INTEGRATED GASIFICATION FUEL CELL (IGFC) DEMONSTRATION TEST

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Introduction

Power generation in the United States relies heavily on coal with 56.3% of the power or 1807 billion kilowatt-hours generated using coal in 1998 as shown in Figure 1. As total U.S. coal consumption increases from 1043 to 1279 million tons a year between 1998 and 2020, the average annual increase is projected to be 0.9 percent. About 90 percent of the coal consumed in the U.S. is used for power generation. In the next 20 years, coal is expected to remain the primary fuel for power generation, although its share of total generation declines between 1998 and 2020 as natural gas increases its share[2].

As concern about the environment generates interest in ultra-clean energy plants, fuel cell power plants can respond to the challenge. Fuel cells convert hydrocarbon fuels to electricity at efficiencies exceeding conventional heat engine technologies while generating extremely low emissions. Emissions of SOx and NOx are expected to be well below current and anticipated future standards. Nitrogen oxides, a product of combustion, will be extremely low in this power plant because power is produced electrochemically rather than by combustion. Due to its higher efficiencies, a fuel cell power plant also produces less carbon dioxide. Fuel cells in combination with coal gasification, are an efficient and environmentally acceptable means to utilize the abundant coal reserves both in the United States and around the world.

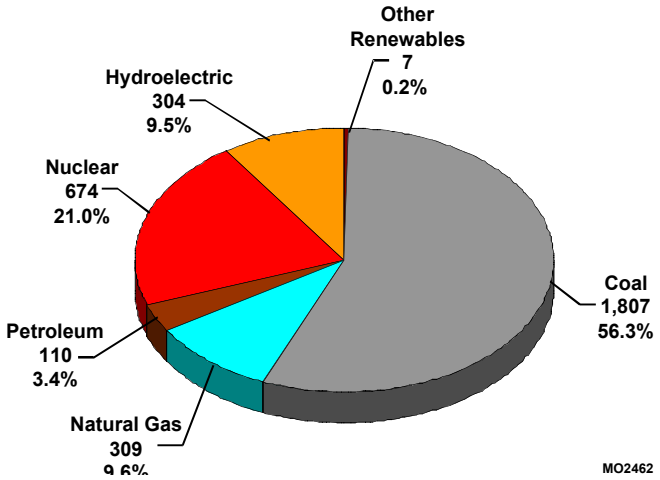

Figure 1

1998 U.S. Electric Generation by Fuel Type (Billion Kilowatt-hours)[1]

Source: U.S. DOE/EIA "Annual Energy Review 1998" (Data for U.S. Electric Utilities)

To demonstrate this technology, FuelCell Energy Inc. (FCE), is planning to build and test a 2-MW Fuel Cell Power Plant for operation on coal derived gas. This power plant is based on Direct Fuel Cell (DFC™) technology and will be part of a Clean Coal V IGCC project supported by the US DOE. A British Gas Lurgi (BGL) slagging fixed-bed gasification system with cold gas

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clean up is planned as part of a 400 MW IGCC power plant to provide a fuel gas slip stream to the fuel cell. The IGCC power plant will be built by Kentucky Pioneer Energy, a subsidiary of Global Energy, in Clark County, KY.

This demonstration will result in the world's largest fuel cell power plant operating on coal derived gas. The objective of this test is to demonstrate fuel cell operation on coal derived gas at a commercial scale and to verify the efficiency and environmental benefits.

Fuel Cell Power

The carbonate fuel cell derives its name from its electrolyte, which is made up of potassium and lithium carbonates. Figure 2 shows a simplified flow schematic of the carbonate fuel cell power plant. Syn-gas from the gasification plant clean-up system is cleaned up further and moisturized. The moisturized syn-gas is fed to the anode side of the fuel cell where methane is internally reformed and CO is shifted to CO_2 and H_2. Spent fuel exits the anode and is further oxidized in the anode exhaust oxidizer to supply oxygen and CO_2 to the cathode. The resulting reactions in the fuel cell anode and cathode produce DC output which is inverted to AC. The cathode exhaust supplies heat to the fuel clean-up, steam boiler and co-gen system as it is vented from the plant.

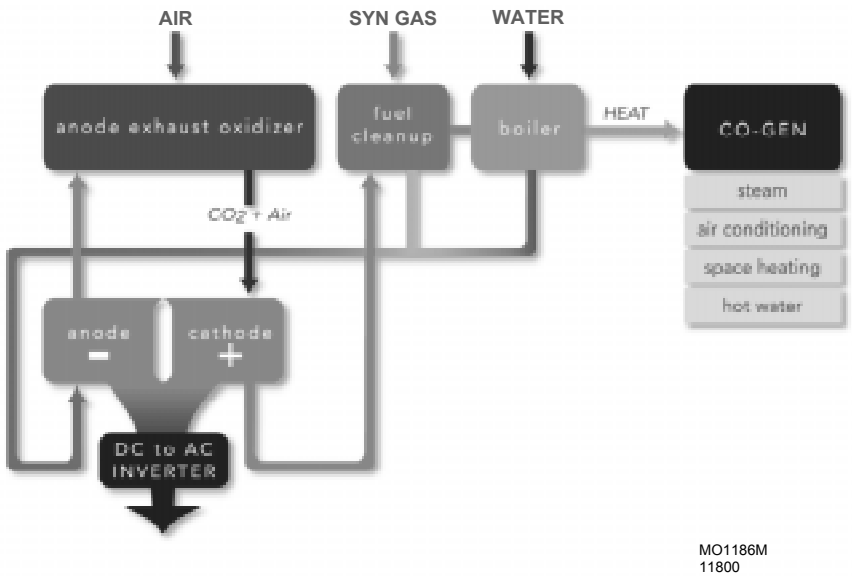

Figure 2.
Fuel Cell Power Plant Simplified Process Schematic

A 3-MW fuel cell power plant designed to operate on natural gas, shown conceptually in Figure 3, will be the basis for the power plant operating on coal derived gas. Two fuel cell modules, each housing four fuel cell stacks, produce the DC power. An inverter converts the DC power to AC. The balance of plant equipment includes thermal management, water treatment, switchgear and controls.

Figure 3
3-MW Fuel Cell Power Plant for Natural Gas

System studies

Fuel cell systems operating on coal have been studied extensively in past years. A simplified block diagram of a fuel cell power plant system is shown in Figure 4. Gasification is used to convert the solid fuel to a gas which is processed to remove sulfur compounds, tars, particulates, and trace contaminants. The cleaned fuel gas is converted to electricity in the fuel cell. Waste heat from the carbonate fuel cell is used to generate steam required for the gasification process and to generate additional power in a bottoming cycle.

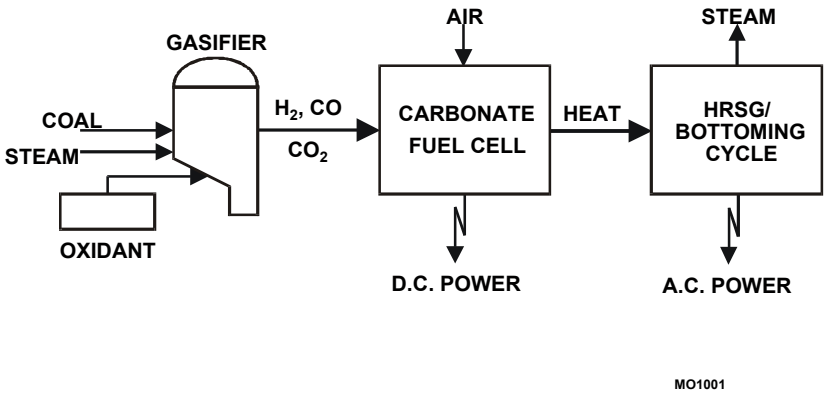

Figure 4
Integrated Gasification Fuel Cell System Simplified Block Diagram

At a 200 MW scale, past studies[4,5,6] indicated that using conventional gasification and clean-up technologies, a heat rate of 7379 (46.3 % HHV efficiency) can be achieved with IGFC utilizing BGL gasification and low temperature clean-up. This plant would require 1800 tons/day coal

and generate a net output of 205 MW. Later studies[7,8,11] indicated that higher efficiencies, 51.7% –53.5%, can be achieved with higher methane producing gasifiers and by using hot gas clean-up. More recently[12], studies of hybrid fuel cell/turbine systems have shown that LHV efficiencies of 70% can be achieved on natural gas. This system utilizes a gas turbine as a bottoming cycle to the fuel cell, as shown in Figure 5. This concept can be applied to coal gas systems as well.

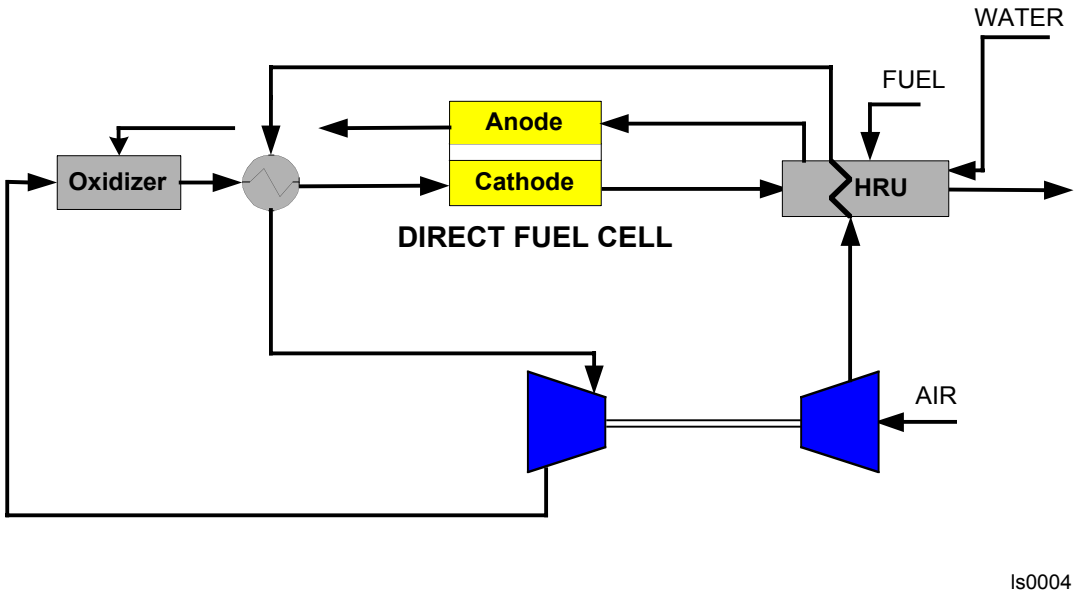

Figure 5
High Efficiency Hybrid Fuel Cell/Turbine Power Cycle

Emissions from this plant would be extremely low and below any current or anticipated future standards. Figure 6 compares the combined SOx, NOx, and solid waste emissions of existing commercial technologies, IGCC and IGFC. IGFC technology achieves the lowest levels of pollutant emissions in addition to lower CO_2 emissions and make-up water requirements. The CO_2 emission is 1.54 lb/kWh and the make-up water requirement is 6.8 GPM/MWh.

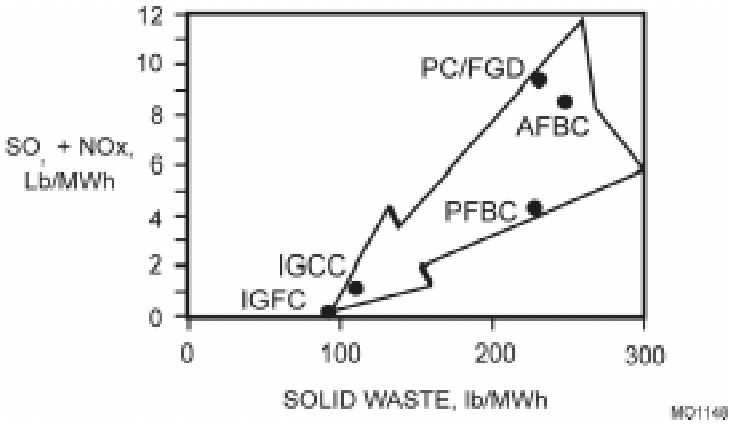

Figure 6
Environmental Impact Comparison of IGFC and Other Technologies

Experimental testing

Experimental testing of a 20 kW sub-scale fuel cell stack was conducted[9] at Louisiana Gasification Technology Inc. (LGTI) in 1993-4 by Destec as shown in Figure 7. This was the world's first test of a carbonate fuel cell on coal derived gas. Gas from the entrained flow Destec gasifier was further cleaned-up after bulk gas clean-up by the fuel cell test facility and supplied to the fuel cell. The fuel cell operated on syn gas from the gasifier and inter-changeably with natural gas providing normal performance and stable operation. After completion of the test, the fuel cell was disassembled for post-test inspection. Analysis of the components indicated no evidence of degradation and no detectable accumulation of coal gas borne contaminants in the fuel cell electrolyte or in the hardware. These results paved the way for a larger scale demonstration test.

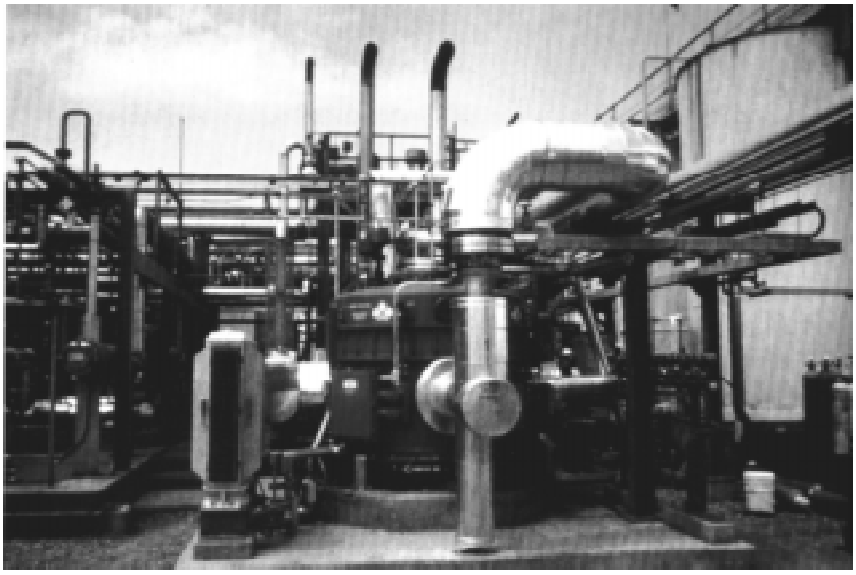

Figure 7
20 kW Carbonate Fuel Cell Test at the LGTI Gasification Facility

Clean coal demonstration test

FuelCell Energy is planning to build and test a 2-MW carbonate fuel cell power plant as part of the Kentucky Pioneer Energy Project by Global Energy. The plant will be located in Trapp, KY and will be operational in 2003. This project, supported by DOE as part of the Clean Coal Technology Program will include a 400-MW Integrated Gasification Combined Cycle (IGCC) and a 2-MW fuel cell power plant (Integrated Gasification Fuel Cell, IGCF) as shown in Figure 8. The project will feature Advanced Fuel Technology briquettes made of Kentucky coal and Municipal Solid Waste (MSW) as fuel in the gasification process, adding a renewable fuel component to the project. The use of municipal solid waste as fuel reduces fuel cost to the power plant and provides low cost waste elimination. British Gas/Lurgi (BGL) gasification technology and General Electric advanced turbine power generation will be utilized for the IGCC.

As shown in Table 1 emissions from this plant will be significantly lower than conventional coal fired plants using PC boiler, atmospheric fluidized bed, and pressurized fluidized bed technologies.

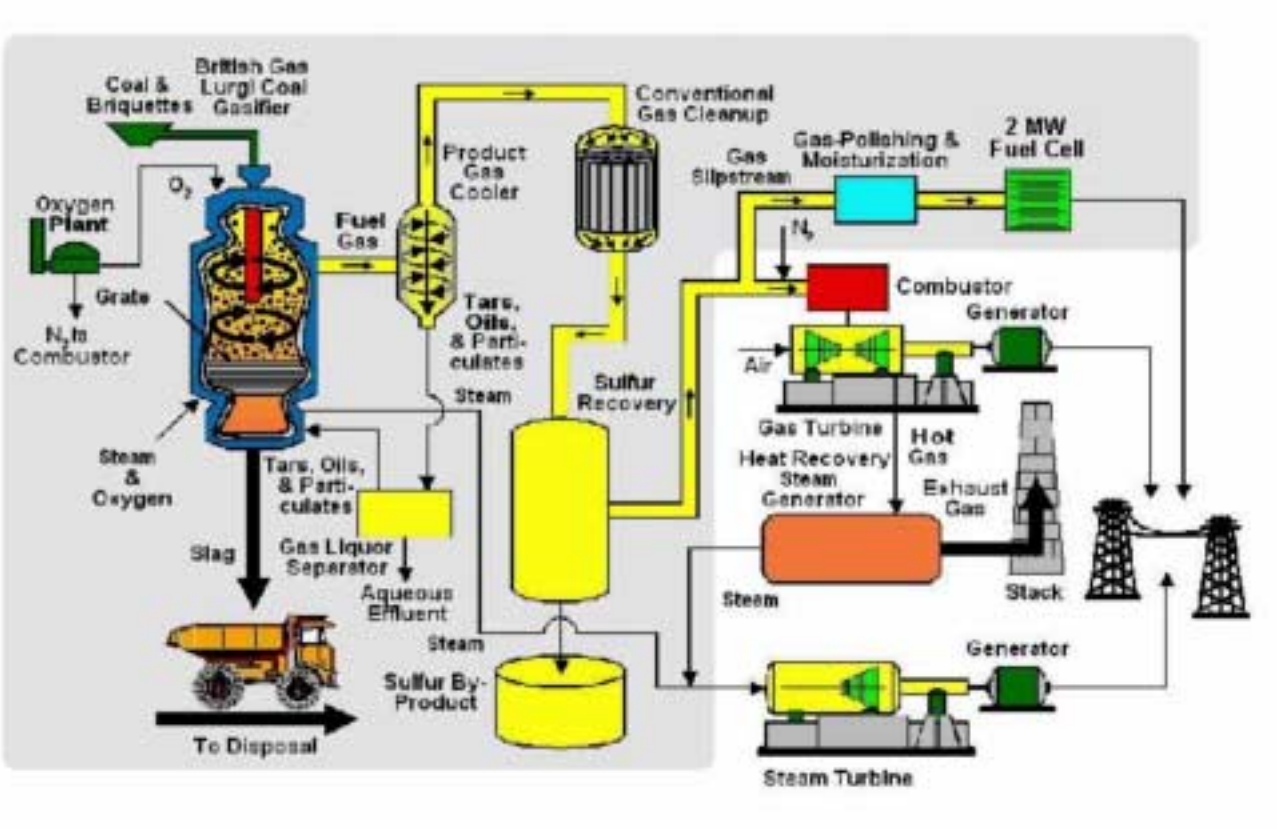

Figure 8
400-MW IGCC and 2-MW Fuel Cell Power Plant Process Flow Diagram[14]
Source: DOE Project Fact Sheet (Modified)

Table 1
Typical Emission Levels and Waste from Coal Based Power Plant Types

2.5% SULFUR EASTERN COAL *Source: EPRI With Adjustments By Duke Energy*				
PLANT TYPE	SO_2 EMISSIONS LB/MWH	NO_x EMISSIONS LB/MWH	SOLID WASTE (DRY) LB/MWH	CO_2 VENT GAS LB/MWH
Pulverized Coal (PC w/ESP Only)	35.7	11.2	136	1871
Pulverized Coal with FGD and LNB (90 percent S Removal, NO_x Control	3.6	5.8	232	1908
Atmospheric Fluidized Bed Combustion (AFBC)	3.6	4.9, 0.5 (SNCR)	249	1975
Pressurized Fluidized Bed Combustion (PFBC)	3.3	0.9	230	1826
Integrated Gasification combined cycle (IGCC) (99 Percent S Removal)	0.3	0.9	123	1695
BGL IGCC (99 Percent S Removal, 15 PPM NO_x)	**0.3**	**0.4**	**115**	**1585**
BGL IGFC	**0.25**	**0.18**	**90**	**1540**

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