCC	NGCC
Nominal Efficiency HHV %	33	40	43	52	44	52	60
SO ₂ Emissions lb/10 ⁶ Btu	1.3	0.05	0.017	---	0.025	0.017	---
NO _x Emissions lb/10 ⁶ Btu	0.5	0.15	0.028	0.028	0.07	0.024	0.024
Particulate Emissions lb/10 ⁶ Btu	0.05	0.01	0.002	---	0.01	0.002	---
Fuel Type Cost - \$/MM Btu	Coal 1.2	Coal 1.2	Coal 1.2	Gas 3.5 - 7.5	Coal 1.1	Coal 1.1	Gas 4.0-7.0
Capital Cost 1999 \$/kW	N/A	1050	1100	550	1000	950	500
Cost of Electricity 1999 ¢/kWh	4.0	3.6	3.5	4.0 - 6.8	3.4	3.2	3.5-6.0

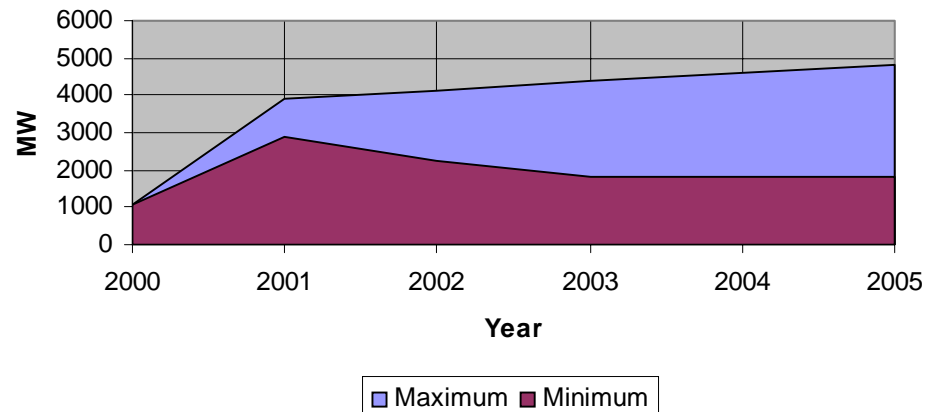
IGCC Projected Energy Market Penetration

10 Year Outlook
New Power Equipment Purchases [GW]



Market Trend:
IGCC will be a significant participant in the near future power market.

IGCC Market Forecast



**IGCC is
currently the
most
competitive
new Power
Plant option in
the US.**

