Kentucky Pioneer Energy IGCC
CCT Fuel Cell Demonstration

Cooperative Agreement No. DE-FC21-95MC31262

BASIS OF DESIGN

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EXECUTIVE SUMMARY

The objective of this project is to demonstrate the significant improvement in efficiency and environmental performance of carbonate fuel cell technology in coal based power generation systems. As part of this project, FuelCell Energy (FCE) is designing and constructing a Direct Fuel (DFC) Cell power plant to operate on coal-derived syngas. The original site for this project was the Kentucky Pioneer Energy (KPE) Integrated Gasification Combined Cycle (IGCC) project site in Trapp, Kentucky as part of the U.S. Department of Energy (DOE) Clean Coal Technologies V Program. However, in order to expedite the project schedule it was relocate to the Wabash River Energy Limited (WREL) Gasification site in Terre Haute, Indiana, where the gasification plant is already in operation. This will allow completion of the demonstration more than 2 years ahead of the estimated current schedule at the Trapp Kentucky site.

Design of the syngas processing system for the original KPE site in Trapp, Kentucky was initiated by preparation of a preliminary PFD and material and energy balances. Due to the planned change of site to the Wabash River site and the differences in the gasification/clean up system, the design of the syngas processing is being updated for the new location.

DESIGN BASIS

The Fuel Cell Power Plant will be based on FCE's standard natural gas-fueled two-module Direct Fuel Cell (DFC) power plant design, adapted to operate on syngas after its initial operation and checkout on natural gas. Its balance of plant (BOP) components will be sized to enable plant power generation of up to 3.0 MW (net ac) using future technology replacement Fuel Cell Stack Modules containing FCE's "mature" generation of fuel cell stacks. It will be highly modularized, and will feature high efficiency, quiet operation, low emissions, and a small footprint.

The Syngas Fuel Preparation Facility will convert the treated syngas from the Wabash gasification plant into fuel gas suitable for the Fuel Cell Stack Modules. This will be accomplished by (1) Additional desulfurization of the syngas to lower its sulfur content further, and (2) methanating the syngas (in order to utilize the cooling effect of the endothermic methane reforming reactions within the fuel cell stacks). The Syngas Fuel Preparation Facility will be located adjacent to the Fuel Cell Power Plant.

The Project's operating characteristics and performance presented in this document reflect fuel cell technology advances that FCE expects to achieve in the near future. The majority of the Fuel Cell Power Plant's balance of plant (BOP) equipment (including the inverter system) and all of the Syngas Fuel Preparation Facility equipment is based on proven and commercially available technology.

1.0 General Design Considerations

The plant will meet the following requirements:

- Location: Terre Haute, Indiana
- Plant Fuel Capability:
  - Anode Fuel Gas Makeup: Coal/Pet Coke derived syngas, natural gas (one at a time)
  - Oxidizer Burner Fuel: Natural gas or peak shave gas
- Overall Plant Performance Targets (Nominal Values)

Rated Power Output	2.0 MW (Net AC), lower on syngas due to lower Btu value of syngas
Power Output Turndown	25% to 100% of Rated Sustainable Output (stable operation below 25% and islanding)

- Electrical Characteristics

Output Voltage	480 Volts Power Quality: IEEE Standard 519
Power Factor Range	0.90 Lag to 0.90 Lead at Rated Output
Power Output Phase	3 Phase, Wye, 4 Wire
Frequency, Hz	60
DC to AC conversion efficiency	95% or greater
Black Start Capability	Not included; connection to grid will be required or stand alone 480Vac generator provided

- Plant Controls — Designed for unattended operation with local and remote dispatching/control

- Height — 25 feet

- Plant Constructability Basis — Modular (skidded) design. Truck-transportable skids complete with pre-installed piping, valves, insulation, instrumentation, and electrical wiring. The plant will be configured to minimize number of skids to limit footprint requirements and to limit interconnectivities during installation.

- Plant Design Life Expectancy — 35 years

- Equivalent Availability — 95%

- Fuel Cell Stack Modules

Number required in Plant	Two
Stack Module Design	Internally Insulated Nearly-Cylindrical Vessel, truck-transportable modules, each containing four fuel cell stacks
Fuel Cell Type/Configuration	Carbonate/DFC (Direct Internal Reforming/Indirect Internal Reforming (DIR/IIR)
Operating Temperature	1050-1194°F
Operating Pressure	<1 psig
Stack Module Rated Output	1.0 MW (net ac) on natural gas
Design Service Life Expectancy	10,000 – 40,000 hours, based on fuel cell stack generation
Replacement Philosophy	Replacement fuel cell stack modules will be available to meet the 35-year design

	operating life of the plant, and will be designed to fit into the plant without requiring modifications to the balance of plant components.
• Noise	60 dB(A) or less at 100 feet from the plant boundary (fence).

Fuel Cell Stack Conditioning Requirements

All fuel cell stack modules will be preconditioned before being installed at the site.

Plant Control Requirements

The plant will be designed for unattended operation with local and remote dispatching/control. The control system will be able to communicate with a remote monitoring station located at FCE's facilities in Danbury, CT for diagnostic purposes.

Control of the plant will be accomplished using a Scaleable Process Control System (SPCS). The majority of control and monitoring interfaces to the process will be via "Smart Type Transducers" communicating over Foundation Fieldbus segments, Modbus Links to PLC's controllers with classic I/O providing, motor control and multiplexor interfaces to the non-smart instruments.

The SPCS controllers, power supplies, bus interface modules, I/O racks, data historian/WEB server and an Engineering Operator Work Station with a laser printer (for maintenance) will be housed inside the Electrical Equipment enclosure located inside the plant Inside Boundary Limit (IBL).

The WEB server will interface via a telephone modem for remote communications and a telephone pager for annunciating alarms.

Materials Selection Requirements

The metallurgy of piping and equipment will be selected to ensure the purity and freedom from particulates (including pipe slag, rust, etc.) of the anode fuel gas and cathode oxidant gas supplied to the fuel cell Stack Modules.

<u>Electrical Classification (Preliminary, based on DFC Process Design Guide)</u>

On-site equipment and controls will be designed for electrical classification per code (e.g. Class 1, Division 2, Groups B & D).

FCE Provided Equipment

FCE will manufacture the fuel cell stack modules. The balance of plant equipment will be manufactured by subcontractors and delivered to the site by FCE.

Global Energy Provided Process Gases, and Utilities

Global Energy is responsible for providing the following gases and utilities at a regulated pressure to a tie-in location adjacent to the plant site: syngas, natural gas, electricity, municipal water, and sewer connection for process waste water.

Process Safety Considerations

Special process safety considerations are listed below:

- The stack modules and balance of plant equipment (BOP), where applicable, will be designed to withstand pressure spikes induced by internal deflagrations by adequate structural design.

Special process safety hazards include the following:

- Leaks of treated syngas downstream from the Feed Treatment System and fuel gas will not be detectable by smell. Strategically located combustible gas detectors will be provided to detect methane gas and fuel gas leaks in the Fuel Gas Preparation system.

- Carbon monoxide, present in significant concentrations in the fuel gas from the Gasification facility and anode exhaust gas, is highly poisonous. Strategically located combustible gas detectors will be provided to detect CO leaks in the fuel gas, anode exhaust gas piping and the Oxidizer.

2.0 Site Data

Site and climatic design conditions for the WREL Gasification site are listed in Table 1.

TABLE 1. SITE DATA FOR THE WREL SITE

CONDITION	DESIGN POINT[1]	SITE SPECIFIC DATA
Elevation	0 ft. above sea level	520 ft. above sea level
Avg ambient Temperature, °F	60	59
Min Ambient Temperature, °F	-20	-20
Max Ambient Temperature, °F	104	100
Avg Ambient Pressure, in Hg	29.9	
Avg Relative Humidity, %RH	60	60
Wind Loading @ 33 ft, PSF	30[2]	
Precipitation, in/hr	2.5	2.4 in-25 yr interval
Snow Load, PSF	30[3]	20
Ambient Dust Loading, Avg/yr	27μgm/m^3	Dust and Coal Dust
Ambient Gaseous Halide Conc, Avg/yr	20 ppbw	
Ambient Gaseous SO_x Conc, Avg/yr	<10 ppb	
Seismic Zone (US	4	2A
Height Limit, ft	25	
Noise Limits, db(a) @ 100 ft	60	“Normal OSHA Work Place”

3.0 Fuel Basis

The Fuel Cell Power Plant will be supplied with treated syngas from the WREL Gasification plant after acid gas removal. The gas analysis shown in Table 2 is representative of the range of compositions estimated for the coal gasification plant. When syngas is not available from the gasification plant, and during initial startup and commissioning, natural gas will be used as feed to the fuel cell power plant.

TABLE 2. WREL Syngas Data

Component	Coal operation	Petroleum Coke Operation
H_2 vol %	34.4	33.2
CO vol %	45.3	48.6
CO_2 vol %	15.8	15.4
CH_4 vol %	1.9	0.5
N_2 vol %	1.9	1.9
Argon vol %	0.6	0.6
Total Sulfur ppmv	301	280
HHV, Btu/SCF	277	268

[1] DFC basis used for plant performance projections and design of equipment.
[2] This wind load of 30 PSF is based on a wind speed of <90 mph and Exposure C. Exposure C is defined as “Open terrain and scattered obstructions have height generally <30 ft” (American Society of Civil Engineers standard ASCE 7-88).
[3] Snow load is equivalent to a ground snow load of 40 PSF and a snow exposure factor of 0.7 (Uniform Building Code UBC-97)

Natural gas can be used as an alternate fuel for the fuel cell power plant and is used in the thermal oxidizer for the pilot and as startup fuel to heat up the plant. The natural gas analysis for the site is shown in Table 3. The reference gas and range/limit data are the basis of design for the equipment in the DFC power plant.

TABLE 3. NATURAL GAS ANALYSIS

	Fuel Cell Power Plant Design Basis		WREL Site Specific	
	Range	**Performance Gas**	**Range[4]**	**Performance Gas[5]**
Composition				
Methane, vol %	80 – 100	93.0	95.8-96.1	96.00
Ethane, vol %	0 – 10	1.9	2.13-2.23	2.17
Propane, vol %	0 – 3	0.6	0.28-0.33	0.30
Butanes, vol %	0 – 1.25	0.5	0.10-0.12	0.11
Pentanes+, vol %	0 – 0.5	0.0	0.10-0.12	0.1
Unsaturated Hydrocarbons	None	None	None	None
Inert Gases				
Nitrogen, vol %	0 – 3	1.1	0.34-0.39	0.35
Carbon Dioxide, vol %	0 – 3	1.1	0.96-0.99	0.97
Total Inerts, vol %	0 – 6	2.2	1.3 - 1.38	1.32
Oxygen	0 – 0.2	0.0	0.0	0.0
Impurities				
Total Sulfur, ppmv	0 – 12	6		6
Grains/100 SCF	0 – 0.7	0.36		0.36
H_2S, ppmv	0 – 0.8	0		0
COS, ppmv	0 – 2	0		0
Odorants, ppmv	0 – 12	6		6
Halogens (Cl, etc)	None	None		None
Dust, Gum, Solid Matter	None	None		None
Water, lb/MMscf	0 - 7	Dry		Dry
Physical Properties				
Heating Value, Range				
- LHV, Btu/scf	870 – 1000	933		933
- HHV, Btu/scf	970 – 1100	1035		1035
Pressure, psig	15 – 20	15		15
Temperature, °F	40 - 75	60		60

4 Source "Power Plant Needs List" E-mail from Jeff Stockton WREL to George Steinfeld (FCE), dated 6/24/02
5 The Performance Gas Composition is estimated from the average of the range.

4.0 Water Basis

Municipal potable water is supplied to the plant to meet its process water requirements. The data in Table 4 shows the range of water compositions that the plant is designed for. The performance water criteria listed in the table is the basis to be used for estimating the plant's water treatment requirement and flow at rated output and the WREL water is representative of the municipal water supply at the WREL site.

TABLE 4 WATER ANALYSIS

	RANGE / LIMITS (DFC® BASIS)	REFERENCE WATER (DFC® BASIS)	WREL WATER RANGE
Quality			
Calcium (Ca), mg/l as $CaCO_3$	0 – 120	44	
Magnesium (Mg), mg/l as $CaCO_3$	0 – 30	16	
Sodium (Na), mg/l	N/A	16	< 24
Bicarbonate (HCO_3), mg/l as $CaCO_3$	0 – 90	50	
Chloride (Cl), mg/l	0 – 50	17	< 31
Sulfate (SO_4), mg/l	0 – 90	20	< 80
Total Dissolved Solids, mg/l	0 – 350	135	< 392
Total Hardness as $CaCO_3$, mg/l	0 – 150	60	< 310
Silica (SiO_2), mg/l	0 – 10	3	< 4.6
Iron (Fe), mg/l	0 - 0.1	0.03	< 2.0
Copper (Cu), mg/l	0 - 0.05	0.01	< 0.05
Silt Density Index	0 – 5	2	
Specific Conductance, micromho/cm	0 – 580	205	< 563
PH	7 - 8.5	7.6	7 – 8
Properties			
Temperature, °F	40 – 90	59	
Pressure, psig	50 – 65	60	

Notes: 1. Source: "Fuel Cell Power Plant Needs List", E-mail from Jeff Stockton WREL to George Steinfeld (FCE), dated 06/24/02.

5.0 Plant Interfaces

The process gases, utility services, and control interfaces listed in Table 5 will be required for the fuel cell power plant. WREL is responsible for line sizing, pressure relief, and pressure regulation up to the plant interface location.

TABLE 5. PLANT INTERFACES

PLANT INTERFACE REQUIREMENTS
Process Gases Coal/Coke- Derived Syngas Natural gas
Utility Services Potable Water Electricity Sewer Flare
Control Interfaces Data communications link(s) to WREL control center/ dispatch facility & FCE monitoring Station

6.0 Plant Operating Requirements

The WREL Fuel Cell Power Plant will be designed to operate on syngas from the WREL gasification facility when operating on either coal or pet coke or a blend of both. During periods when syngas is not available the fuel cell power plant can operate on natural gas.

7.0 Process Systems Design

The functionality of each of the major process systems is described below.

Syngas Preparation System

The design of the Syngas Preparation Unit is based on receiving a syngas from the WREL gasification plant that has been desulfurized but can have up to 320 ppmv total sulfur content. The sulfur is primarily a combination of H_2S and COS and has to be reduced to 0.1 ppm. A sorbent such as ZnO can be used to capture the H_2S and the COS can be either hydrogenated or hydrolyzed to form H_2S, which can be captured by ZnO. After desulfurization the syngas will be methanated in three stages with intercooling. The resulting methane rich gas is fed to the fuel cell power plant.

Natural Gas Fuel Preparation System

The Natural Gas Fuel Preparation System will treat natural gas for use as a fuel within the fuel cell plant as follows:

1. Preheat if required during cold weather in an optional heater,
2. Desulfurize and remove other contaminants from the gas at ambient temperature, in the Cold Gas Desulfurizers;
3. Pre-reform to remove higher hydrocarbons

Nitrogen Gas Supply System

The Nitrogen Gas Supply System will provide low pressure nitrogen gas for purging operations and protecting the Fuel Cell Stack Modules during Plant Shutdown/Trip modes. The Nitrogen Gas Supply System consists of pressurized gas cylinders. Additional nitrogen will be required for use in certain maintenance activities.

Nitrogen will be required in the plant for:
1. purging of the fuel gas piping and fuel cell anodes at the beginning of start-up,
2. purging of the fuel gas piping prior to maintenance activities,
3. purging of the Cold Gas Desulfurizer canisters before change-out,
4. providing an inert gas curtain of the fuel cell cathode exit line when the plant is placed in Shutdown mode to avoid a vacuum condition in the stack module as the module cools down,
5. purging of the fuel gas piping and fuel cell anodes when the plant is placed in Shutdown mode to avoid Ni carbonyl formation (within the Prereformer and the RU) and condensation of the moisture.

Heat Recovery System

The Heat Recovery System will:

1. Collect the cathode exhaust gas exiting the Fuel Cell Stack Modules
2. Utilize waste heat from the cathode exhaust gas to
    a. superheat the anode fuel gas, and
    b. humidify and preheat the feed natural (or peak shave) gas
3. Vent the cooled cathode exhaust gas to the atmosphere.

The system includes a portion of the cathode exhaust gas piping to the Heat Recovery unit. The Heat Recovery System will include an internal bypass to limit the heat addition in the humidifier and thus control the exit temperature of the humidified fuel gas such that the operating temperature limit of the downstream Preconverter is not exceeded.

Oxidizer Supply System

The Oxidizer Supply System will:

1. Compress ambient air for cathode oxidant makeup
2. Collect, mix with the pressurized air stream, and catalytically oxidize the anode exhaust gas from the Fuel Cell Stack Module System
3. Generate cathode oxidant gas at the flow rate, composition, and temperature required for fuel cell power generation, and
4. Deliver the oxidant gas to the Fuel Cell Stack Module System.

The Oxidant Supply System will also burn desulfurized natural gas in the pressurized air stream to generate a hot effluent gas to achieve the temperatures and flow rates required for controlled heating and cooling of the fuel cell stack modules during plant startup, shutdown, and standby operation.

The Oxidant Supply System is designed to integrate the operation of the fuel cell anodes and cathodes during power generation by:

1. Utilizing the residual fuel energy and sensible heat in the anode exhaust gas to heat air to the required oxidant gas temperature, and
2. Recirculating the carbon dioxide generated in the fuel cell anodes back to the fuel cell cathodes to support the cathode reactions. All components of the Oxidant Supply System will be located on a single skid.

Fuel Cell Stack Module System

The Fuel Cell Stack Module System will:

1. Receive superheated anode fuel gas from the Fuel Gas Preparation System and hot cathode oxidant gas from the Oxidant Supply System,
2. Generate dc electric power for the Inverters by converting the fuel energy in the anode fuel gas to electrical energy, and
3. Discharge anode exhaust gas to the Oxidant Supply System and cathode exhaust gas to the Heat Recovery System.

The Fuel Cell Stack Module System will include two Fuel Cell Stack Modules (containing four fuel cell stacks each).

Inside the fuel cell stacks, anode fuel gas will be reformed and electrochemically reacted with the cathode oxidant gas to generate dc power according to the following reactions:

$$CH_4 + H_2O \leftrightarrow CO + 3\ H_2 \qquad \text{(Methane Reforming Reaction)}$$
$$H_2O + CO \leftrightarrow H_2 + CO_2 \qquad \text{(Shift Reaction)}$$
$$H_2 + CO_3^{\equiv} \rightarrow H_2O + CO_2 + 2e^- \qquad \text{(Anode Half-Cell Reaction)}$$
$$CO_2 + \tfrac{1}{2}\ O_2 + 2e^- \rightarrow CO_3^{\equiv} \qquad \text{(Cathode Half-Cell Reaction)}$$

The Fuel Cell Stack Module interfaces with the BOP process piping will be designed to enable changeout of the Fuel Cell Stack Module.

Each initial generation stack module will be nominally rated at 1.0 MW (net ac) power output based on natural gas fuel. The plant may be derated somewhat for operation with a syngas fuel derived from gasification. The stack modules will be gas-tight to provide environment containment at operating pressures up to 2 psig.

Water Treatment System

The Water Treatment System will:

(1) Purify chlorinated municipal water for use as fuel gas humidifier makeup; and
(2) Provide a 10-hour service capacity of treated water for use during water purification equipment outages.

The system is designed for operation with makeup water that meets the performance water criteria in Table 4, and will be easily amenable to upgrades to accommodate makeup water qualities outside these design limits.

The Water Treatment system is designed for continuous, reliable, and automatic operation.

Instrument Air System

The Instrument Air System will produce dry, compressed air and distribute it to pneumatically operated control valves and panel purges in the balance of plant (BOP) equipment. Oil-free, rotary type air compressors are used.

Electrical Balance of Plant

The Electrical Balance of Plant converts the DC electric power generated by the fuel Cell Stack Modules to AC electric power. The Electrical Balance of Plant contains all electrical system protective devices and the distribution and control devices for auxiliary loads.

8.0 Environmental Emissions and Effluents

An estimate of the plant's environmental emissions is listed in Table 6. Continuous effluent streams from the plant during normal operation are:

1. The fuel cell's cathode exhaust exiting the exhaust stack. Air emissions in the fuel cell exhaust gas are nearly negligible. SO_x emissions are essentially zero because the fuel gas feed to the fuel cells contains less than 0.1 ppmv sulfur, and NO_x emissions are low due to the low operating temperatures in the Oxidizer and fuel cells. VOC's and carbon monoxide emissions are also very low.

2. The liquid effluent from the plant during normal operation includes reject/regeneration/backwash water from the Water Treatment system. The quality and temperature of the effluent water stream are expected to be satisfactory for their disposal into a municipal sewer.

Solid wastes generated in the plant require disposal intermittently. These include spent sulfur absorbent and deactivated catalysts. The spent material is collected in waste bins prior to being shipped off-site. The Preconverter and oxidation catalysts are suitable for recycle/sale to catalyst reclaimers. The spent sulfur sorbent will be returned to the supplier for regeneration or disposal. Other intermittent wastes will occasionally be generated, such as used lube oil that must be replaced per equipment vendor specifications.

Rainwater or washdown water from the site can be directed to a stormwater drain. Oil leakage beneath rotary equipment is contained to allow clean up during the regular maintenance.

TABLE 6 EMISSIONS ESTIMATES SUMMARY (1)

Emission / Effluent	Rated Output Estimated Emissions (ppmv)
Air Emissions	
SO_2	0.026
NO_x (as NO_2)	0.267
CO	0.2
VOC (as C)	2.4
PM (μg/acm)	249

Note: (1) Values listed are wet-basis based on concentrations measured on sub-MW scale DFC operating on natural gas. PM concentration adjusted for stack temperature.

9.0 Layout

Most of the plant equipment is packaged in modules or skids, which are placed on concrete foundations. The skidding philosophy consists of combining equipment on common skids in order to minimize the plant footprint, and reduce the interconnection activities in the field. The plant requires a rectangular footprint. The plant height will not exceed 25 feet.

The plant's piping and structural interfaces with the fuel cell stack modules are designed to be identical to those planned for all other megawatt class DFC Fuel Cell Modules.

An access zone capable of supporting the module transporter and the crane used to install and remove the Fuel Cell Stack Modules and other equipment skids, and which enables access for catalyst/sorbent/brine salt removal and replacement, will be provided adjacent to the physical plant boundary. A laydown area will be provided adjacent to the plant during construction.

Process and Plant Configuration

The fuel cell power plant will first operate on natural gas then it will operate on clean syngas supplied by the coal gasification plant. The design philosophy is to develop a standard Direct Fuel Cell (DFC) power plant optimized for natural gas and rated for 2.0 MW, then determine its performance using syngas fuel. The syngas is treated in a fuel preparation unit to increase the methane content. The plant can therefore use the cooling effect of the endothermic methane reforming reactions within the DFC fuel cell stacks.

A block diagram of the power plant configuration is shown in Figure 1. Fuel (natural gas) (shown in dotted lines) enters an electric heater and then the cold gas desulfurizer. The desulfurizer contains activated carbon beds to remove contaminants from the gas.

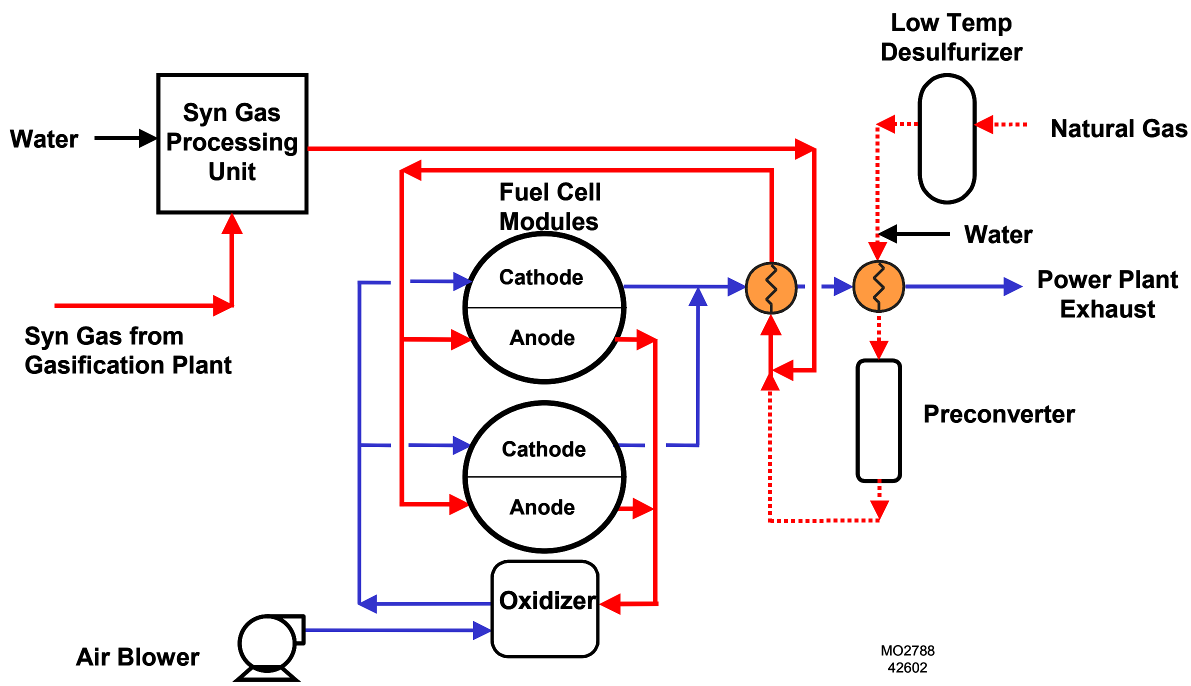

Figure 1. Fuel Cell Power Plant Simplified Process Flow Diagram

The desulfurized fuel is humidified and preheated using waste heat from the fuel cell exhaust. The stream is fed to a deoxidizer (not shown in Fig 1) to remove O_2 present in natural gas and peak shave gas and then to a preconverter. The preconverter reforms higher hydrocarbons generating hydrogen. The stream is superheated using the waste heat from the fuel cell exhaust and fed to the anodes in the fuel cell modules.

The depleted fuel from the anodes goes to the oxidizer, where the unused fuel is catalytically oxidized with air supplied by the air blower (shown in blue lines in Figure 1). The exit stream from the oxidizer is fed to the cathodes in the fuel cell modules. The exhaust from the fuel cell modules is used to supply heat for the fuel treatment processes. These heat exchangers are located in the Heat Recovery Unit (HRU). A catalytic polishing unit is also installed in the HRU to recover heat by oxidizing any combustible gases that may be present in the cathode exhaust.

The plant also contains a startup system (an electric heater and blower) that is used to initially raise the temperature of the fuel cell modules from ambient to about 150°F. A nitrogen gas supply system provides low-pressure nitrogen for purging operations during plant trips and shutdowns. A water treatment system supplies deionized water for fuel gas humidification.

There are two fuel cell stack modules each containing four stacks. Inside the fuel cell, the anode fuel gas is reformed and electrochemically reacted with the cathode oxidant as to generate DC power:

$CH_4 + H_2O \rightarrow CO + 3\ H_2$	(Methane Reforming Reaction)
$H_2O + CO \rightarrow CO_2 + H_2$	(Shit Reaction)
$H_2 + CO_3^{=} \rightarrow CO_2 + H_2O + 2e^-$	(Anode Half-Cell Reaction)
$CO_2 + ½O_2 + 2e^- \rightarrow CO_3^{=}$	(Cathode Half-Cell Reaction)

The electrical equipment in the plant contains inverters to convert the DC electric power generated by the fuel cell stack modules to AC electric power, transformers and switchgear required for the plant. The electrical/control center incorporates a Distributed Control System (DCS) required for operating the plant.

During syngas operation the fuel stream from the gasifier will pass through a syngas processing unit that desulfurizes and methanates the syngas from the WREL gasification system.

Power Plant Description

The overall plant footprint is 2935 ft^2. The Clean Coal Fuel Cell Power Plant is highly modularized, consisting of the Fuel Cell Stack Modules as well as mechanical and electrical equipment skids. The skidding philosophy, combining equipment on common skids, has resulted in a smaller plot plan. All components are designed for outdoor installation and are truck-transportable to the site using standard or customized trailers.

Figure 2 depicts a 3-D model of the fuel cell demonstration power plant. This does not yet include the syngas treatment facility to be built in two skids that will be placed next to the fuel cell power plant.

There are four BOP skids, from left to right, the Fuel Processing skid, Anode Gas Oxidizer/Heat Recovery skid, Water Treatment/Instrument Air skid, and the Power Conditioning skid. Two fuel cell modules, shown in the cylindrical vessels, and a start-up blower complete the power plant.

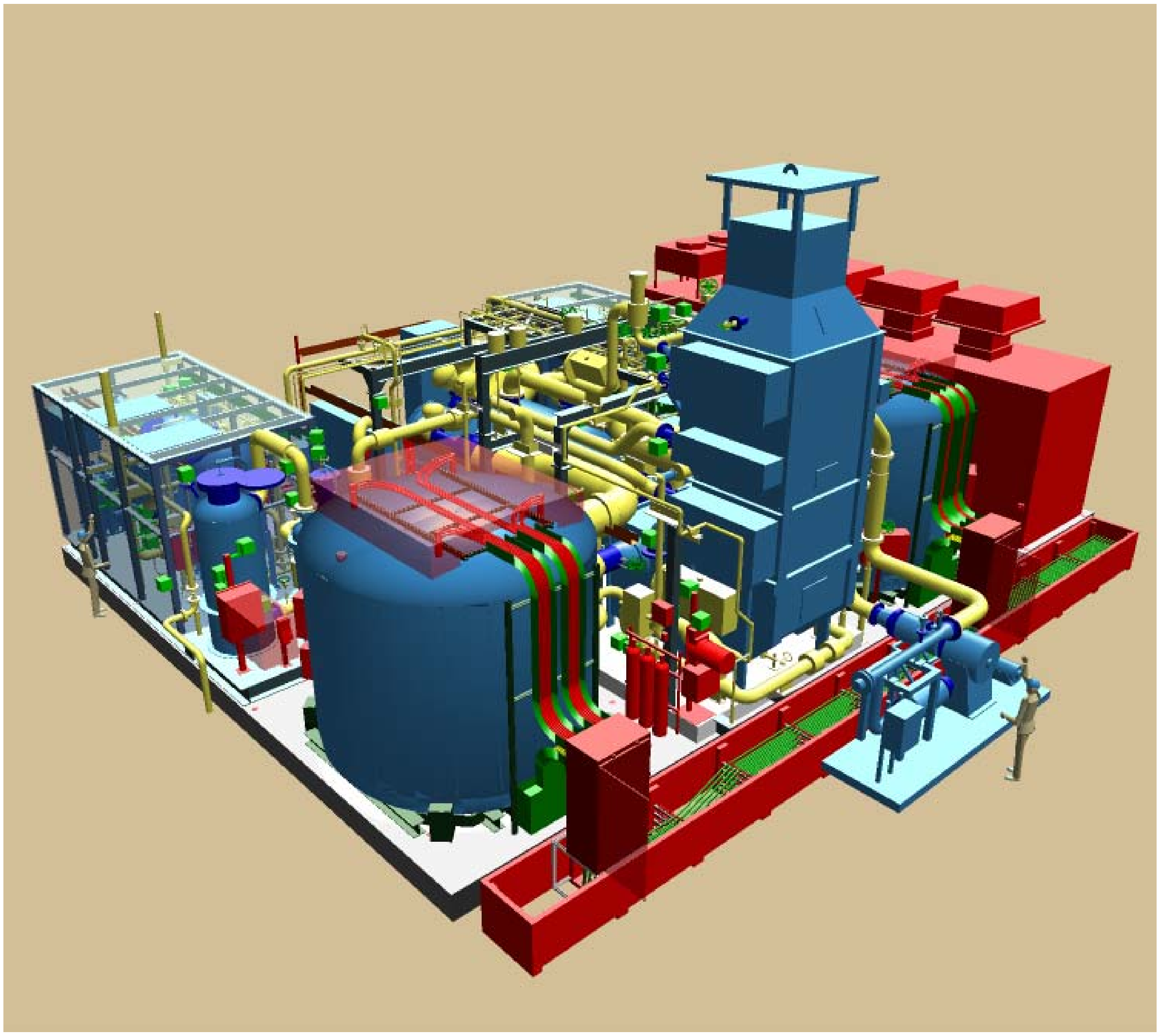

Figure 2. Fuel Cell Power Plant

The BOP equipment skids will be pre-assembled and tested at the fabrication shop before shipment to the site. The Fuel Cell Stack Module will be assembled and conditioned in the FCE Danbury, CT conditioning facility. Inter-connecting piping between skids has been minimized in the plant design and will be fitted at the skid fabricator to insure proper fit. The instrumentation and electrical components on the skids will be pre-wired, with all connections terminating at junction boxes.