



# King County Fuel Cell Demonstration



## Project Summary • March 2008



FuelCell Energy

### BACKGROUND



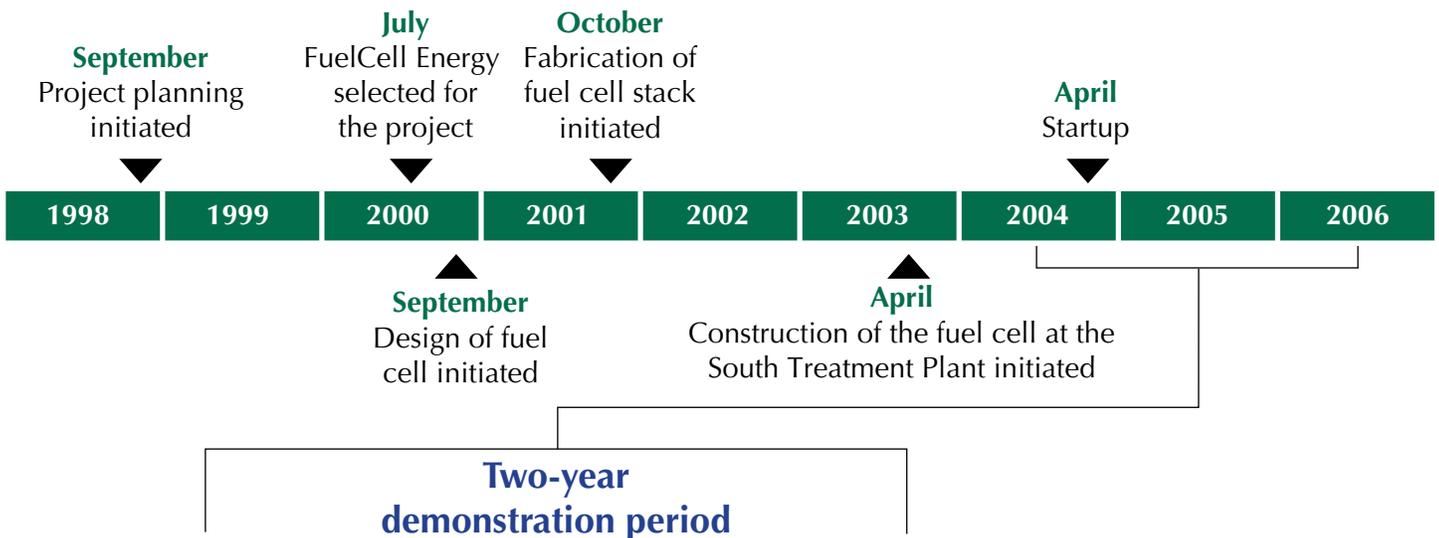
Fuel Cell Demonstration Project site at the South Treatment Plant

Working with the U.S. Environmental Protection Agency and FuelCell Energy, Inc., King County sponsored the world's largest demonstration project of a single-unit fuel cell power plant. Using digester gas from the county's South Wastewater Treatment Plant in Renton, WA, the fuel cell was operated during a two-year demonstration project. The fuel cell power plant was sized to produce 1 megawatt (MW) of electricity and designed to capture additional waste heat for recycle to the treatment plant hot water system.

King County began its investigation of fuel cells for electrical power generation in 1997. FuelCell Energy, Inc. was selected in 2000 to design and construct a molten carbonate fuel cell

power plant. Two project goals were established to measure fuel cell performance during the demonstration period – (1) demonstrate that the molten carbonate fuel cell technology can be adapted to use anaerobic digester gas as a fuel source and (2) achieve a nominal plant power output target of 1 MW (net AC) using either digester gas (DG) or natural gas (NG).

### Project Timeline



#### Operation – Year 1

- 1-MW operation on NG and DG
- Emission and noise testing
- Incorporation of auto fuel switchover
- One month waste heat recovery
- DG condensation problems

#### Operation – Year 2

- Stack failure and replacement
- Stack replaced within 30 days
- 850-kW capacity (derated from 1-MW)
- Off-line due to non-related construction
- Continued problems with DG condensate
- NG operation for remainder of project

## PROCESS FUNDAMENTALS

### How Does a Fuel Cell Work?

Fuel cells are electrochemical devices that convert chemical energy from fuels containing hydrogen directly to electricity and heat. Combustion is not needed.

Similar to a battery, a fuel cell has hundreds of individual cells. Cells are grouped to form a stack. Each fuel cell contains an anode, cathode, and electrolyte. A hydrogen-rich fuel, such as digester gas, enters each stack and reacts with oxygen in the air to produce electricity in each cell.

A typical battery has a fixed supply of energy. But fuel cells are like large continuously operating batteries that generate electricity as long as they get a fuel, such as methane, which is a large component of digester gas.

### Fuel Cell Advantages: High Efficiency, Low Emissions

Electricity is typically generated in a two-step process:

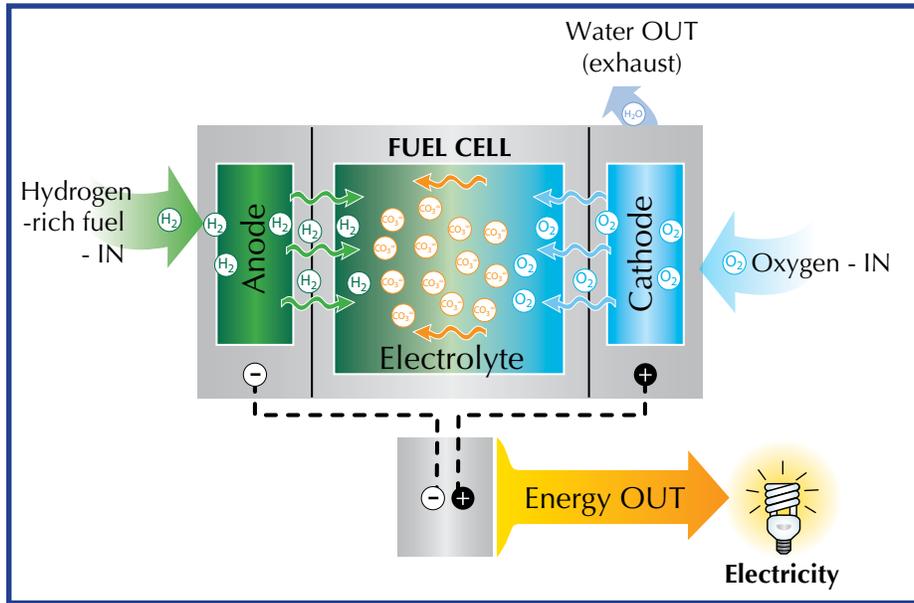
Fuel is combusted to produce mechanical energy (or heat), which then turns a generator to produce electricity. Fuel cells convert fuel directly to electricity. By dropping the mechanical energy step, fuel cells are

more efficient than traditional methods of generating electricity and produce very low emissions.

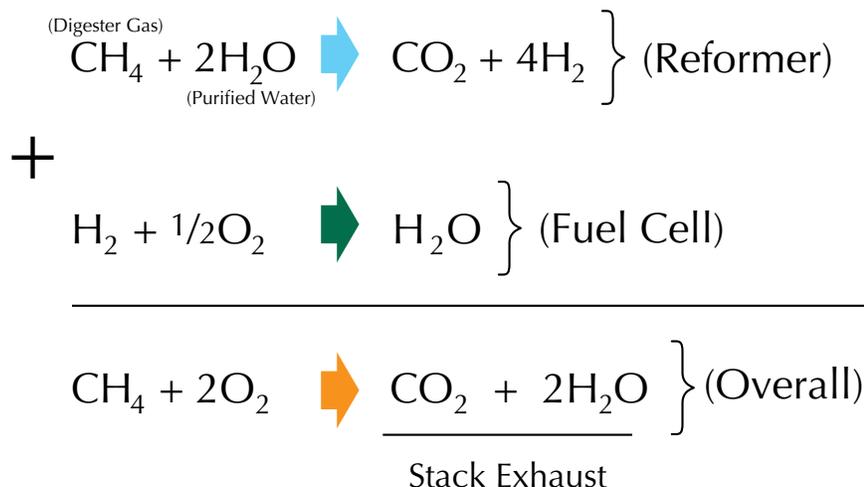
### Molten Carbonate Fuel Cells

Fuel cells are defined by their electrolyte, or the material inside them. There are five types of commercial fuel cells: solid oxide, phosphoric acid,

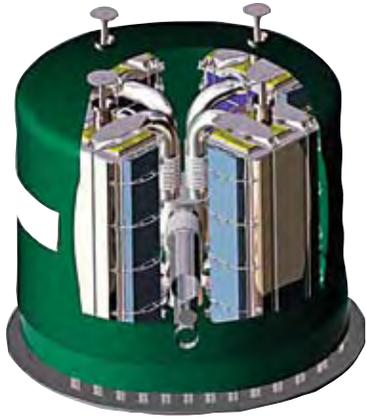
alkaline, proton exchange membrane and molten carbonate. King County's South Treatment Plant used the molten carbonate fuel cell (MCFC) which operates at 1,100° F and is designed with reforming (conversion of methane to hydrogen) incorporated into the fuel cell stack. The fuel cell power plant components included fuel scrubbing, fuel processing, power production, power inverter, and heat recovery (reference fuel cell process flow diagram).



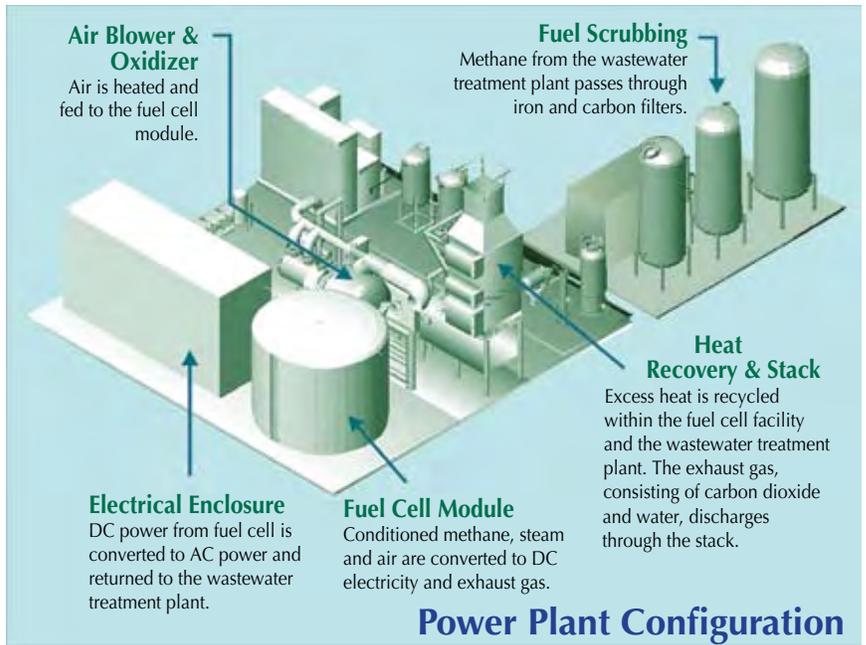
### Molten Carbonate Fuel Cell Chemistry



# DEMONSTRATION POWER PLANT OPERATION



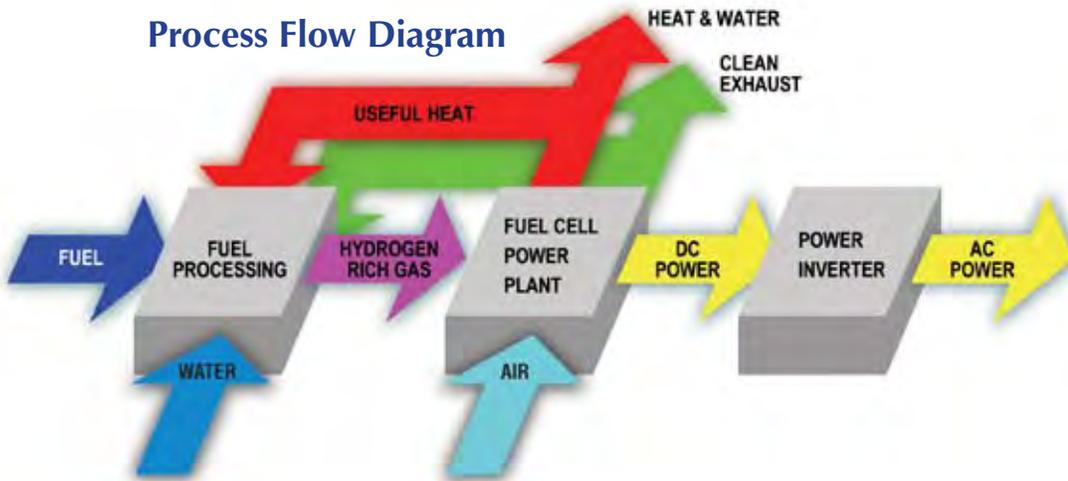
**Fuel Cell Module  
(4-stack assembly)**



**Power Plant Configuration  
(<sup>1</sup>/<sub>4</sub>-acre site at South Plant)**

Source: Brown and Caldwell

## Process Flow Diagram



## Demonstration Power Plant Operating Conditions at 1MW Net Output

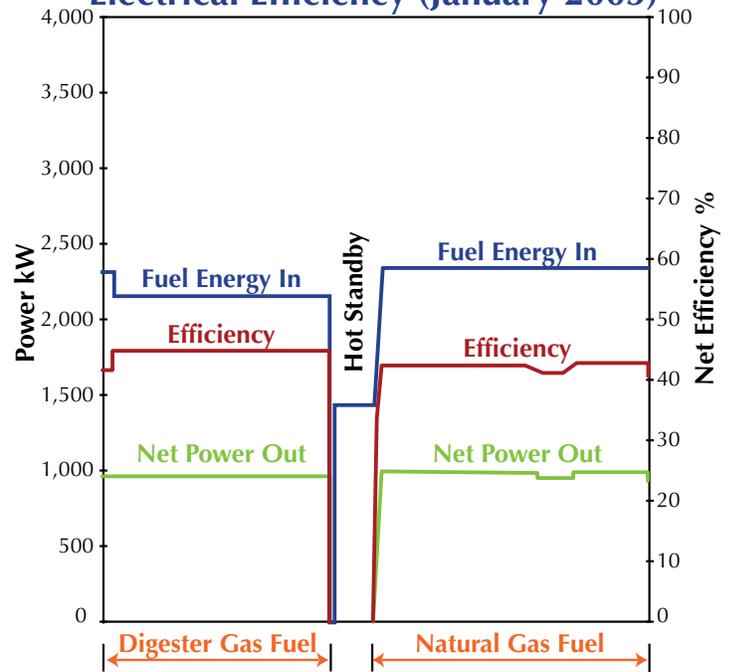
Digester Gas	
Gas Flow	225 scfm
Lower Heating Value	550 Btu/ft <sup>3</sup>
Methane Content	60 %
Carbon Dioxide Content	38 %
Natural Gas	
Gas Flow	140 scfm
Lower Heating Value	900 Btu/ft <sup>3</sup>
Methane Content	98 %
Carbon Dioxide Content	0 %
Water	
Water Flow	2.5 gpm

## DEMONSTRATION POWER PLANT OPERATION (continued)

### Demonstration Power Plant Performance

<b>Operating Time</b>	
<i>Digester Gas Fuel</i>	2,226 hr
<i>Natural Gas Fuel</i>	8,507 hr
<b>Power Generation</b>	
<i>Digester Gas</i>	2.1 million kWh
<i>Natural Gas</i>	7.1 million kWh
<b>Power Output</b>	
(2% stack de-rating every 6 months)	850 – 1,000 kW
<b>Electrical Efficiency</b>	
Digester Gas	44 – 46 %
Natural Gas	42 – 45 %
<b>Overall Efficiency</b>	
Electrical + waste heat recovery	58 – 61 %
<b>Emissions</b>	
CO	<= 13 ppm
NO <sub>x</sub>	<= 0.2 ppm
NMHC	< 1 ppm

### Fuel Cell Power Production and Electrical Efficiency (January 2005)



## DEMONSTRATION PROJECT OBSERVATIONS AND CONCLUSIONS

Based on the two-year operating period, project operation and maintenance observations include:

- The project represented a successful research and development effort.
- The power plant control system was modified to provide automated fuel source switching and to respond to process transients.
- The power plant subsystem configurations are being modified in future fuel cell designs based on the demonstration operating experience.
- Appropriate selection of a stable methane source in the wastewater treatment plant digester gas system is critical to reliable operation of the fuel cell power plant.
- The power plant had numerous components requiring frequent maintenance and high replacement cost (fuel cell stack life of < 3 years).
- The operation of the power plant was highly automated.

#### Alternative formats available

**206-684-1247 or 711 (TTY relay)**

Produced by: WLR Visual Communications and Web Unit  
File Name: 0802FuelCellSummary mdev  
Printed on recycled paper. Please recycle.

### Project Partners

FuelCell Energy of Danbury, CT (\$9.4M), the U.S. Environmental Protection Agency (\$8.6M), and King County (\$2.3M) provided financial support for the South Treatment Plant Fuel Cell Demonstration Project. The U.S. Environmental Protection Agency provided the federal funds to King County through annual cooperative agreements. The total value of the project was \$20.3 million.

CH2M HILL of Bellevue, WA, and Brown & Caldwell of Seattle, WA, provided engineering services to King County for the fuel cell project. Hawk Mechanical Contractors, Inc. of Redmond, WA, installed the fuel cell.



**King County**

Department of Natural Resources and Parks  
Wastewater Treatment Division  
Planning and Compliance Section

**Fuel Cell Demonstration Project**  
201 South Jackson Street, Suite 512  
Seattle, WA 98104-3855  
206-263-3883 or 711 (TTY relay)  
<http://dnr.metrokc.gov/wtd/fuelcell/>