APPLICATION OF BGL GASIFICATION

OF SOLID HYDROCARBONS FOR

IGCC POWER GENERATION

2000 Gasification Technologies Conference
San Francisco, California
October 8-11, 2000

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ABSTRACT

Since last year's GTC Conference, a considerable number of significant events have occurred in the gasification technology marketplace. New IGCC projects have come on stream with commercial operation, other new IGCC projects have been announced and started in development, environmental issues have gained emphasis, and energy prices, notably natural gas, have escalated dramatically. Directionally, all of these events appear to have created a more favorable atmosphere for IGCC projects.

Related to an ongoing IGCC project currently in development, a joint analysis has been performed by Global Energy, General Electric Power Systems, and Praxair to evaluate technical and economic elements for the performance of BGL Gasification Technology based on solid hydrocarbon fuel feed to an IGCC for power generation.

Results of the analysis provide a picture of the relative economics in today's environment for electrical power generation by conventional natural gas fired combined cycle power systems compared to using BGL Gasification Technology in an IGCC configuration.

INTRODUCTION

Over the last few years there have been a number of new Integrated Gasification Combined Cycle (IGCC) plants placed in operation, under construction, or otherwise in development, representing numerous technologies and fuel applications. Typically, the new IGCC plants have utilized either solid or liquid hydrocarbons as feed, gasification methods including entrained flow, fixed bed or fluid bed technologies, and power blocks utilizing various gas turbine systems and manufacturers.

Global Energy has several commercial IGCC projects under development based on using BGL Gasification Technology to gasify solid hydrocarbons for power production. Coincident with these development efforts, several feasibility studies have been performed related to diverse applications of the BGL Gasification Technology. This paper deals with the application of BGL Gasification Technology fueled with coal and incorporating an Oxygen plant provided by Praxair and a Power Island using 7FA Gas Turbines provided by General Electric Power Systems.

MACRO-ECONOMIC BACKGROUND

The original concept for performing this particular analysis evolved from ongoing technical analyses and business discussions related to several IGCC projects currently in development by Global Energy. The origins of these projects considered site issues and microeconomics of project specifics; additionally Global Energy kept an eye on the fundamental macroeconomic issues that were driving the IGCC industry and furthering its growth.

The interesting event that occurred at the inception of this analysis was the dramatic increase in energy prices this year, notably in prices for electrical power and natural gas. Accordingly, the analysis shifted its focus to consider the position of BGL Gasification Technology in the IGCC industry, the economic status of a commercial BGL based IGCC relative to power from natural gas, and a consideration of other factors of note in the rapidly changing world of energy prices.

BASIS FOR ANALYSIS

For purposes of this analysis, a single design case was developed and analyzed for the BGL Gasification Technology application, essentially considering use of Pittsburgh # 8 coal as the solid hydrocarbon feed to the Gasification Island.

OVERALL IGCC CONFIGURATION

As shown in Attachment C, the overall project configuration includes the Gasification Island, comprised of the BGL gasification units, ASU, and syngas cooling and cleanup units, and the Power Island, which consists of two General Electric 7FA gas turbine generators and HRSGs and one steam turbine, all optimized for firing on syngas, but capable of operation on natural gas. At site design, ambient conditions of 59ºF, 14.28 psia and 60% RH, Gross and Net Electrical Power Output are approximately 586MW and 538MW, respectively, and Net Heat Rate is 8072 BTU/KWh, HHV. Plant capital cost is assumed to be $1000/KW. The plant includes normal offsites, utilities and infrastructure required to support the main operating units.

GASIFICATION ISLAND

As shown in Attachment D, the BGL Gasification process is a fixed bed type gasifier that uses a lock hopper system to admit dry feed to the pressurized reaction vessel. The gasifier units are refractory lined and water jacket cooled. As the feedstock descends it is heated by rising high temperature gases. Moisture and volatile light hydrocarbons leave the coal soon after the feed enters the gasifier unit and exit the gasifier with the syngas stream. Oxygen and steam are injected near the bottom of the unit and react with devolatilized coal to provide thermal energy needed for the formation of syngas components. The high temperature also converts the inert ash content of the coal into vitreous frit or slag.

The vitreous frit is removed from the bottom of the gasifier via a lock hopper and is water quenched, thus capturing the inorganic content of the feedstock as a glassy silica matrix material resembling coarse sand. The vitreous frit is an environmentally benign synthetic aggregate material suitable for use as roadway base, roofing material and seawall construction.

The BGL Gasification IGCC system offers the following features:

- High gasification efficiency (carbon conversion), typically over 92%,
- Use of run-of-the-mine coal or other carbon-based feedstock,
- High thermal efficiency and simple heat exchanger for convenient heat recovery,
- High gasifier throughputs,
- Superior environmental performance, and
- A closed loop system with no primary stack and no ash residue.

The synthesis gas produced in this process is made up primarily of carbon monoxide and hydrogen (more than 85% by volume), and smaller quantities of carbon dioxide and methane.

Hot syngas leaving the top of the gasifier is quenched and purified. Particulates and other impurities are removed in this initial gas processing stage. Heavier oils and tars will condense during cooling, and are returned to the gasifiers for reflux into the hearth zone.

Sulfur compounds in the feedstock are converted mainly to H2S and smaller quantities of COS in the raw syngas. Over 99% of these are removed through acid gas cleanup and sulfur recovery units prior to combustion in the gas turbines, resulting in exceptionally low SO2 emissions. The acid gas cleanup is accomplished using a selective solvent; the sulfur recovery is accomplished with the use of a process unit employing the Claus reaction to generate elemental sulfur. The elemental sulfur in these compounds is a commercially saleable product.

POWER ISLAND

The Power Island is based on a configuration of two trains of dual-fuel General Electric 7FA gas turbines with hydrogen-cooled generators. Each train is coupled to its own Heat Recovery Steam Generator (HRSG), which together will provide superheated steam for a single steam turbine generator. The system enables transfer to natural gas should syngas flow be interrupted. This provides for Power Island availability equal to that of conventional natural gas fired power plants.

Prior to entering the gas turbine combustor, the syngas is saturated with water and is then superheated. Additionally, nitrogen from the ASU is moisturized, superheated, and injected into the turbine combustor, effectively diluting the fuel to reduce NOx emissions. Saturating the syngas and the addition of saturated nitrogen also increases the mass flow to the gas turbine, resulting in increased electrical power generation.

Exhaust gas from each gas turbine is routed to a dedicated HRSG producing superheated steam. This steam is used to power a steam turbine generator and to meet the needs of the Gasification Island and the overall plant.

DESCRIPTION OF ANALYSIS

The analysis was aimed at an assessment of the economic considerations for power generation using solid hydrocarbon feed, specifically Pittsburgh # 8 coal, processed in an IGCC mode, which employed BGL Gasification Technology and General Electric 7FA gas turbines.

The analysis defined a specific IGCC plant configuration as noted, and accordingly, plant capital and operating costs were defined using estimated costs for fuel feed and other required support streams. The cost of electrical power was calculated based on those parameters, and further analyzed by calculating variations of power cost as a function of varied capital costs and gasifier feed costs.

As a parallel evaluation, the analysis also looked at the cost of power generation from natural gas fired combined cycle plants of similar capacity, using varied prices for natural gas. A comparison was made between these two fuel scenarios to allow reflection on potential market opportunities.

RESULTS

The analysis results are presented in detail in the attachments and show that IGCC power generation systems with solid hydrocarbon feeds can be competitive with natural gas fired combined cycle (NGCC) systems. Results show equivalent Cost of Electricity (COE) for IGCC and NGCC Systems at certain natural gas and gasifier feedstock prices. For example, natural gas at about $3.75/MBTU and coal at $1.00/MBTU will both yield a COE of 4.90 cents/KWh. While these electrical power prices are not likely to stimulate consideration of the large capital investment required to build a self-sufficient project financed power plant, rising prices for natural gas clearly make IGCC increasingly attractive as an option for power generation.

An important factor, which has the potential to directly improve today's IGCC economics, is the utilization of the BGL gasifier unit's ability to handle a wide variety of fuel (feedstocks), including Refuse Derived Fuel (RDF). For example, a mixture of coal at $1.00/MBTU and RDF at $0.00/MBTU at a ratio of 50/50 by heat content equated to a gasifier feedstock price of $0.50. This places electricity generated from a BGL based IGCC on par with electricity from a NGCC if the price of natural gas is $3.00, within the range of annual average fuel costs considered reasonable by developers motivated to build an electric power plant.

CONCLUSIONS

Macroeconomic forces have created an atmosphere today where use of gasification to produce power is a real and competitive alternative to natural gas. There are a number of Gasification Technologies that are commercially proven and in a state of readiness to establish new commercial projects based on IGCC concepts using solid hydrocarbon feeds. BGL Gasification Technology is one of those technologies, with its own unique attributes, and potential for further technical and economic enhancements through application of evolving Power Island technology, as well the as use of co-production scenarios, which provide additional impetus to favorable and improved project economics.

The specific results of the analysis performed indicate that:

- If high natural gas prices are sustained, IGCC will be the economic preference over NGCC in more future power generation projects; and

- Even if natural gas prices level off or decline slightly, the application of BGL gasification using a composite feedstock of coal and RDF will improve IGCC economics and make it

the technology of choice in more future power generation projects.

Furthermore, the following prospects have the potential to further improve IGCC economics:

- GE Power Systems technology developments such as the 7H and 9H Systems^{TM}, rated in IGCC at 460 MW and 550 MW respectively, will further improve IGCC economics. The real cost of oxygen has historically dropped about 3% per year. Praxair's process, equipment, and systems development activities expect to provide similar improvements in the future.

- The co-production of materials such as hydrogen, methanol, ammonia, steam, plus Fischer-Tropsch generated liquid transportation fuel products will improve economics.

- Ongoing developments by Global Energy are also expected to contribute to further economic enhancements for IGCC projects. The know-how derived from these activities is expected to provide significant benefits to current and future BGL projects. There are three IGCC projects publicly announced by Global Energy in various stages of project development, each based on using BGL Gasification Technology in an IGCC scenario. Global Energy is also in the process of acquiring Berlinwasser's gasification co-production facility Sekundärrohstoff Verwertungszentrum Schwarze Pumpe GmbH (SVZ) Recycling Project in Schwarze Pumpe, Germany, as well as the right, title and interest in SVZ's proprietary gasification technology, including its gasification-related patents. The facilities also include a new BGL gasifier, further enhancing Global's knowledge of the BGL Gasification Technology.

A collective view of all of these ongoing events suggest that further significant improvements for IGCC economics are likely to occur, and that use of BGL Gasification Technology for IGCC projects can provide notable economic benefits to this rapidly growing market.

SUPPORTING CONTRIBUTORS TO PAPER

The companies supporting the analysis efforts include Global Energy, General Electric Power Systems, and Praxair. Each organization has significant involvement and presence in the rapidly growing IGCC industry as follows:

Global Energy

Global Energy Inc. is an international independent energy company with expertise in Gasification Technology, Alternative Fuels and Environmental Technology. The company is a founding member of the Washington, D.C.-based Gasification Technologies Council, together with General Electric, Texaco and 11 world-class companies. Global Energy is focused on Gasification Technology projects designed to improve environmental and economic results for the power, refining, chemical, steel, fuel cell, and pulp and paper industries. The company has

more than 5,000 MW of project activity in development, construction and operation in the Americas and Europe, with business development interests worldwide. The company is well aligned with the U.S. DOE's Vision 21 plan for Multi-fuel, Gasification Technology, Co-production systems.

General Electric Power Systems

GE Power Systems is one of the world's leading suppliers of power generation technology, energy services and management systems, with year 2000 revenue estimated at $14.5 billion. The business has the largest installed base of power generation equipment in the global energy business. GE Power Systems provides turnkey equipment, service and management solutions across the power generation, oil and gas, distributed power and energy rental industries.

Praxair

Praxair is a technology pioneer and global leader in the industrial gases industry. The company is the largest industrial gases company in North and South America, and one of the largest worldwide. Praxair is also a recognized leader in the commercialization of new technologies that bring productivity and environmental benefits to a diverse group of industries.

SUPPORTING BACKGROUND REFERENCES

U.S. Department of Energy, "Clean Coal Technology - The Investment Pays Off", November 1999.

U.S. Department of Energy, "Clean Coal Technology Demonstration Program Project Fact Sheets", June 1999.

General Electric Power Systems, "Integrated Gasification Combined Cycle Gas Turbine Technology", 1999.

DePuy, et al., "From Coal or Oil to 550 MWe via 9H IGCC", Gasification Technology Conference, October 1999.

U.K. Department of Trade and Industry, "Gasification of Solid and Liquid Fuels for Power Generation - Technology Status Report", December 1998.

U.S. Department of Energy, "Vision 21 - Clean Energy for the 21st Century", November 1998.

U.S. Department of Energy, "Focus - Energy Solutions for the 21st Century", September 1998.

U.K. Department of Enterprise, Coal R&D Report, "Integrated Gasification Combined Cycle Technology in the U.K. - Analysis of 300 MWe IGCC Power Plant", November 1992.

Bellinger, et al., "Clean Power - The BGL Gasifier", June 1987.

Scott, et al., "Application of the British Gas/Lurgi Slagging Gasifier for Combined Cycle Power Generation", International Consulting Service - British Gas plc, November 1985.

ATTACHMENTS

A. Energy Information Agency (EIA) – US Gas and Oil Prices

B. Energy Information Agency (EIA) – Fossil Fuel Prices to Electric Utilities

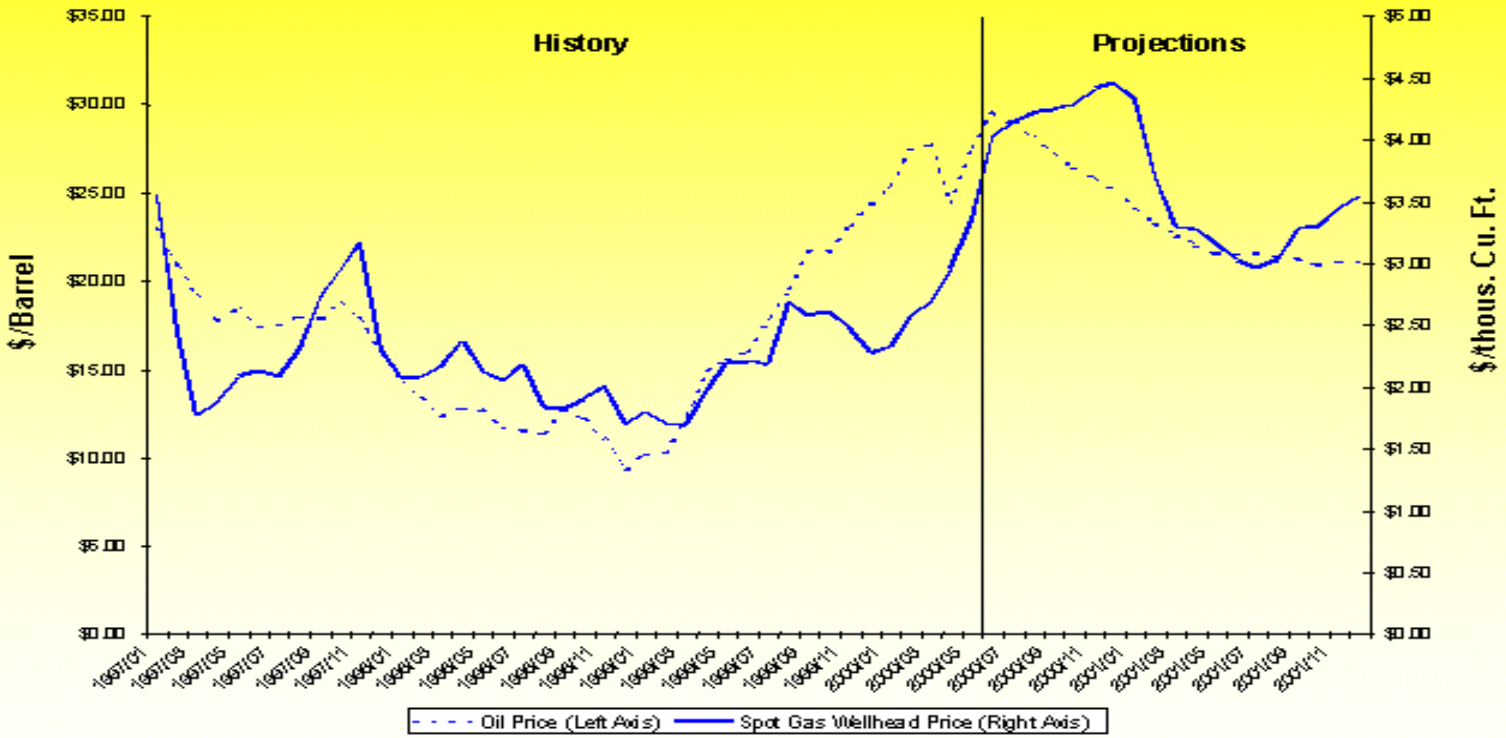
C. BGL IGCC Process Diagram

D. Schematic Diagram of BGL Gasifier

E. Basic Analysis Assumptions

F. 20 year Levelized Cost of Electricity (COE) vs. Fuel Price

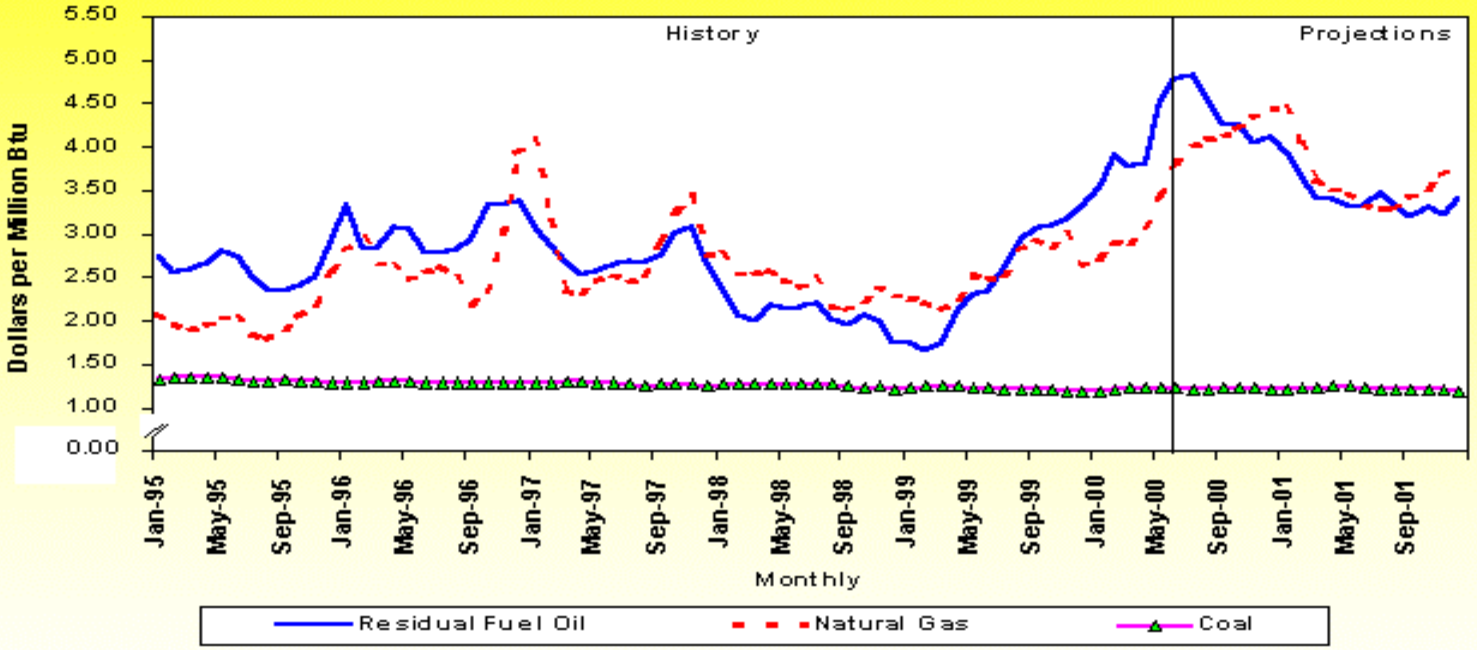
U.S. Gas and Oil Prices



Sources: History: EIA; Projections: Short-Term Energy Outlook, July 2000.

www.eia.doe.gov

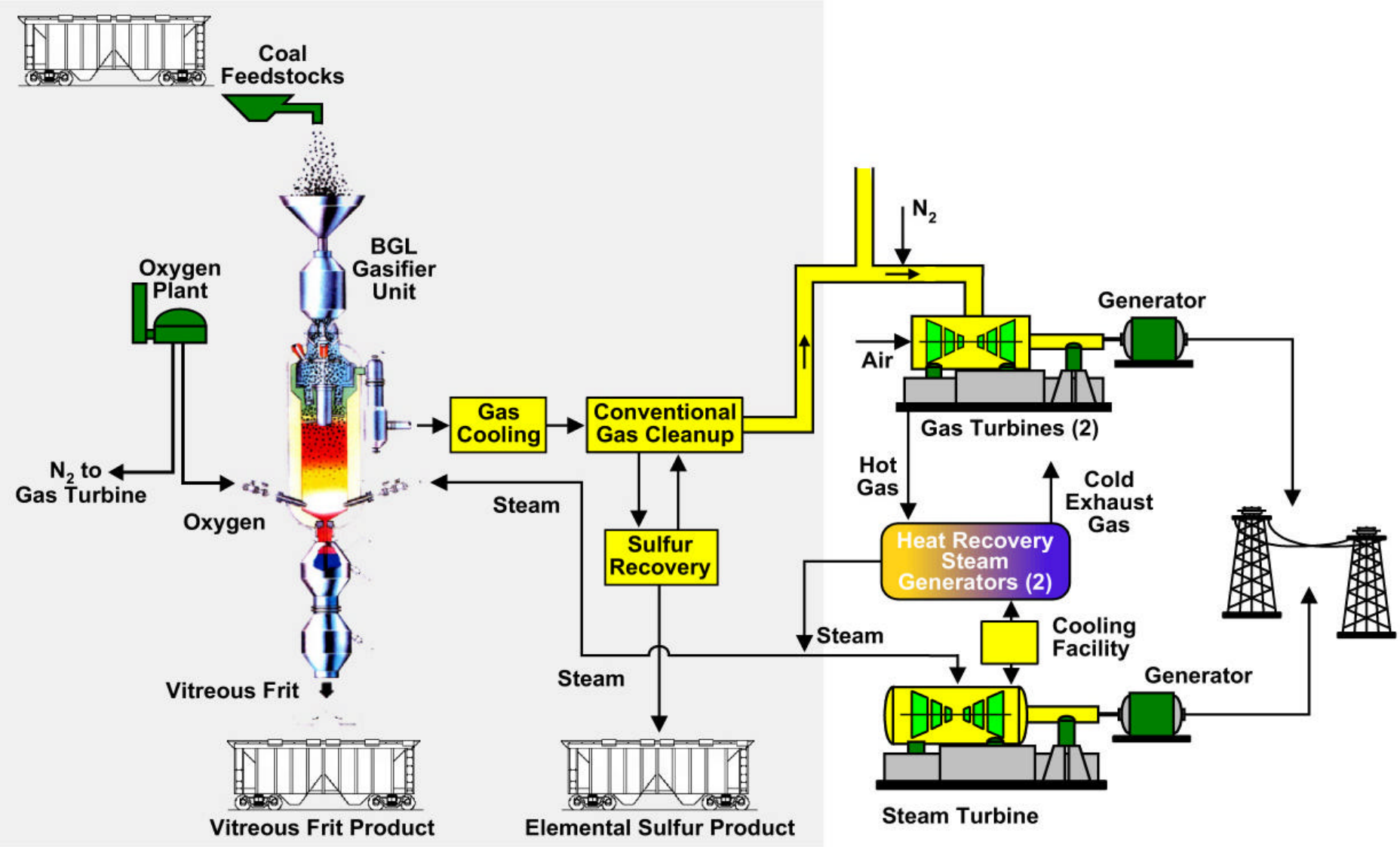
Fossil Fuel Prices to Electric Utilities

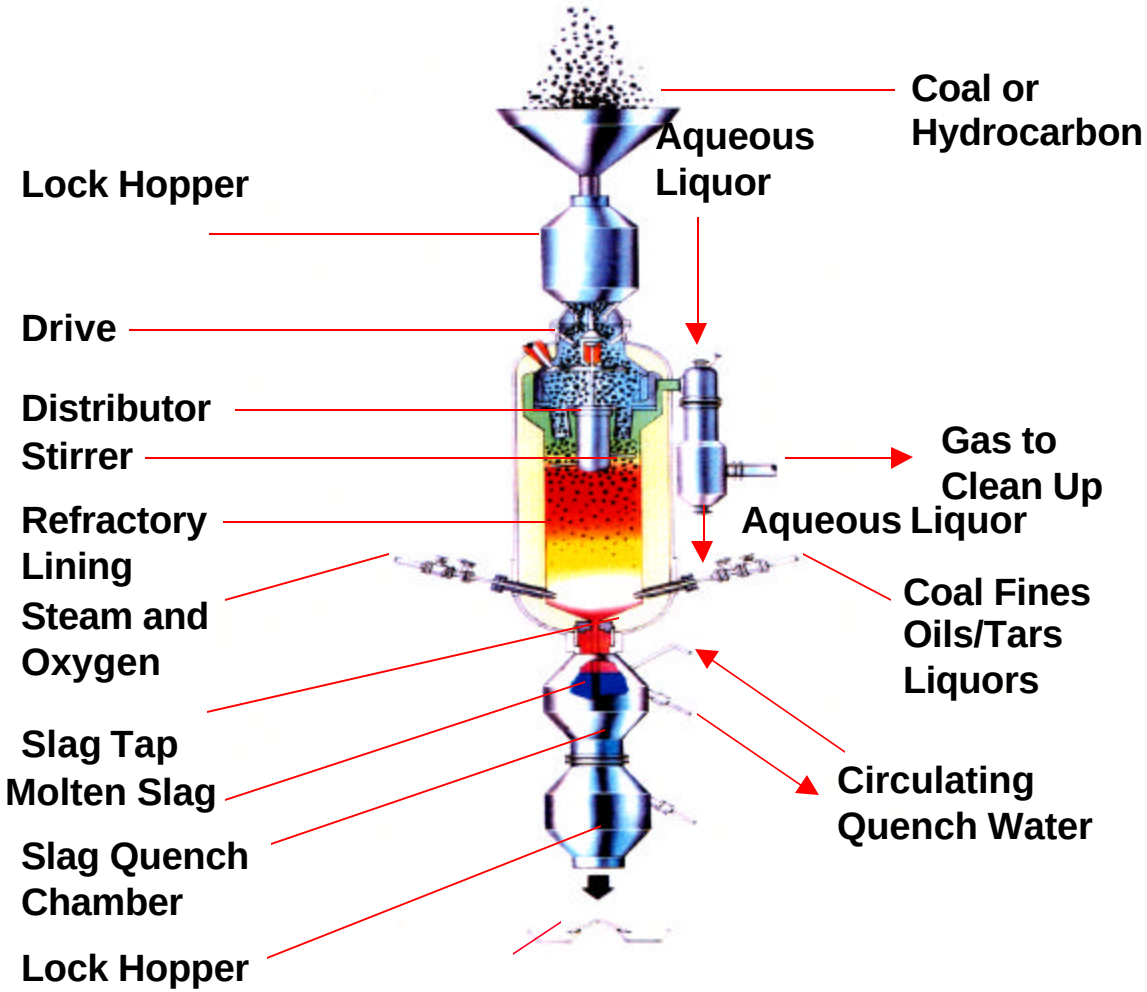


Sources: History: EIA; Projections: Short-Term Energy Outlook, July 2000.

www.eia.doe.gov

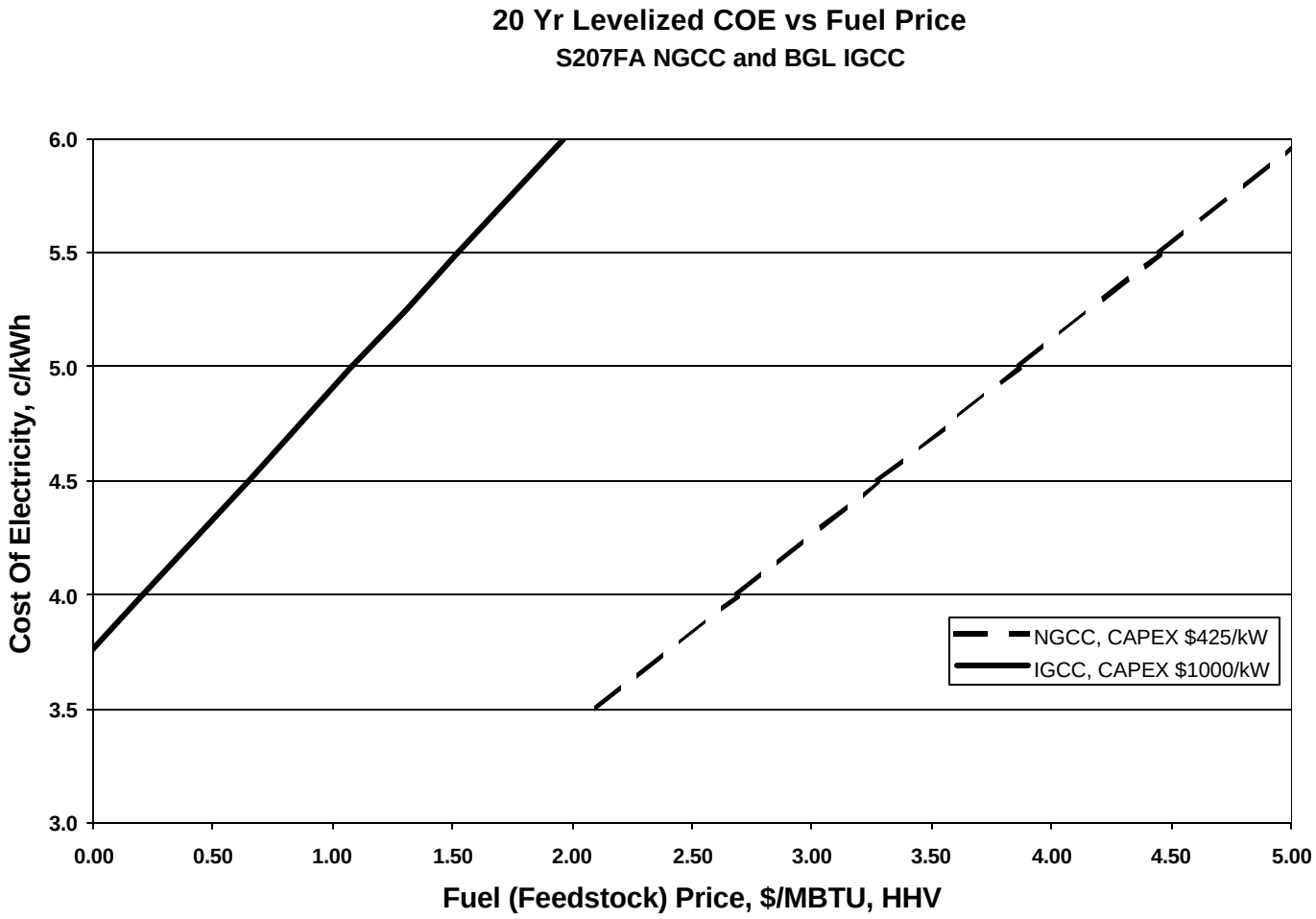
Global Energy BGL Gasification Technology IGCC Process Diagram




Coal or
Hydrocarbon
Aqueous
Liquor
Lock Hopper
Drive
Distributor
Stirrer
Gas to
Clean Up
Refractory
Lining
Aqueous Liquor
Steam and
Oxygen
Coal Fines
Oils/Tars
Liquors
Slag Tap
Molten Slag
Circulating
Quench Water
Slag Quench
Chamber
Lock Hopper

Basic Analysis Assumptions:

- US Gulf Coast Equipment and Installation Costs
- Site ambient conditions: 59F, 14.28psia, 60%RH
- Economic evaluation term: 20 years
- Fixed charge rate: 18%
- Discount rate: 10%
- Escalation: 3.5%
- Construction interest and owners costs: 20% of turnkey capital cost
- Capacity Factor: 91.3%


20 Yr Levelized COE vs Fuel Price
S207FA NGCC and BGL IGCC
Cost Of Electricity, c/kWh
6.0
5.5
5.0
4.5
4.0
3.5
3.0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
Fuel (Feedstock) Price, $/MBTU, HHV
NGCC, CAPEX $425/kW
IGCC, CAPEX $1000/kW