V.D.6 Low-Cost Co-Production of Hydrogen and Electricity*

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Subcontractors:

- University of Alaska, Fairbanks, AK
- Udelhoven Oilfield System Services, Anchorage, AK

Project Start Date: November 13, 2006
Project End Date: November 13, 2009

*Congressionally directed project

Objectives

- Demonstrate efficient, reliable and durable solid oxide fuel cells for stationary applications.
- Demonstrate co-production of electricity and hydrogen.
- Determine the feasibility of a delivered cost of hydrogen below $2.50 per gasoline gallon equivalent (gge) by 2010.

Technical Barriers

From the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan, specific technical barriers addressed by this project are:

Section 3.4: Fuel Cells

(A) Durability

(B) Cost

(C) Performance

Section 3.6: Technology Validation

(I) Hydrogen and Electricity Co-Production

Technical Targets

TABLE 1. Progress Towards Meeting Technical Targets for Low-Cost Co-Production of Hydrogen and Electricity

Characteristic	Target	Current Status
Planar Solid Oxide Fuel Cell (PSOFC) Performance (System Efficiency)	>45% PSOFC system efficiency η = (alternating current power exported to grid)/(lower heating value of natural gas)	Achieved >45% PSOFC system efficiency in lab; Alaska site build 80% complete.
PSOFC Performance (Peak grid-tied power)	25 kW grid-tied fueled by natural gas	>25 kW grid-tied demonstrated in lab; Field demonstration planned to begin calendar Q4, 2008.
PSOFC Performance (Durability)	Operate system for 1 year in the field	Demonstrated >3,000-hour run in lab; Field demonstration planned to begin calendar Q4, 2008.
Hydrogen Purity	Sufficient purity to power a proton exchange membrane fuel cell	<4 ppm CO; <100 ppm CO_2 achieved. Higher flows and/or higher power density required to achieve purity target. Full scale unit under test Q3, 2008.
Hydrogen Production	19 kg/day peak hydrogen production by purifying PSOFC anode exhaust	Subscale hydrogen pump purified PSOFC exhaust at a rate that extrapolates to a full scale design to meet 19 kg/day. Full-scale prototype under test Q3, 2008.
Distributed Production of Hydrogen from Natural Gas	2010 Target: $2.50/gge (delivered)	Financial analysis using DOE H2A model in process.

Accomplishments

- Demonstrated rated power of 25 kW grid-tied PSOFC system fueled by natural gas using standard Bloom Energy hot box.
- All balance-of-plant components have been validated with a run exceeding 3,000 hours on original hardware.
- Demonstrated >45% PSOFC system efficiency (η).
- Operational learning from steady-state and transient conditions on natural gas was implemented into the controls code.
- Team of operators trained for round-the-clock system monitoring.

- Site readiness for one year fuel cell demonstration 80% complete: includes commercial partner selection, site design and construction, electrical and gas interconnection (utility) approval.
- Demonstrated subscale hydrogen pump performance that extrapolates to a full-scale design to meet 19 kg/day target; full-scale unit from H2 Pump, LLC built; test with PSOFC Q3, 2008.

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Introduction

Bloom Energy's fuel cell systems, when manufactured in high volume, can produce low-cost hydrogen by co-producing hydrogen and electricity simultaneously with one common set of low-cost equipment. The main objectives of this project are to 1) deliver and field test a fuel cell electricity generator in Alaska; 2) demonstrate hydrogen production from a hydrogen pump in a lab-based fuel cell system similar to that to be operated in Alaska, and 3) analyze the feasibility of a delivered cost of hydrogen below $2.50 per gge.

Approach

The project is divided into two phases. In Phase 1 we will design, build and test an electricity generator, integrated with a hydrogen purifier supplied by a vendor. The PSOFC system schematic with hydrogen byproduct is shown in Figure 1. To the extent technically feasible, as we build the PSOFC systems, we will pull standard parts and subassemblies from inventory, adding custom components to satisfy the project requirements. In Phase 2, we will demonstrate those technologies. We will operate the fuel cell system with the cooperation of a host customer in Alaska and work closely with them to gain an understanding of how this technology can solve real problems for commercial customers. A change from last year is that hydrogen production will be demonstrated at Bloom Energy's California-based laboratory. Results from the hydrogen demonstration will be independently validated by the University of Alaska, Fairbanks.

- Test a vendor-provided hydrogen pump prototype in stand-alone mode (completed).
- Analyze the volume and purity of hydrogen produced by prototype unit (completed).
- Design the integration of the vendor provided hydrogen pump production unit with our PSOFC system (completed).
- In our lab, test the hydrogen pump integrated with our PSOFC system (pending).
- Analyze the volume and purity of hydrogen produced (pending on full-scale system).
- Operate the PSOFC system in the field for twelve months (pending).
- Analyze the efficiency and availability of the fuel cell; project in-field availability and durability (pending).
- Analyze the results of PSOFC electricity and hydrogen co-production (pending).

Results

Phase 1 of this project is nearly complete. The hydrogen production system design and hardware build are complete. Fuel cell site readiness is 80% complete. Site readiness for the hydrogen production demonstration is complete. Phase 2 is the upcoming system and hydrogen pump demonstration.

Fuel Cell Site Readiness

The fuel cell demonstration site in Anchorage, Alaska was designed and permitted in Q1, 2008. Construction began in April. As of July, 2008, construction is nearly complete. Chugach Electric, the local electric cooperative (utility), has approved the electrical interconnection.

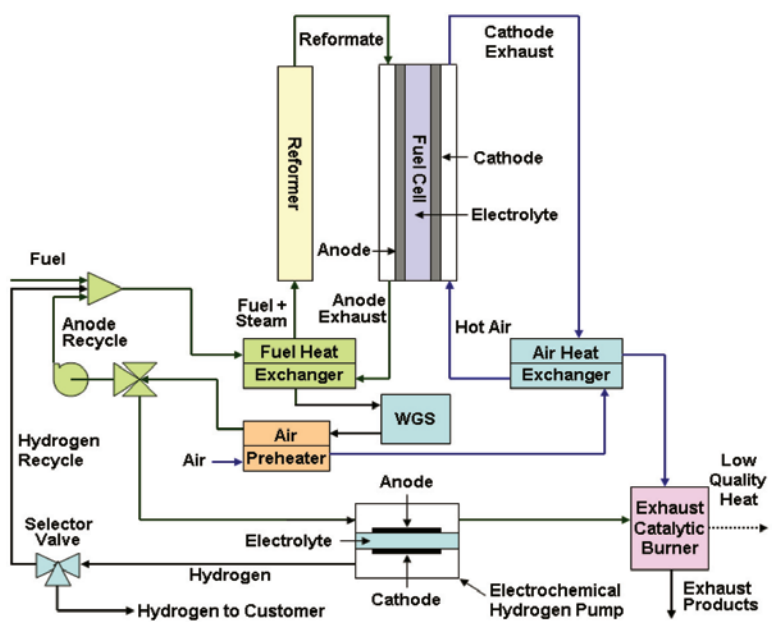

FIGURE 1. PSOFC System Schematic with Hydrogen Byproduct

Hydrogen Pump System Design

A hydrogen pump from H2 Pump, LLC of Latham, New York was chosen as the demonstration vehicle for the hydrogen production portion of the project. A small-scale H2 Pump product was validated at Bloom Energy's laboratories. To test the sub-scale (15-cell) H2 Pump, anode exhaust from a Bloom Energy PSOFC stack was directed to the hydrogen pump inlet and current applied to the pump. Hydrogen output flows were measured as were the power and fuel utilization data. Gas purity measurements were performed at the inlet and outlet of the device as shown in Figures 2-4.

The small-scale hydrogen pump demonstrated that hydrogen pumping: 1) is scalable; 2) has high electrochemical efficiency (low power required/kg H_2) ~$0.12/kg H_2 at $0.10/kWh electrical costs; 3) is a continuous flow device having a near infinite turn down ratio with minimal parasitics when not pumping hydrogen; 4) can pump hydrogen on demand; and 5) can create the required system pressure (up to ~5 psig).

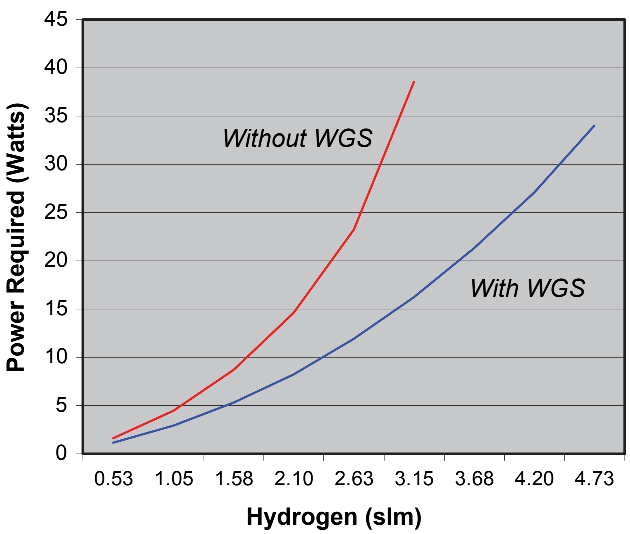

FIGURE 2. Power Required to Pump Hydrogen with and without Water-Gas Shift (WGS) Reactor

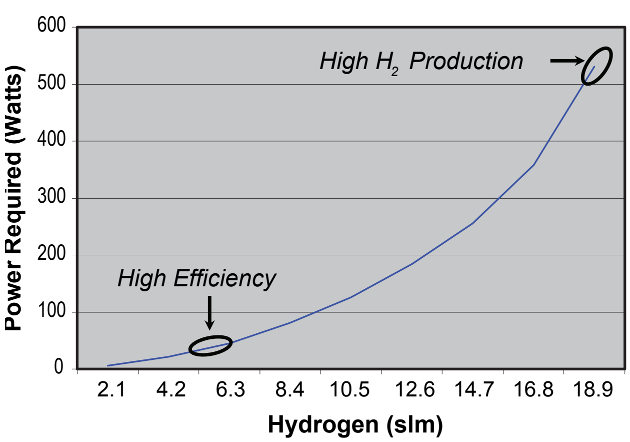

FIGURE 3. H2 Pump Capability with WGS

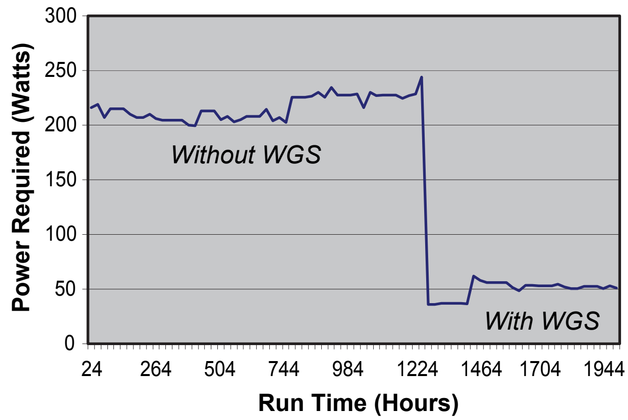

FIGURE 4. Pump Daily Power Readings

The 15-cell sub-scale hydrogen pump performance extrapolated to a 120-cell full-scale pump to meet the project goal of producing 19 kg/day when the fuel cell is operated for high hydrogen production.

Testing with an H2 Pump showed that with Bloom Energy PSOFC anode exhaust gas composition, 980:1 reduction in CO_2 and 2,600:1 reduction in CO from input to outlet was achievable at low power. Therefore, a 10% CO_2 on the inlet will result in ~100 ppm CO_2 at the outlet and 1% CO in the inlet will result in ~4 ppm while operating at low power. Higher power/higher flows for hydrogen production will increase the purity, proportional to flow and proportional to the square root of power.

From the results of the 15-cell pump testing, system design and readiness for the 120-cell, full-scale H2 Pump testing was completed. The full-scale H2 Pump has been built and is in final test at the vendor. Bloom Energy is readying a system similar to the fuel cell to be delivered to Alaska in which the full-scale product will be demonstrated.

In anticipation of hydrogen testing at the Bloom Energy facility, a complete Hydrogen Safety Review was completed and submitted to the Project Officer in June, 2008.

Conclusions and Future Directions

Next steps in this project include the following:

- Complete site construction.
- Install PSOFC system at Anchorage, Alaska facility.
- Electrical interconnection of PSOFC system to commercial facility and Chugach Electric grid and operate for one year.
- Large-scale hydrogen pump integrated into lab-based PSOFC system in California and tested.