CHANGING MARKETS AND NEEDS LEAD THE DOE TO REFOCUS AND EXPAND THE INTEGRATED GASIFICATION COMBINED CYCLE TECHNOLOGIES PROGRAM

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ABSTRACT

Changing market conditions, brought about by utility deregulation and increased environmental regulations, have encouraged the Department of Energy/Federal Energy Technology Center (DOE/FETC) to restructure its Integrated Gasification Combined Cycle (IGCC) program. The program emphasis, which had focused on baseload electricity production from coal, is now expanded to more broadly address the production of a suite of energy and chemical products. The near-term market barrier for baseload power applications for conventional IGCC systems has combined with increasing opportunities to process a range of low- and negative-value opportunity feedstocks to provide incentives for the refocused and expanded IGCC program. The new program is developing a broader range of technology options that will increase the versatility and the technology base for commercialization of gasification-based technologies. This new strategy supports gasification in niche markets where, due to its ability to coproduce a wide variety of commodity and premium products to meet market requirements, it is an attractive alternative. By obtaining operating experience in industrial coproduction applications today, gasification system modules can be refined and improved leading to commercial guarantees and acceptance of gasification technology as a cost-effective technology for baseload power generation and coproduction as these markets begin to open.

INTRODUCTION

Integrated Gasification Combined Cycle (IGCC) combines gasification with gas cleaning, synthesis gas conversion, and turbine power technologies to produce clean and affordable energy. The combination of combustion turbine and steam turbine is highly efficient in generating electricity. The synthesis gas can be converted to fuels for clean efficient fuel cell generation of power and conversion to high quality liquid fuels. Different variations of the combinations can offer to industry the capability to use low-cost and readily available carbonaceous energy resources and wastes in highly efficient energy conversion options. These options can be selected to meet any of a whole host of market applications as may be suitable for the particular business opportunity. Compared with today's commercial and advanced technologies, IGCC is one of the most efficient and environmentally friendly technologies for the production of low-cost electricity and synthesis gas and can be readily adapted for concentrating and sequestering CO_2. IGCC is the only advanced power generation technology that is capable of coproducing a wide variety of commodity and premium products to meet future market requirements. Through specific selections of the gasification-based technologies, an IGCC configuration can be built to convert virtually any carbon-based feedstock into such varied products as electric power, steam, hydrogen, high-value liquid fuels, and value-added chemicals.

The basic IGCC process for the production of electricity (see Figure 1) initially converts the carbonaceous feedstock in a gasifier into a synthesis gas, a mixture of carbon monoxide and hydrogen. The synthesis gas is cleaned of particulates, sulfur, and other contaminants and is then combusted in a high efficiency gas turbine/generator. The heat from the turbine exhaust gas is extracted to produce steam to drive a steam turbine/generator. The Brayton cycle gas turbine operating in conjunction with the traditional Rankine cycle steam turbine make up this combined cycle. Gasifier technology and combined cycle integrated in this way offers high system efficiencies and ultra-low pollution levels, ultimately reaching efficiencies of 60%, near-zero pollution, and closing the carbon cycle.

In addition to steam and power, the clean synthesis gas can be catalytically converted into hydrogen, environmentally superior transportation fuels, and a variety of chemicals in the coproduction mode. The high quality steam can also be exported for applications other than the production of electricity.

WHY SHOULD INDUSTRY BE INTERESTED?

IGCC has inherent characteristics which will enable major energy industries -- electric power generation, petroleum refineries, chemicals, fuels, and energy users -- to remold their technology and business structure to meet future market needs and take advantage of new opportunities. Deregulation, restructuring, and new types of cost competition are emerging with increased environmental pressures. As a result, the boundaries of these industries and the business structures will be changing significantly. The inevitable result will be opportunities for lower cost, more efficient, and less polluting energy conversion technologies that complement and contribute to the structural changes in both the technology base and business interests of the major energy industries. The unique advantages of IGCC systems have created a significant market for gasification technologies in industrial market applications. Gasification is the only technology that offers both upstream (feedstock flexibility) and downstream (product flexibility) advantages.

Worldwide energy consumption is expected to grow 75 percent between 1995 and 2020, according to the Energy Information Administration (International Energy Outlook 1998). Almost half of the world's future increase (or increment) in energy demand will occur in developing Asia. China alone expects to more than double its current electric generating capacity by 2015. This nation of 1.8 billion people will be considering new technology as a way to reduce environmental and health challenges from increasing energy consumption while, at the same time, using its abundant coal resources. The United States and the rest of the world will also increase its energy consumption and will confront similar energy and environmental challenges.

WHERE IS IGCC TODAY?

Gasification Worldwide

The stage is set for IGCC to play a major role in the domestic and global energy market. There are over 350 gasification units operating worldwide, producing the equivalent of about 20,000 MW. More than 300 of the units are producing synthesis gas (H_2 and CO) rather than power. The largest concentration of gasifiers is at SASOL in South Africa with about 100 fixed-bed gasifiers. China contains the next largest inventory, licensing more than 20 gasifiers and there are 14 gasifiers operating in North Dakota at the Dakota Gasification plant.

In addition to traditional coal utility IGCC applications, gasification technologies have been used in the conversion of coke, residual-oil, and biomass to power, steam, and chemicals and new facilities are being installed for additional applications. In fact, residual oil and coke account for 50 percent of the feed to gasifiers worldwide. Coal accounts for 42 percent of gasifier feedstock, and natural gas fuels 8 percent of all gasification. With the emphasis on reducing fuel costs, waste disposal costs and CO_2 emissions, a number of small projects will be using biomass as the gasifier feed and are either already operating or are near completion.

There are eight IGCC plants that are in construction or are operating in the petroleum refining industry both domestically and internationally. In these applications, the refinery residues are converted to synthesis gas to fuel a combined cycle and co-produce hydrogen for use in upgrading transportation fuel quality. There has been a great deal of activity in Europe, particularly in Italy where at least four projects are moving ahead that could add 1,500 MW to the Italian power grid before the year 2000. In the U.S., Texaco is operating a 35 MW IGCC at its El Dorado Plant in Kansas. The plant is proving that small-scale gasification combined cycle plants are economical and can convert hazardous waste streams into products. Two additional projects that integrate gasification with refining (the Motiva Refinery in Delaware and the Exxon Baytown Refinery in Texas) have awarded architectural and engineering contracts for design and construction.

Competition within Energy Markets

During the coming years, competition between the types of power systems and fuel resources will continue and as long as natural gas remains readily available and relatively inexpensive, natural gas-based power systems are likely to be the technology of choice. As natural gas becomes more expensive, lower cost energy resource options such as coal and alternative fuels will increasingly become the preferred choice and gasification the best technology to use these resources in efficient IGCC and syngas conversion technologies.

The capital cost for a natural gas-fired combined cycle plant is about one-half the cost of an IGCC plant that gasifies coal. IGCC is capital intensive; it needs economies of scale and fuel cost advantages to be an attractive investment option. However, IGCC costs can be improved by integrating processing steps and energy uses in a synergistic way with industrial applications. For example, gasifiers can operate on low-cost opportunity feedstocks, can be used to convert hazardous waste into useful products, reduce or eliminate

waste disposal costs, and can coproduce power, steam, and high-value products for use within the host plant or for export. Fluidized-bed combustors compete with IGCC in smaller cogeneration markets due to their ability to handle a wide range of feedstocks; however, IGCC has the added advantage of product flexibility, which can make it a more economical option for certain industrial applications.

Achievements

The key to commercializing technology is to demonstrate, on a commercial scale, its technical, economic, and environmental performance. DOE's Clean Coal Technology Program, a cost-shared effort with private industry, continues to be a cost effective and successful approach for moving technologies from bench scale to the marketplace. Within the structure of this program, there are three IGCC base-load power production projects and a gasification products conversion project that are relevant demonstrations of the level of commercial readiness of gasification-based technologies. These projects are individually and collectively evidencing the maturity of this technology base. The projects are:

- Wabash River Coal Gasification Repowering Project
- Tampa Electric Company IGCC Project
- Piñon Pine IGCC Power Project
- Liquid Phase Methanol (LPMEOH) Demonstration Project

IGCC PROGRAM

To meet energy market demands and to break the barriers to global commercial acceptance of gasification-based technologies, the IGCC Program strategy emphasizes increased efficiencies, cost reduction, feedstock and product flexibility, and near-zero emissions of pollutants and CO_2. As a result of the development and demonstration projects funded by the DOE's IGCC program and the CCT program achievements mentioned in the projects above, significant progress has been made to reach the capability shown at the left margin of Figure 2, namely about 40 percent efficiency and $1,200 total plant cost per KW. It is anticipated that with the continued development of oxygen blown systems, hot gas cleaning, membranes, and advanced gasifier systems that further improvements in efficiency and reductions in cost will likely be achieved as shown in Figure 2. An overall pictorial of the FETC IGCC Product Team's view of IGCC R&D Issues is shown in Figure 3. Specific categories of R&D issues and consequent planned activity areas are identified in the figure. To achieve these goals, the strategy is broken down into four distinct areas:

- **Research and Development**

DOE/FETC is sponsoring a multitude of R&D contracts with industry, academia, nonprofit institutions and government laboratories that support the goals of the IGCC program. Research activities include ***advanced gasifier*** designs that have the potential to reduce capital and O&M costs, improve thermal efficiency, and process alternative feedstocks. The transport gasifier is being developed through a coordinated program utilizing several research facilities. One of the focus areas of this research is refractory materials and instrument development to improve gasifier performance, operational control, and reliability. Researchers are also developing fluid dynamic data and advanced computational fluid dynamic models to support the development of the transport gasifier and desulfurizer. The use of biomass and municipal waste as gasifier feedstocks for power and coproduction applications are being evaluated. Novel technologies for ***gas cleaning and conditioning*** are being developed to reduce capital and operating costs and to meet the stringent requirements for cogeneration and coproduction applications. These new technologies are needed to assure the supply of ultra-clean gas for fuel cell and catalytic conversion of syngas to fuels and chemicals as well as enabling advanced processes to effectively separate CO_2. These technologies focus on minimizing consumables and waste products. Research is also being conducted in the area of ***advanced gas separation*** technologies with the goals of reducing both capital and operating costs, improving plant efficiency, and concentrating and capturing CO_2. Researchers are investigating novel hydrogen separation technologies which are capable of operating at high temperatures and pressures and in the presence of chemical and particulate contaminants. New air separation technologies, such as mixed conducting ceramic membranes, for producing lower cost oxygen are also being developed. And lastly, technologies that can generate ***value-added products*** to minimize waste disposal and improve process economics are being evaluated. Processes that will improve the quality of the ash, slag, and sulfur by-products from the plant are being developed because adding value to these products will not only enhance the plant revenues, but will more effectively use all of a resource with less waste.

- **Systems Engineering and Analyses**

A variety of economic analyses, process performance assessments, and market studies are being conducted to provide sound engineering and economic guidance for future R&D initiatives and to support commercialization activities, both domestically and internationally. Some examples include: an IGCC

optimization study for baseload power, cogeneration of steam, and coproduction of power and transportation fuels. These studies will help to define future R&D efforts and will provide the lowest cost and highest efficiency approaches. The R&D efforts can then be aimed at: reducing material costs and consumables as well as total plant costs; a detailed market analysis and the development of a commercialization strategy tailored for coproduction applications; and system studies to assess the production, mitigation, and sequestration of CO_2 in IGCC applications for baseload power generation, cogeneration, and coproduction and concepts for achieving zero emissions and closing the carbon cycle.

- **Technology Integration/Demonstration**

Demonstrate gasification-based technologies at an industrially relevant scale of operation to confirm process scale-up, provide RAM data, and evaluate process performance. Activities would include providing DOE resources to insure the success of existing IGCC Clean Coal Technology programs through technical assistance and R&D projects. The scope of demonstrations will be expanded to incorporate fuel cell, turbine integrations, and hybrids and extend the versatility of demonstrated technology.

- **Product Outreach**

Funding for RD&D activities is becoming increasingly difficult to find in both the private and public sectors. In an effort to overcome these obstacles, DOE/FETC has implemented an aggressive outreach program to communicate, coordinate, and partner with anyone who has a stake in the outcome of IGCC RD&D efforts including: power generators; industrial firms; financial institutions; environmental groups; local, state, and Federal legislators; taxpayers, and others. As part of this activity, stakeholders will be educated on the technical, economic, and environmental benefits of the IGCC systems. Further outreach will be accomplished by coordinating activities with other Federal, state and local government programs and organizations whose programs are complementary to IGCC to avoid potential redundancies. Finally, the formation of multinational partnerships, consortia and user groups will assure a coordinated research effort and continued commercialization activities for gasification-based technologies.

ACHIEVING THE VISION

By the year 2015, gasification-based technologies will have gained global acceptance and as a result will have penetrated worldwide power generation markets, achieved widespread use in the petroleum refining market, and attained, via coproduction, deployment in the fuels and chemicals market. Gasification-based processes will be the technology of choice by being the low-cost leader and providing superior environmental performance through modularity of design and fuel flexibility for easy integration into multiple applications. Commercial guarantees and financing will be readily available, therefore, minimizing the need for government incentives. This will result in improved U.S. industrial competitiveness and enhanced U.S. energy security through increased use of domestic resources. Beyond 2015, the Federal government will continue to develop advanced low-cost technologies to achieve America's goals of economic prosperity in multiple markets, energy security and environmental quality, leading toward zero discharge of all pollutants and greenhouse gases.

Early Entrance Coproduction Plants

The versatility of coproducing power and fuels accelerates deployment of both IGCC and synthesis gas conversion technologies, increases capacity factor, and reduces risks. Coproduction would allow a reduction in oil imports by producing significant quantities of ultra-clean fuels from domestic resources with little or no carbon emissions. However, private investors and process developers are hesitant to invest in the design and construction of coproduction plants until technical, economic, and technology integration risks are acceptable. DOE is implementing a strategy to help mitigate these risks through the support of early entrance coproduction (EECP) small-scale commercial plants that will demonstrate the successful operation of the integrated technologies. They will be constructed adjacent to existing infrastructures, and be capable of processing multiple feedstocks and producing more than one product. These EECP plants will be built by an industrial consortia in partnership with state and federal governments. Once the identified risks have been shown to be acceptable by successful operation, future commercial plants would not require Federal funds for construction and deployment.

Vision 21

Ultimately, gasification will be the cornerstone technology for a new fleet of energy plants for the 21st Century, called Vision 21. These energy plants are highly efficient systems (greater than 60%) that will co-produce low-cost electric power, transportation fuels, and high-value chemicals, all tailored to the geographic energy market demands. The feedstock and product flexibility of gasification-based technologies, coupled with their high efficiency and ultra-low emissions, make them a core part of the Vision 21 concept.

Vision 21 is DOE's strategy for advancing the research and development of technologies critical to creating the integrated energy plants of the coming century. R&D by DOE and industry partners will focus on issues that are key to improving the efficiency, versatility and cost-effectiveness of IGCC components and systems, and to furthering synergies between IGCC and other advanced energy and environmental control technologies.

CONCLUSIONS

Ultimately, IGCC could become the technology of choice for electric power generation. Improvements in IGCC performance are possible through continued development and integration of advanced technologies. Thanks to investments in energy research, development, and demonstration by the Federal government and industry partners, U.S.-based companies are poised for leadership in emerging world markets for IGCC systems, positioning them at the center of a vital energy industry in the 21st century.

FIGURE 1. INTEGRATION GASIFICATION COMBINED CYCLE
Technology Options

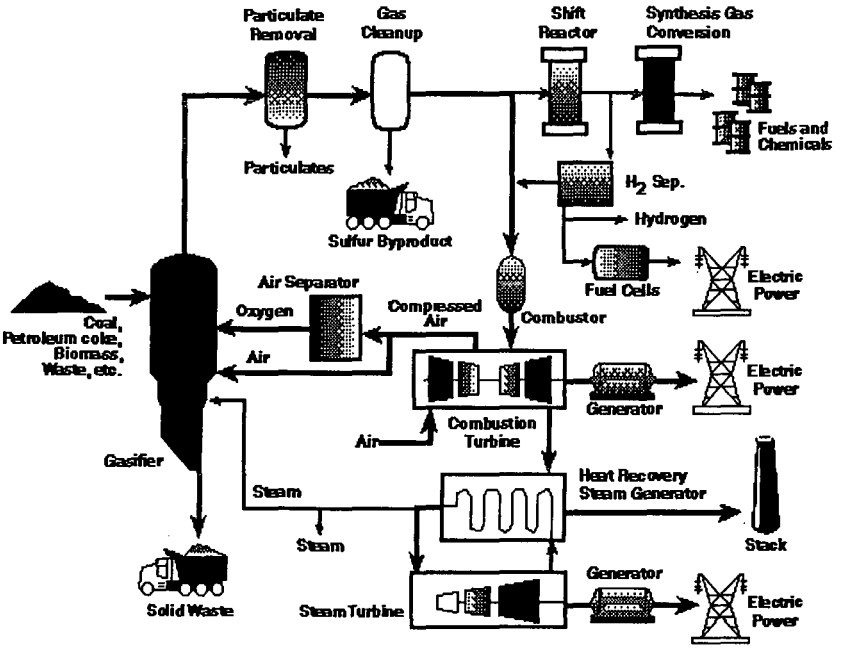

FIGURE 2. POWER GENERATION IGCC CAPITAL COST IMPROVEMENTS

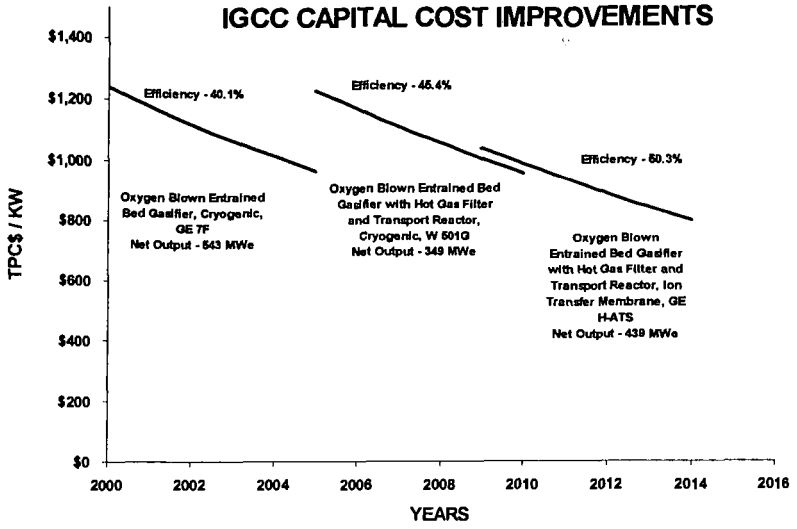

FIGURE 3. IGCC R&D ISSUES