VII.14 Fuel Cell Power Model: Evaluation of CHP and CHHP Applications

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Project End Date: Project continuation and direction determined annually by DOE

Objectives

- Accurately model performance of stationary fuel cells in combined heat and power (CHP) and combined heat, hydrogen, and power (CHHP) applications.
- Combine detailed performance information with a comprehensive discounted cash flow methodology to evaluate lifecycle costs.

Technical Barriers

This project addresses the following technical barriers from the Systems Analysis section (4.5) of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(B) Stove-piped/Siloed Analytical Capability

(C) Inconsistent Data, Assumptions and Guidelines

(E) Unplanned Studies and Analysis

Contribution to Achievement of DOE Systems Analysis Milestones

This project will contribute to achievement of the following DOE milestones from the Systems Analysis section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

- Milestone 26: Annual model update and validation. (4Q, 2010)
- Milestone 39: Annual update of analysis portfolio. (4Q, 2010)

Accomplishments

- Published Version 1.2 of the Fuel Cell Power Model.
- Provided presentations, webinars, and one-on-one guidance to train Fuel Cell Power Model users.
- Used the Fuel Cell Power Model in support of a wide range of actual and proposed fuel cell installations as well as theoretical research projects.
- Analyzed the effect of additional fuel for CHHP system hydrogen overproduction, finding that using additional fuel to boost hydrogen production reduces hydrogen cost.
- Compared fuel cell CHHP and steam methane reforming (SMR) hydrogen production strategies, finding that hydrogen production from CHHP is less expensive than from SMR for small-scale systems.
- Modeled a case study of a system combining dairy farm digester gas and fuel cell CHP, finding a payback time of about 7 years with an 8.5% internal rate of return (IRR) and emissions savings of about 750 g CO_2eq/kWh electricity generated.

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Introduction

The U.S. Department of Energy's H2A platform is a Microsoft Excel–based economic analysis model that provides transparent, consistent, and comparable results for DOE's hydrogen modeling efforts. H2A hydrogen production and delivery models geared toward use of hydrogen as a vehicle fuel have been in use for several years. However, stationary fuel cell systems that produce electricity, heat, and hydrogen–known as "tri-generation" systems–also offer potential advantages: lower hydrogen production cost, inherently distributed hydrogen production, lower fossil energy use and greenhouse gas (GHG) emissions, reduced electricity transmission congestion, lower capital investment risk, and backup power functionality. DOE views tri-generation systems as critical for early fuel cell market transformation and requires modeling to evaluate the potential costs and benefits. This need resulted in creation of the Fuel Cell Power Model. Because the Fuel Cell Power Model is based on the H2A platform, it can be used for cross-cutting analysis in conjunction with other DOE tools, including the H2A production and delivery models, H2A Delivery Scenario Analysis Model (HDSAM), Macro System Model (MSM), Hydrogen Demand and Resource Analysis (HyDRA), and Scenario Evaluation, Regionalization and Analysis (SERA).

The Fuel Cell Power Model analyzes the technical and economic aspects of high-temperature fuel cell–based tri-generation systems in CHP and CHHP applications. This type of system would provide onsite-generated heat and electricity to large end users such as hospitals and office complexes. The hydrogen produced could be used for fueling vehicles or stored for later conversion to electricity. In the model, users select which technologies are used in the system–such as hydrogen fuel cells, photovoltaic panels, and electrolyzers–and define each technology's cost and performance parameters (Figure 1). Users also select fuel costs and, for the phosphoric acid fuel cell system, demand priority (i.e., whether the system follows electricity or heat demand) and can accept default financial parameters or enter custom parameters. Hourly electricity, heat, and hydrogen demand profiles and renewable energy supply profiles can be entered or selected from databases. The model uses the inputs, default values and calculations, and a standard discounted cash flow rate of return methodology to determine the cost of delivered energy, with reference to a specified after-tax IRR. It also determines the amount and type of energy input and output and the associated GHG emissions. Version 1.2 of the Fuel Cell Power Model was completed in Fiscal Year (FY) 2010. Training was provided to Fuel Cell Power Model users, and the model was used to analyze a variety of CHP and CHHP applications.

Approach

The potential advantages of a fuel cell–based tri-generation system depend on numerous variables, including the type of building/application using the system, geographic location, utility grid interaction, financial assumptions, and economic incentives. To evaluate the cost of producing electricity, heat, and hydrogen accurately, the Fuel Cell Power Model analyzes energy supply and demand for each hour over the course of a year. Case studies demonstrate

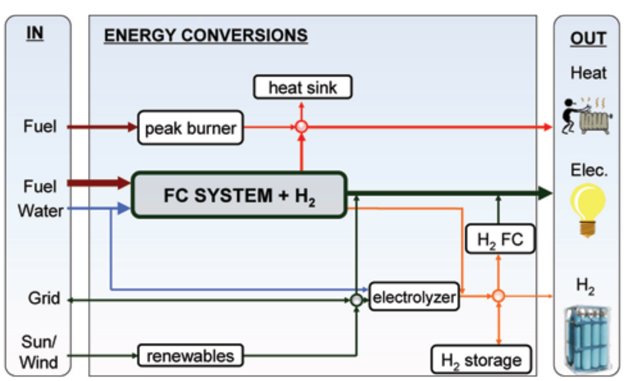

FIGURE 1. Fuel Cell Power Model Tri-Generation System Component-Selection Diagram

the model's functionality and value for modeling various applications and tri-generation regimes. The enhancements to Version 1.2 of the model enable financial decision-makers to evaluate the business case for a CHP or CHHP installation using a variety of financial metrics.

Results

Version 1.2 of the Fuel Cell Power Model was completed, which included the following enhancements:

- A single simple-to-use home for business case analyses, including calculating: cost without IRR, simple payback period, solutions for different variables (e.g., IRR, net present value), total lifecycle cost, benefit-to-cost ratio, and savings-to-investment ratio.
- Enhanced presentation of financial output from the model.
- More accurate evaluation of the "baseline" system (building energy costs prior to installation of the fuel cell system).
- Enhanced differentiation between technical operating and cost parameters and financial parameters, providing financial analysts with a more streamlined user interface dedicated to financial analysis.

Training and support was provided to Fuel Cell Power Model users, including presentations, webinars, and one-on-one guidance. Market transformation analyses were completed for several commercial and government entities. In addition, a variety of organizations used the Fuel Cell Power Model to support a wide range of actual and proposed fuel cell installations as well as theoretical research projects, including the following:

- National Renewable Energy Laboratory campus
- NASA Ames Research Center
- Los Alamitos Military base
- U.S. Postal Service Distribution Facility, San Francisco
- Materials and Systems Research, Inc.
- Sandia National Laboratories/Lawrence Livermore National Laboratory campus
- Three stores in a large grocery chain
- Five large food-processing facilities
- DOE generic scenario studies
- Spatial model development for deployment in conjunction with SERA
- Biogas case studies

Among the DOE studies conducted using the Fuel Cell Power Model was an analysis of the effect of additional fuel for CHHP system hydrogen overproduction; the study found that using additional fuel to boost hydrogen production reduces hydrogen cost. Another study compared fuel cell CHHP and SMR hydrogen production strategies, finding that hydrogen production from CHHP is less expensive than from SMR for small-scale systems (Figure 2).

A case study was developed for a system combining dairy farm digester gas and fuel cell CHP (Figure 3).

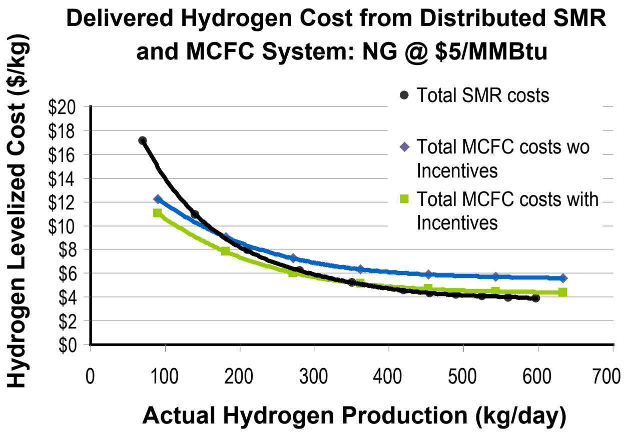

FIGURE 2. Delivered cost from distributed SMR and molten carbonate fuel cell systems at various levels of hydrogen production, with a natural gas price of $5/MMBtu.

Input data included capital costs, operation and maintenance costs, expected life, and performance of the digester, gas cleanup, and fuel cell components; applicable government incentives; on-site energy demands; and energy costs. Using these data, the Fuel Cell Power Model showed a payback time of about 7 years with an 8.5% IRR. It also showed a GHG emissions reduction of about 750 g CO_2eq/kWh electricity generated, primarily owing to less GHG-intensive manure management and displacement of grid electricity (Figure 4).

Conclusions and Future Directions

In FY 2010, Fuel Cell Power Model efforts focused on three areas: improving the model's analytical capabilities (including the completion of Version 1.2), training and supporting the model's user community, and performing analyses using the model. Future work may include the following:

- Enhance the Fuel Cell Power Model in response to needs identified through its user community.
- Enhance the model's business case analysis capabilities using experience from the business community.
- Develop additional case studies, with data from actual fuel cell installations for comparison.

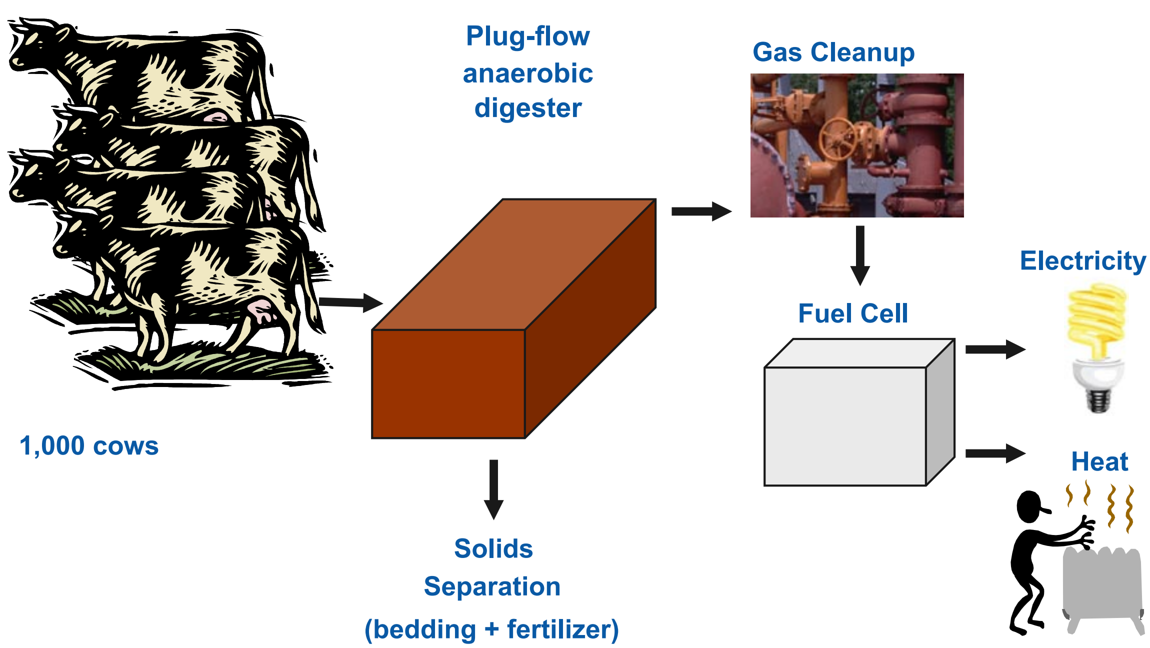

FIGURE 3. Schematic of the Case Study System Combining Dairy Farm Digester Gas and Fuel Cell CHP

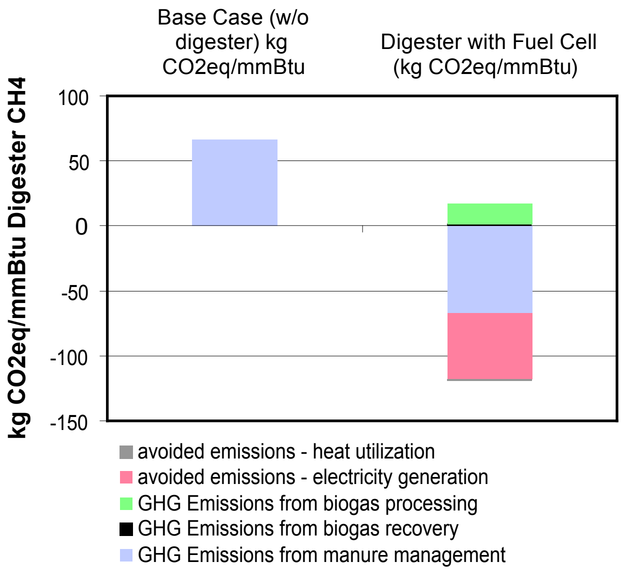

FIGURE 4. GHG emissions comparison of case study digester/fuel cell system versus a baseline system for manure management.

- Use the Fuel Cell Power Model to evaluate early hydrogen transition scenarios and the potential effects on electricity systems and GHG emissions.
- Add analysis capabilities for solid oxide fuel cells and residential-sized systems to the Fuel Cell Power Model.
- Integrate the Fuel Cell Power Model with DOE's MSM and SERA.

FY 2010 Publications/Presentations

1. Steward, D. *Fuel Cell Power Model for CHHP System Economics and Performance Analysis,* NREL/PR-560-47123, Delivering Renewable Hydrogen Workshop – A Focus on Near-Term Applications Palm Springs, CA, November 16, 2009.

2. Steward, D. and Penev, M. *Fuel Cell Power Model for CHP and CHHP Economics and Performance Analysis,* NREL/PR-560-47915, Electric Utility Consultants, Inc. webinar, March 30, 2010.

3. Steward, D. *Fuel Cell Power Model for CHHP System Economic Analysis,* California Hydrogen Business Council Meeting, March 4, 2010.