5. U.S. Electric Utility Perspective of IGCC Technology

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Introduction

Integrated Gasification Combined Cycle (IGCC) technology has become a reality in the U.S. for power generation. With one unit in operation, and two more in the final phases of construction, there will soon be over 600 MW of IGCC at a commercial scale. This paper looks at IGCC from the perspective of a utility company in the U.S. Subjects covered in this paper are: 1) efficiency benefits, 2) emission reductions, 3) fuel flexibility, 4) by-products, 5) repowering, and 6) new unit additions. A description of Tampa Electric Company's Polk Power Station IGCC Project is also covered.

Technology

During the 1960-1970 high-growth period in the U.S., the amount of installed capacity doubled from 190,000 MW to almost 400,000 MW. The prevalent choice for power generation was large pulverized coal-fired steam generating units, with sizes up to 1,000 MW. With these large units, the electric utility industry realized its most efficient power generation year during 1968. During the period 1970-1984, much more capacity was installed, almost doubling again. During that period of time, the electric utility industry was made subject to an ever-increasing number of environmental laws and regulations, covering emissions of air, water, and solid waste. The addition of flue gas desulfurization systems and electrostatic precipitators for fly ash removal caused significant decreases to generation efficiency. Using coal and meeting stricter environmental standards became more costly and difficult.

Combustion turbine technology has been available to electric utilities for many years. Since they were primarily used for peaking power needs, the low efficiency and high fuel cost were not a big concern. Recent developments from the aircraft engine industry have highlighted fuel diversity and efficiency. Many new installations are taking advantage of 150-200 MW (at 60 Hz) combustion turbines with efficiencies of 40 percent in simple cycle operation, and well over 50 percent in the combined cycle mode. Many of the newest power generation installations in the U.S. have utilized natural gas-fired combustion turbines in the combined cycle mode. With low gas prices, combustion turbines have become the technology of choice for most new installations.

Gasification technology has been available for many years in the chemical industry, but is very new to the electric utility industry. During the 1970's and 1980's, the U.S. faced oil supply crises, and the government and industry realized that the growing dependence on foreign oil was a strategic disadvantage for the U.S. Research expanded quickly into technologies that could utilize the vast coal resources in the U.S. The ability to convert low cost coal into a clean gas and then burn it in an efficient combustion turbine/combined cycle was seen to have significant potential for solving energy strategy concerns.

During the late 1980's, the Cool Water Gasification Project became the first IGCC unit in the U.S. Its purpose was to demonstrate the integration of coal gasification technology with the increasingly efficient combined cycle technology. Several years of testing proved that IGCC was technically successful, and that it was available for commercial development for large power generation projects. With decreasing coal prices, and increasing prices for natural gas, utilities began to seriously evaluate IGCC. The Department of Energy's Clean Coal Technology Program gave IGCC its entrance at the large, commercial scale.

Efficiency Benefits

Even with the use of supercritical pressure operation, and improvements to steam turbines, the large, pulverized coal units still can only reach about 40 percent efficiency. Through the use of the very efficient combustion turbine technology, IGCC now offers efficiencies greater than 40 percent, with 45 percent expected in the next few years. The average heat rate for U.S. steam electric generating units is 10,568 Btu/kWh. The IGCC projects being developed under the Clean Coal Technology Program have design heat rates in the range of 8,500-9,000 Btu/kWh. Therefore, IGCC can offer 10-20 percent greater overall efficiency than other commercially available technologies. In a business environment that is becoming more competitive, greater efficiency and lower fuel costs can provide many benefits to an electric utility facing increasing gas prices and an aging fleet of generating units.

Emission Reductions

The Clean Air Act Amendments of 1990 require major reductions by utilities of SO_2 and NO_x. These reductions will total about 10 million tons of SO_2 and 2 million tons of No_x. The reductions will be accomplished in two phases. Phase I began in 1995, when reductions were required at 110 power plants. For the most part, these were the largest units in the country, burning high sulfur coals. Most of these units were able to comply with the reduction requirements by switching to low sulfur coals. Others installed flue gas desulfurization (FGD) systems.

Phase II will begin in 2000, and will affect essentially all of the utility generating units in the U.S. The sulfur reduction requirements are even greater than in Phase I and will require major changes to either fuel type or the addition of very efficient FGD. However, there will be many older units where FGD will not be cost effective for a short remaining life. The acid gas removal systems used in IGCC recover sulfur compounds more efficiently than the limestone based flue gas desulfurization systems commonly used on coal-fired units. Research and development on zinc-based hot gas cleanup technology may provide hydrogen sulfide removal approaching 99 percent. IGCC technology provides the additional benefit of allowing a utility to continue to use low cost high sulfur coal, while achieving very high sulfur removal efficiency. This will allow utilities that are considering retirement of an older unit to repower it with the same or higher output, and comply with the Clean Air Act Amendments.

The IGCC process is also inherently low in NO_x emissions. Due to the burner enhancements being made on combustion turbines, NO_x emissions below 10 ppm are available with natural gas firing. Development of combustors to burn syngas with these low levels is proceeding quickly. NO_x control with IGCC is very effective when using nitrogen injection from the air separation plant. Nitrogen injection cools the flame, reducing NO_x formation, so that downstream removal technologies such as selective catalytic reduction (SCR) are not needed. This allows for low cost compliance with NO_x regulations.

Table 1 shows the emissions of SO_2 and NO_x for several different power plants. It presents these emissions in pounds per megawatt-hour generated. This index is more accurate than using pounds per million Btu of heat input, since it takes into account the inherent efficiency of the IGCC unit. The units described are the Wabash River unit before and after the repowering, the Indiantown fluid bed combustion unit, the conventional coal-fired Orlando Utilities unit, Polk Power Station(IGCC), and the DEMKOLEC IGCC unit in the Netherlands. The DEMKOLEC unit has very low emissions of SO_2 since it burns low sulfur coal. As the reader can see, IGCC can provide an efficient and effective method for meeting compliance on new or repowered units.

Tablee 1. Emissions per MWh

	lbs. SO_2	lbs. NO_x
Wabash River Unit #1 Coal	32.4	7.9
Wabash River Unit #1 IGCC	2.3	0.8
Indiantown FBC	1.76	1.76
Orlando Utilities Station Unit #2 Coal	1.58	1.58
Polk Power Station Unit #1 IGCC	1.49	0.87
DEMKOLEC IGCC	0.48	1.36

Fuel Flexibility

As Table 2 shows, the gasification process brings significant fuel flexibility to the utility industry. In addition to the conventional fuels that utilities use (coal and oil), a wide range of "feedstocks" can be used to generate power from this chemical process. With fuel being the largest single cost of producing electricity, every utility must find ways to lower fuel cost. This is becoming more important as competition increases in the electric utility industry.

Tablee 2. Fuel Flexibility

- High sulfur coal
- Low sulfur coal
- Petroleum coke
- Blends
- Waste Fuels
- Heavy Oil

In order to comply with the Clean Air Act Amendments of 1990, many utilities have switched to eastern low sulfur coal. In many cases, that low sulfur coal costs more than the higher sulfur coal. However, the increasing use of inexpensive western Powder River Basin coal has caused a significant drop in the cost of compliance. Utilities have opened up their markets to many types of coals, including those from foreign countries. The Phase II requirements will cause utilities to look more seriously at SO_2 removal technologies, since coal sulfur content may not be low enough to assure compliance.

By repowering or retrofitting with IGCC, the utility can open up its fuel market to low quality, yet high carbon content, fuels. These include low volatile coals, petroleum coke, waste fuels, heavy oils, and numerous blends of all of these fuels. Since the gasification process simply requires a carbonaceous feedstock, the utility can now look at fuels that it could never before consider due to the narrower design fuel range of a coal-fired boiler. IGCC can provide both environmental compliance and lower fuel cost.

By-Products

A conventional coal-fired unit produces one or more of the following combustion by-products: fly ash, bottom ash, slag, flue gas desulfurization sludge, and flue gas desulfurization by-product gypsum. Many utility companies sell these by-products for re-use in industry. Where there is no market for these by-products, the utility is left with several hundred thousand tons of solid waste to dispose of each year at great expense. Large tracts of land must be dedicated to disposal. In the case of new units, or existing units where the addition of FGD is planned for compliance purposes, these large amounts of solid waste can lead to community opposition. The ability to produce saleable by-products is becoming more important to utilities and the communities close to the power plants. IGCC can produce saleable slag, sulfur, and sulfuric acid, all of which have well developed international markets. This can solve both the cost and community concerns.

Repowering

A large percentage of the generating capacity in the U.S. is over 30 years old, the common design life basis during the 1960's. Through some life extension efforts, there are many units approaching 50 years of operation. Many utilities are now facing difficult decisions on whether or not to continue life extension projects, with the addition of expensive SO_2 and NO_x controls, or retire the older units. With the difficulty of finding and obtaining environmental permits for new sites, repowering has become an important option for these older units.

For example, Public Service of Indiana's Wabash River Unit #1 went into operation in 1953. That coal-fired unit was sized at about 100 MW. By repowering with IGCC, under the Clean Coal Technology Program, the new Unit #1 will have a net output of 262 MW. That utility was able to increase its generating capacity without the expense of a new site, and with only a minimal environmental permit process.

Repowering with IGCC offers the benefits of greater efficiency, higher output, and extended life, all at low incremental cost. This option will become even more important as the U.S. utility industry becomes more competitive, units continue to age, and more stringent environmental laws are passed.

New Units

As the population of the U.S. continues to grow, the need for additional capacity will grow with it. Utilities will continue to need new capacity. With the problems inherent with new sites, environmental impacts, and other community concerns, the siting and permit process can add many years and considerable cost to the generation expansion project. Given all of the benefits previously noted, such as efficiency, low emissions, low cost fuel, saleable by-products and superior environmental performance, IGCC is a technology of choice for new generation. Partly due to the higher efficiency, the IGCC process uses less water for cooling and other purposes than a conventional coal-fired boiler.

The regulatory agencies are becoming more aware of the merits of IGCC, and are better able to evaluate it along with other potential technologies. A main selling point is the low emissions in pounds per megawatt-hour generated, compared to other technologies. Future potential controls on air toxics, such as mercury, will provide even more needs for IGCC, since much, if not all, of the mercury is tied up in the slag that exits the gasification process.

Tampa Electric Company Polk Power Station

The Site

Tampa Electric Company (TEC) is an investor-owned electric utility, headquartered in Tampa, Florida. It is the principal subsidiary of TECO Energy, Inc., an energy related company involved in coal mining, transportation, and utilization for power generation. TEC has 3,415 MW of generating capacity. About 97 percent of the generation is from coal-fired units. TEC serves about 500,000 customers in and around Tampa, Florida.

Florida is a fast growing area of the U.S. In its generation expansion planning process, TEC evaluated many different processes and fuels sources. During that period of time, the Department of Energy's (DOE) Clean Coal Technology Program was trying to find a site for an oxygen-blown IGCC plant. TEC and DOE reached an agreement whereby DOE is funding 20-25 percent of the cost of TEC's new generating plant, called Polk Power Station Unit #1.

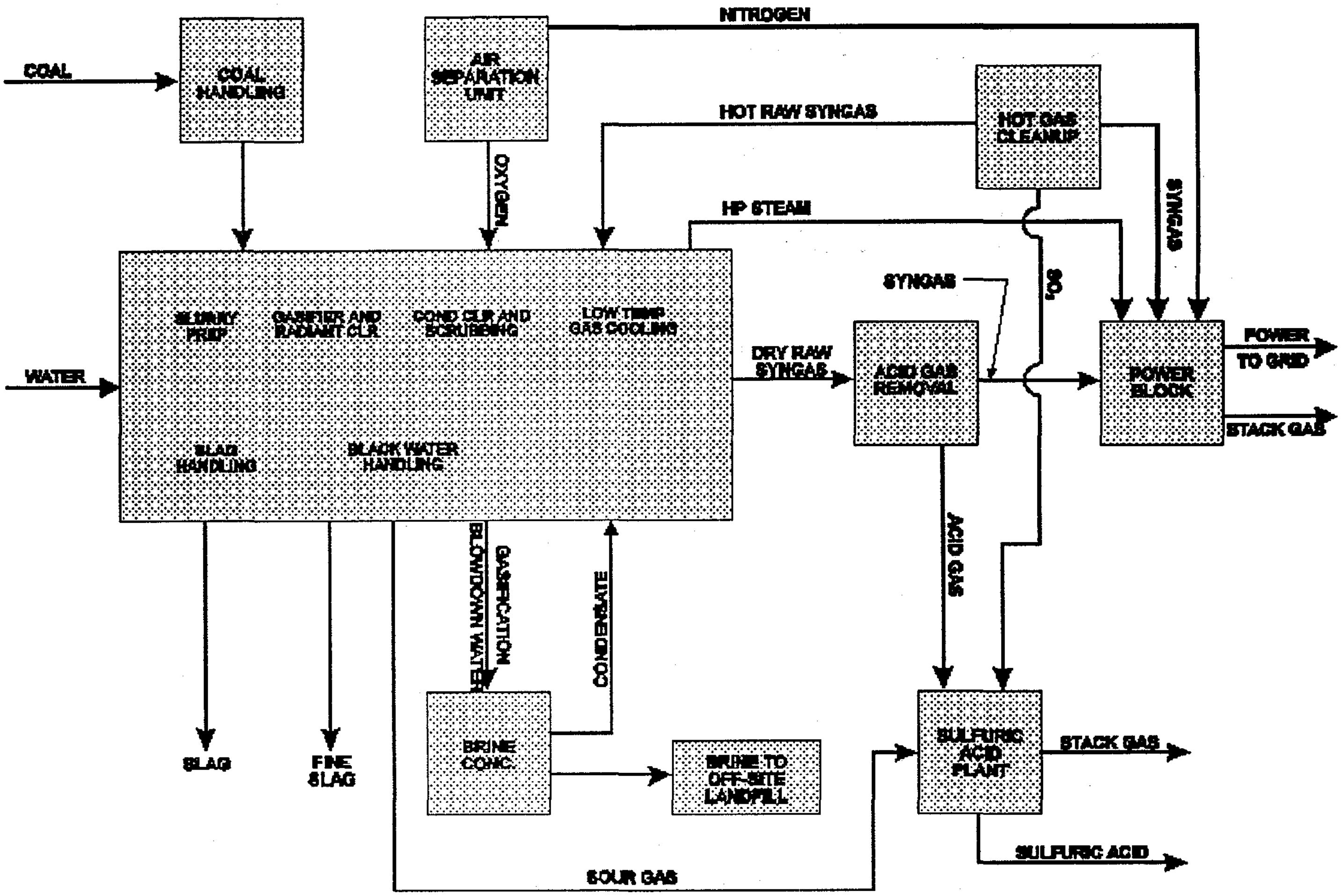
The Polk Power Station is being constructed on an inland site in Polk County, Florida. The site was previously mined for phosphate and is being reclaimed as a part of the plant site development. The site was selected by an independent Community Siting Task Force, commissioned by TEC to locate a site for future generating units.

The seventeen person group included environmentalists, educators, economists, business people, and community leaders. The study, which began in 1989, considered thirty-five sites in six counties. The Task Force recommended three tracts of land in southwestern Polk County that had been previously mined for phosphate. These sites had the best overall environment and economic ratings from the Task Force. The total area for the site is 4300 acres (17.4 square kilometers). About one-third of the site will be used for the generating facilities. TEC is responsible for site development. As part of this overall plan, the existing mining cuts have been modified and used to form an 850 acre (3.4 square kilometer) cooling reservoir.

Gasification Technology and Process

The unit will utilize Texaco's oxygen-blown, entrained-flow gasification technology. A general process flow diagram is shown in Figure 1. Coal will be ground and slurried in rod mills to 60-70 percent solids. The unit is designed to process about 2,000 tons coal per day. The coal slurry and oxygen (from the air separation plant) will be mixed in the gasifier. The coal slurry will be partially oxidized at a temperature in excess of 2,500°F (1,370°C). This will produce syngas at about 250 Btu/scf (LHV). The syngas will exit the gasifier and enter a radiant syngas cooler, where the syngas will be cooled to about 1,300°F (700°C). The radiant syngas cooler will produce high pressure steam at 1,600 psia (110 bar), which will power the steam turbine. From the radiant syngas cooler, two 50 percent streams will enter convective syngas coolers, which will also produce high pressure steam. After those coolers, the syngas will enter gas/gas exchangers that will be used to heat up nitrogen gas and clean syngas, prior to their going to the combustion turbine. The slag formed in the gasifier will be collected at the bottom of the radiant syngas cooler, and then sold to local industry. The cooled syngas will then enter the acid gas removal system, where over 95 percent of the sulfur compounds will be removed. The conventional cold gas cleanup (CGCU) system will use MDEA as the absorbent. The concentrated hydrogen sulfide stream will go to a sulfuric acid plant.

Figure 1. PPS-1 Block Flow Diagram



The air separation plant will use ambient air to produce oxygen for use in the gasifier and nitrogen for the combustion turbine and for ash removal in the radiant syngas cooler. This plant is sized to produce about 2,100 tons oxygen per day, and 6,300 tons nitrogen per day.

As a part of the demonstration project with DOE, the IGCC unit will test a hot gas cleanup (HGCU) system. This will be sized to treat about 10-15 percent of the syngas, and provide sulfur removal using metal oxide (zinc or zinc oxide base) pellets at about 900°F (480°C). In CGCU, the gas must be cooled, cleaned, then re-heated prior to entry to the combustion turbine. The potential advantage with HGCU is that it avoids the irreversible thermodynamic losses of the

CGCU. The HGCU system will also test chloride removal using sodium bicarbonate, and downstream ash removal using a barrier filter.

Combined Cycle Process

The key components of this part of the plant are the combustion turbine, heat recovery steam generator, and the steam turbine. The combustion turbine is a GE 7F. At full load, it will produce 192 MW with syngas and nitrogen injection. The steam turbine is a double flow reheat turbine with low pressure crossover extraction. The unit is designed for highly efficient combined cycle operation with nominal turbine inlet throttle conditions of 1,450 psia (100 bar) and 1,000°F (540°C) and 1,000°F (540°C) reheat temperature. Under normal operation, the combustion turbine will start up on diesel oil, and then transfer to syngas and nitrogen at a higher load.

By-Products

The concentrated hydrogen sulfide from CGCU, and the concentrated SO_2 from the HGCU will flow to the sulfuric acid plant for final treatment. The sulfuric acid plant will produce up to 210 tons of 98 percent sulfuric acid per day. This will be sold to the local phosphate industry, where it will be used in making phosphate fertilizer.

The slag from the gasifier and radiant cooler will be sold to local industry. Slag from TEC's existing coal-fired units has been sold for almost 30 years. It is used in sand blasting grit (for surface preparation prior to painting), roofing tiles, and asphalt filler for paving roads.

The chlorides from the coal will be recovered as ammonium chloride in a brine concentration system. This by-product is expected to be used in the galvanizing industry. Therefore, all of the by-products from this IGCC plant will be sold and used commercially. This will show another one of the benefits of the IGCC process.

Schedule

Construction was completed in early July, and the gasifier was fired with coal slurry for the first time on July 19. Unit shakedown occurred during August and September. As of the first part of October, several hundred hours of gasification operation have been accomplished. Performance testing is scheduled for the balance of October, followed by commercial operation of the unit.

V. CONCLUSIONS AND RECOMMENDATIONS

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The conclusions that can be drawn from this report regarding the potential for IGCC in China are positive and supportive for its demonstration and commercial use in China in the long term. China needs economic growth, electric power plants, coal resource development, and environmental protection controls. At the economic growth rates demonstrated in the past ten years, China needs 15-18 GW per year of new generating capacity for the next 20 to 50 years. Coal is China's primary energy resource to be used as fuel for electric power generation. The annual production of raw coal in China is over 1.2 billion tons. Coal accounts for over 80 percent of China's total energy requirements and over 70 percent of the fuel used for electric power generation in China. Chinese industrial sectors also depend upon coal as an energy source and raw materials for the production of chemicals. To maintain a clean environment China needs to control emissions of SO_2, NO_x solid and liquid wastes resulting from the burning of coal which requires more efficient and high performance coal conversion technologies that have low water consumption. The market for high efficiency and clean coal utilization IGCC technology is clearly shown in China's 9th five year plan which states "the development of clean coal technology should be suited to the transition of the state macro development strategy". IGCC utilization for the production of electric power beyond the year 2000 is also supported by "China's 21st Century Agenda" which clearly defines the Chinese development route to be changed from the traditional development mode to the sustainable mode for the high efficiency utilization of its coal resources.

IGCC is the most clean, most efficient and most mature technology among currently available clean coal power generation technologies. It is also a more environmentally friendly technology than any other coal-based power generation technologies and contributes to the reduction of global emissions and improvement of air quality. China needs this IGCC clean coal technology to support its growing economy and will profit from the U.S. experience gained from the U.S.

Department of Energy (DOE) Clean Coal Technology Program (CCT). The DOE CCT Demonstration Program IGCC projects are in various stages of completion and demonstration at the intermediate utility scale (250MW). The CCT Wabash River IGCC Repowering Project (250 MW) has reached the stage of commercial operation in the production of electricity, and the CCT Tampa Electric IGCC (250MW) project has also reached a stage of commercial operation. The results of a China demonstration of a large scale IGCC technology for power production will assist in proving technology reliability, availability, and maintainability at the larger utility scale and will encourage the use of more efficient CCT technologies in China. The demonstration will also assist in the commercial acceptance of IGCC technology as a high efficiency and environmentally friendly approach for producing power from coal to be used in global utility power plant applications. Demonstration of this high efficiency and non-polluting coal based technology is required at utility sizes greater than 250MW to prove technology scale-up and reliability at the utility scale.

Based upon the favorable results of the U.S. CCT Program, China believes that IGCC is now mature, reliable, flexible and suitable for a variety of coals that can be found in China. Many Chinese coals have been tested and used in gasifiers manufactured in China. A large scale demonstration of IGCC is needed to assure commercial readiness of this technology in China. This approach will allow China to obtain first hand know-how and experience from operating the China IGCC demonstration plant. China already has extensive experience in coal gasification from the chemical industry where 80% of China's chemical production is based on coal. China also has experience with combined cycle power plant operation from projects supported by the Ministry of Electric Power. A recent proposal to build an IGCC plant with refinery residue oil as feed provides a step closer to the IGCC plan for commercialization with coal as feed.

Based upon the U.S. IGCC demonstration experience, the risks for the China IGCC demonstration project will be greatly reduced. Use of equipment made in China will also reduce power plant capital and investment costs compared to U.S. IGCC demonstration plant costs, since the U.S. costs for non-proprietary equipment and systems are significantly higher than similar equipment and associated plant costs in China. Current levels of plant costs, fuel costs, and environmental regulations, which affect overall project costs for large field-constructed power plants, vary within regions and in different countries. In addition, plant costs are also affected by local labor productivity, cost of labor, manufacturing, and costs of components. Systems that can be produced locally in China will be greatly reduced in cost, compared to foreign imports, as will the costs of construction which must be performed by Chinese. Therefore, IGCC plant costs in China can be significantly further reduced based on technology demonstration and associated operating experience gained from the performance of the China demonstration project.

China offers a unique opportunity for additional demonstration of the IGCC technology in larger scales which will improve the reliability, availability and maintainability of the use of this technology in commercial applications in China, the U.S. and in other countries. The adoption for the more efficient and environmentally friendly IGCC technology has a much better opportunity in the Chinese market place where economic growth is the driving factor. In addition, fuel is the largest single cost of producing electricity and electric power generation projects must find ways to lower the cost of fuel over the life of the power plant by using more efficient technology such as IGCC which will provide a 20% margin in efficiency over conventional technology.

The only way China will confirm economic and technical performance of IGCC technology compared to other options will be through the construction and operation of a 200 – 400 MW project. IGCC technology was not given serious consideration in the U.S. and Europe until the clean coal technologies were demonstration to be competitive with natural gas. Through the experience of this project China will incur actual capital and operating costs that will provide useful information for improving the economics of future projects. This focused U.S./Chinese effort to demonstrate IGCC in China will set an example for potential future collaborative efforts in identifying and addressing the world wide need for highly efficient and environmentally friendly technologies such as IGCC.

VI. ACRONYMS AND DEFINITIONS

APPENDIX 1. ACRONYMS AND DEFINITIONS

BFBB	bubbling fluidized-bed boiler
BOT	Build-Operate-Transfer (basis)
Btu	British thermal unit
CAS	Chinese Academy of Sciences
CCT	Clean Coal Technology
CFB	circulating fluidized bed
CGCU	cold (low-temperature) gas cleanup unit
CO_2	carbon dioxide
COE	cost of electricity
DOE	Department of Energy (USA)
EFCC	externally-fired combined-cycle
EU	European Union
FC	fuel cell
FGD	flue gas desulfurization
G	giga - billion - (10^9)
gce/kWh	gram standard coal equivalent/kilowatt-hour
Gtce	giga (billion - 10^9) tons standard coal equivalent
GW	giga - billion - (10^9) Watts
ha	hectare
HGCU	hot gas cleanup unit
HHV	higher heating value
HRSG	heat recovery steam generator
Hz	Hertz – cycles per second
IGCC	integrated gasification combined-cycle
IGFC-CC	integrated gasification fuel cell combined-cycle
IGHAT	integrated gasification humid air turbine
kgce	kilo (thousand - 10^3) grams standard coal equivalent
kha	thousand (10^3) hectares
kt	kilo (10^3) tons
kWh	kilowatt-hours
LEAP	Long-range Energy Alternatives Planning
LGTI	Louisiana Gasification Technology Incorporated
LHV	lower heating value

MCI	Minestry of Coal Industry
MDEA	methyl diethanolamine
MEP	Minestry of Electric Power
MF-T	modified Fischer-Tropsch synthesis
Mha	million (10^6) hectares
MMI	Ministry of Machinery Industry
Mpa	mega (million - 10^6) Pascals
MRF	multistage rotary furnace
Mt	million (10^6) tons
Mtce	million tons standard coal equivalent
MW	mega (10^6) Watts
NGCC	natural gas (fired) combined-cycle
Nm^3	normal cubic meter
No_x	oxides of nitrogen
PC	pulverized coal (firing)
PC-SC	pulverized coal (fired) supercritical boiler
PDP	process design package
PEO	primary energy output
PFBC	pressurized fluidized-bed combustion
PFBC-CC	pressurized fluidized-bed combustor combined-cycle
ppm	parts per million
PRC	People's Republic of China
psia	pounds per square inch, absolute
quad	quadrillion (10^{12}) Btu
R&D	research and development
RMB	(phonetically – Ren Min Be) PRC People's Currency
ROM	run-of-mine
RSA	Republic of South Africa
SASOL	Suid Afrikaanse Steenkool, Olie en Gas Corporasie
SCR	selective catalytic reduction (of NO_x)
SETC	State Economic and Trade Commission
SNG	substitute natural gas
SO_2	Sulfur Dioxide
SPC	State Planning commission
SSTC	State Science and Technology Commission (PRC)
T	tera - trillion (10^{12})

TOE	tons of oil, equivalent
TSP	total suspended particulates
TWh	trillion (10^{12}) Watt-hours
UNDP	United Nations Development Program
US	United States of America