V.A.8 Enlarging the Potential Market for Stationary Fuel Cells Through System Design Optimization

Chris Ainscough (Primary Contact), Sam Sprik, Michael Penev
National Renewable Energy Laboratory (NREL)
15013 Denver West Parkway
Golden, CO 80401-3305
Phone: (303) 275-3781
Email: chris.ainscough@nrel.gov

DOE Manager
HQ: Kathi Epping Martin
Phone: (202) 586-7425
Email: Kathi.Epping@ee.doe.gov

Subcontractor:
University of California Irvine, Irvine, CA (planned)

Project Start Date: January 1, 2011
Project End Date: Project continuation and direction determined annually by DOE

Fiscal Year (FY) 2012 Objectives

- Develop a complete stationary fuel cell model user's guide including:
  - Operational details on the model with guidance on appropriate inputs.
  - Documentation of control strategy algorithms.
  - Instructions on operating and configuring each of the model's component modules.
  - Documentation of energy equations used.
  - Distributed generation system specifications.
- Develop a detailed plan and prioritized list of proposed additional features and enhancements to the model, in concert with stakeholders at DOE, industry, and academia.
- Build a tool for optimizing fuel cell attributes, including control parameters, and system and component sizes for unique individual building characteristics. The tool is flexible for adding user-defined building, fuel cell, financial, control characteristics.
- Use the tool to minimize lifecycle cost, lifetime greenhouse gas (GHG) emissions, or installed capital costs of fuel cell installations.
- Characterize the largest segments of the U.S. building inventory for use in the tool, leveraging the Commercial Building Energy Consumption Survey building survey.
- Characterize building control systems and include in the tool advanced control strategies for integrating fuel cell systems and building control systems.
- Validate the model outputs against real-world data from stationary fuel cell installations.

Technical Barriers

This project addresses the following technical barriers from Fuel Cells section (3.4) of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(C) Performance
(B) Costs

Technical Targets

TABLE 1. Technical Targets that Will Be Evaluated as Parameters in the Stationary Fuel Cell Model

Excerpted from the 2011 Multi-Year Research, Development and Demonstration Plan, Table 3.4.6 Technical targets: 100 kW–3 MW Combined Heat and Power (CHP) and Distributed Generation Fuel Cell Systems Operating on Natural Gas.				
Characteristic	**Units**	**2011 Status**	**2015 Targets**	**2020 Targets**
Electrical efficiency @ rated power	% LHV of input fuel	42–47	45	>50
CHP energy efficiency	%	70–90	87.5	90
Installed cost, natural gas	$/kW	3,500–5,000	3,000	1,500
Number of planned/forced outages over lifetime	Count	50	50	40
Operating lifetime	Thousand hours	40–80	50	80

LHV – lower heating value

FY 2012 Accomplishments

- Implemented the model in a scalable, flexible, modular framework that allows for easy customization in the future by non-programmers.
- Developed a stable graphical user interface (GUI).
- Completed a detailed user guide for the model and incorporated it into the GUI.
- Developed a detailed plan and prioritized list of additional features and enhancements.

- Incorporated model building profiles for 16 different building types in 16 climate zones for three different vintages (768 total), which represent 67% of the U.S. commercial building inventory.
- Synchronized with other DOE-funded projects at Lawrence Berkeley National Laboratory, Strategic Analysis, Inc., and Battelle in order to lay the groundwork for incorporating their cost models.

✧ ✧ ✧ ✧ ✧

Introduction

According to DOE, 80% of the current U.S. building stock will still be in use in the year 2050. For fuel cells to penetrate the stationary market in significant numbers, retrofitting existing buildings with stationary fuel cells must be an important part of the U.S. strategy. This means that systems must be appropriately sized for today's heat and power loads, with some consideration for the energy demands of future construction.

The objective of this project is to construct a software model including proton exchange membrane (PEM), high temperature PEM, molten carbonate, phosphoric acid, and solid oxide fuel cells to optimize sizing and control strategies for particular building types and sizes and geographic locations. This model will be further enhanced with more fuel cell types, more control strategies, optimization capabilities, and further refinements to the user interface and post-processing capability.

Approach

The model is implemented in a scalable, flexible modular MATLAB® framework. The model includes modules for the model buildings (768 so far), control strategies, fuel cell systems, economic inputs, manufacturing cost models, and feedstock costs (electricity and natural gas).

In order to synchronize with other work in industry, the project team is building strong links to other DOE projects that will provide the manufacturing volume models for 1, 5, 25, and 100 kW systems in manufacturing rates of 100, 1,000, 10,000, and 50,000 annually. In addition, NREL is working with stationary fuel cell original equipment manufacturers to incorporate their feedback on the model and allow them the opportunity to test a beta version.

Results

The project team has created a detailed fuel cell model that includes a number of user-customizable modules, which will enable the use of the model for large-scale analysis and simulations, and highly detailed planning and engineering of proposed installation sites.

The Stationary Fuel Cell Model is designed to allow the operator to assess the economics of installing stationary fuel cell systems in a variety of building types in the United States. The model allows the user to select from among four different dispatch strategies to attain different goals: cost minimization, GHG minimization, load following, and peak shaving.

The model contains 16 reference building load profiles, both electric and heat, in 16 different climate zones, with three different vintages. Combined, this allows the user to select from up to 768 different building scenarios.

The user can also control hour-by-hour summer and winter electric grid pricing scenarios, economic factors, and manufacturing costs, along with natural gas prices.

The main screen of the model allows the user to add and configure modules, and explore different views of the building heat and electricity loads. This is shown in Figure 1.

The fuel cell modules in the model are designed to allow the user to easily update, change, and copy in order to add new and different types of fuel cells and other non-fuel cell CHP systems (see Figure 2).

Figure 3 shows an example of the manufacturing cost models NREL will incorporate from other DOE projects. These models include cost as a function of system size and annual manufacturing volume.

Figure 4 shows the main output screen from the model. This allows the user to quickly compare the lifetime fuel and electricity costs of the building with and without the fuel cell system. Often the fuel cell will result in significantly higher fuel costs, but reduced electricity costs often result in a net savings on energy consumption.

Conclusions and Future Directions

NREL has created a flexible software model that will help fuel cell developers and DOE assess the ability of stationary fuel cell systems to penetrate the existing commercial building market in the United States.

For future work, NREL will expand the available fuel cell types, implement design of experiments and optimization capability, improve the execution speed, work with other DOE projects to continue including cost models, and provide input to the Commercial Building Energy Consumption Survey 2012 survey.

FY 2012 Publications/Presentations

1. *Enlarging the Potential Market for Stationary Fuel Cells Through System Design Optimization*, presented at DOE Annual Merit Review, May 14–18, 2012, Washington, D.C.

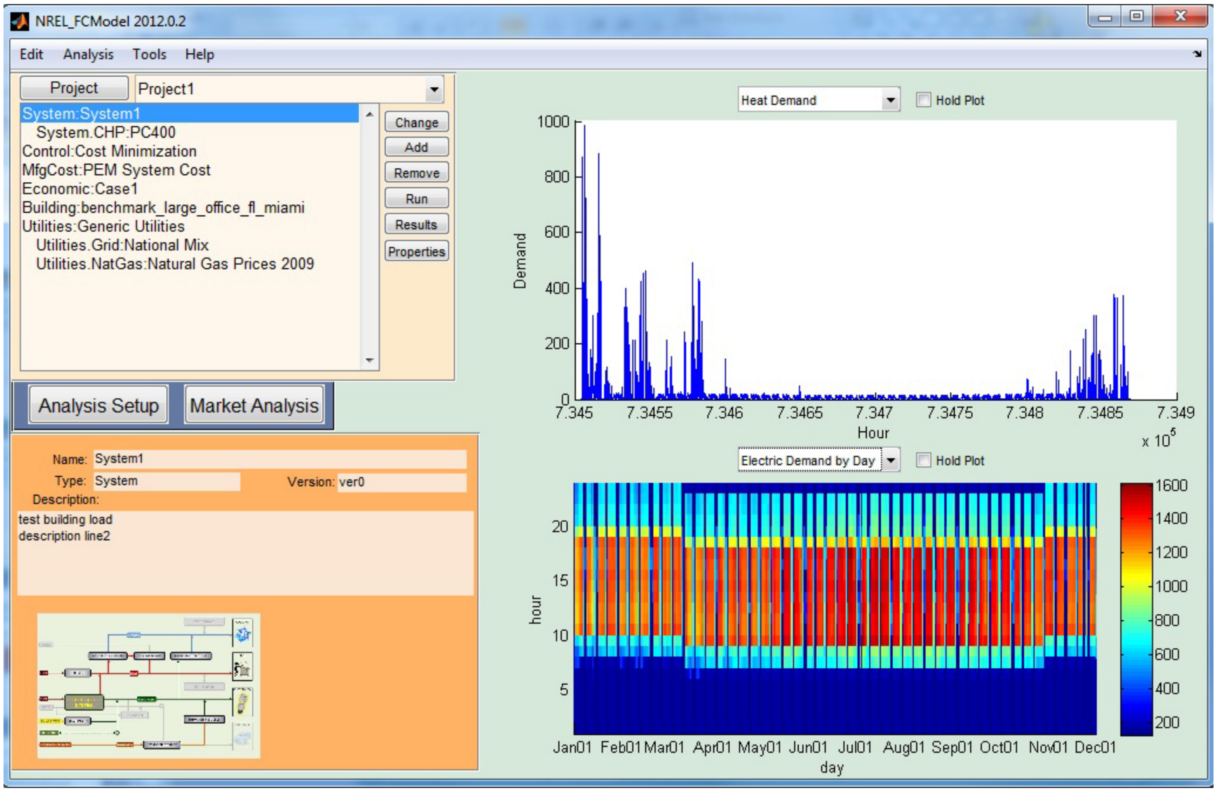

FIGURE 1. The main model screen, which consists of four panels that allow users to specify modules, see building profiles, and see component data

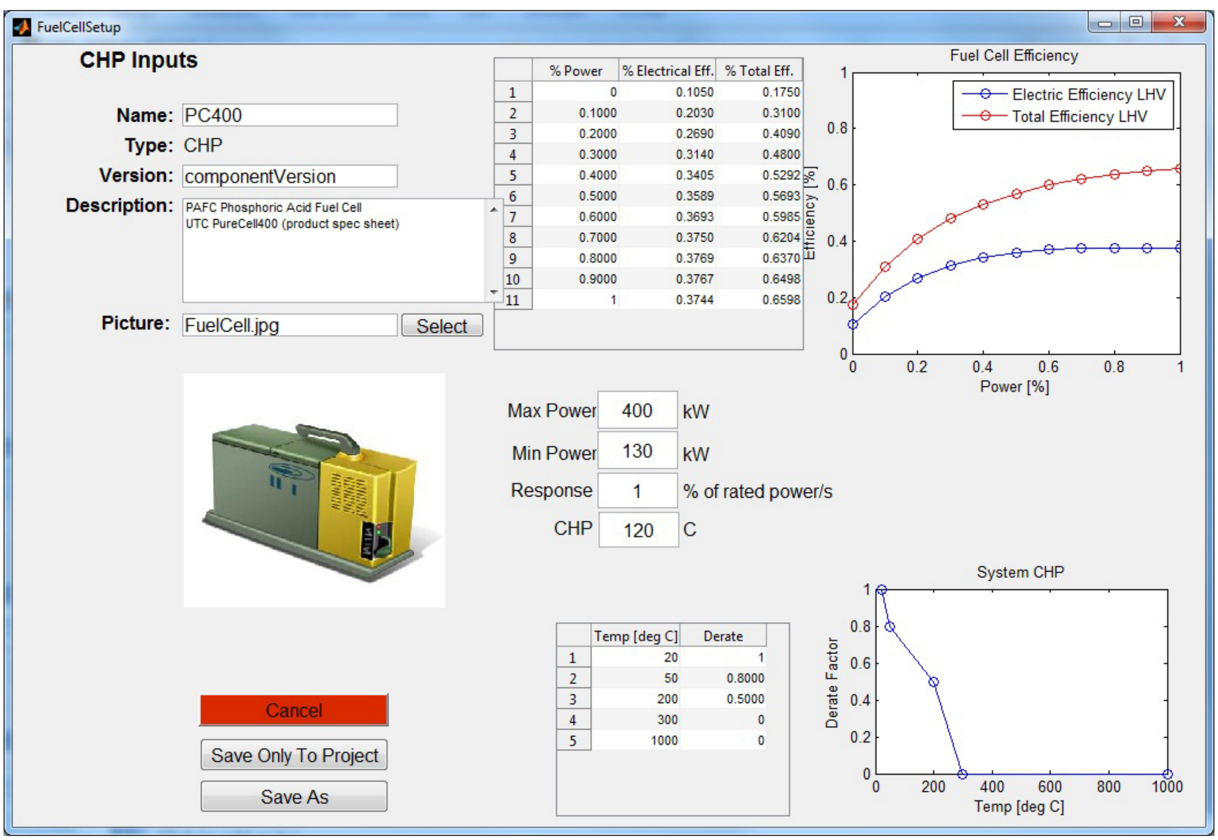

FIGURE 2. The fuel cell module allows users to quickly modify the fuel cell (or other CHP system) behavior and performance

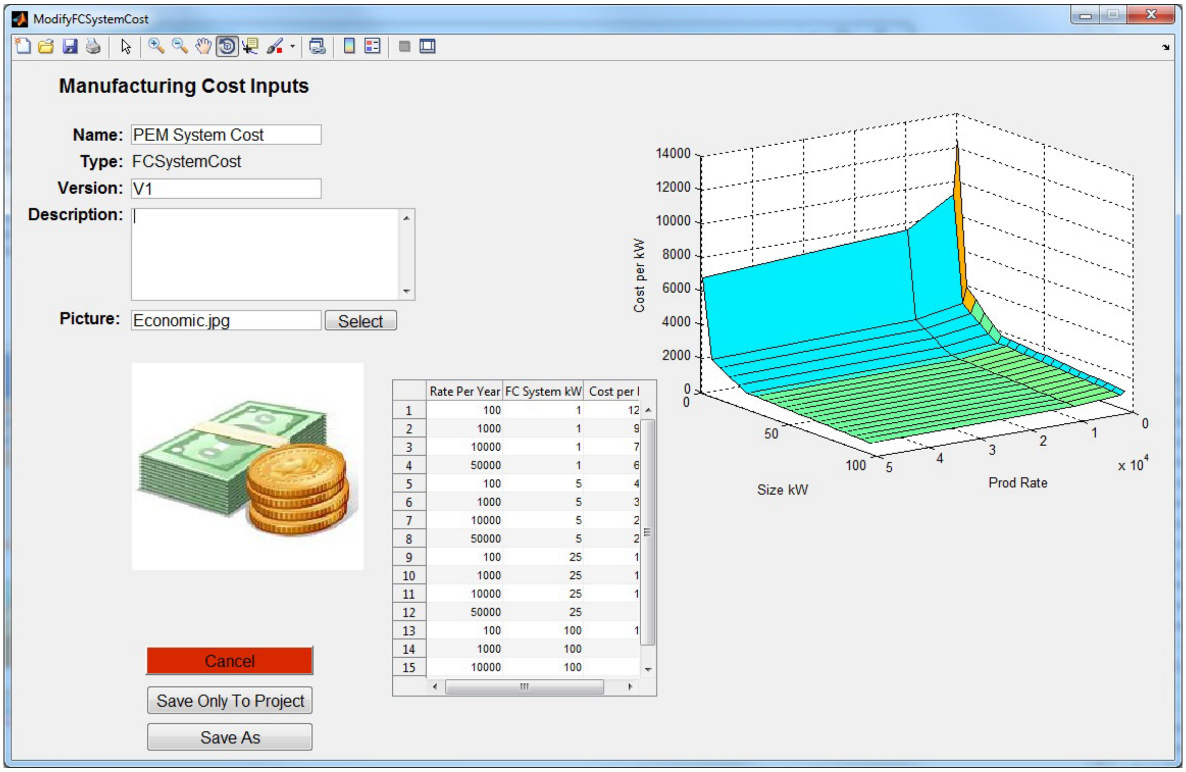

FIGURE 3. Manufacturing cost surfaces will be imported from other DOE projects performing detailed cost analysis

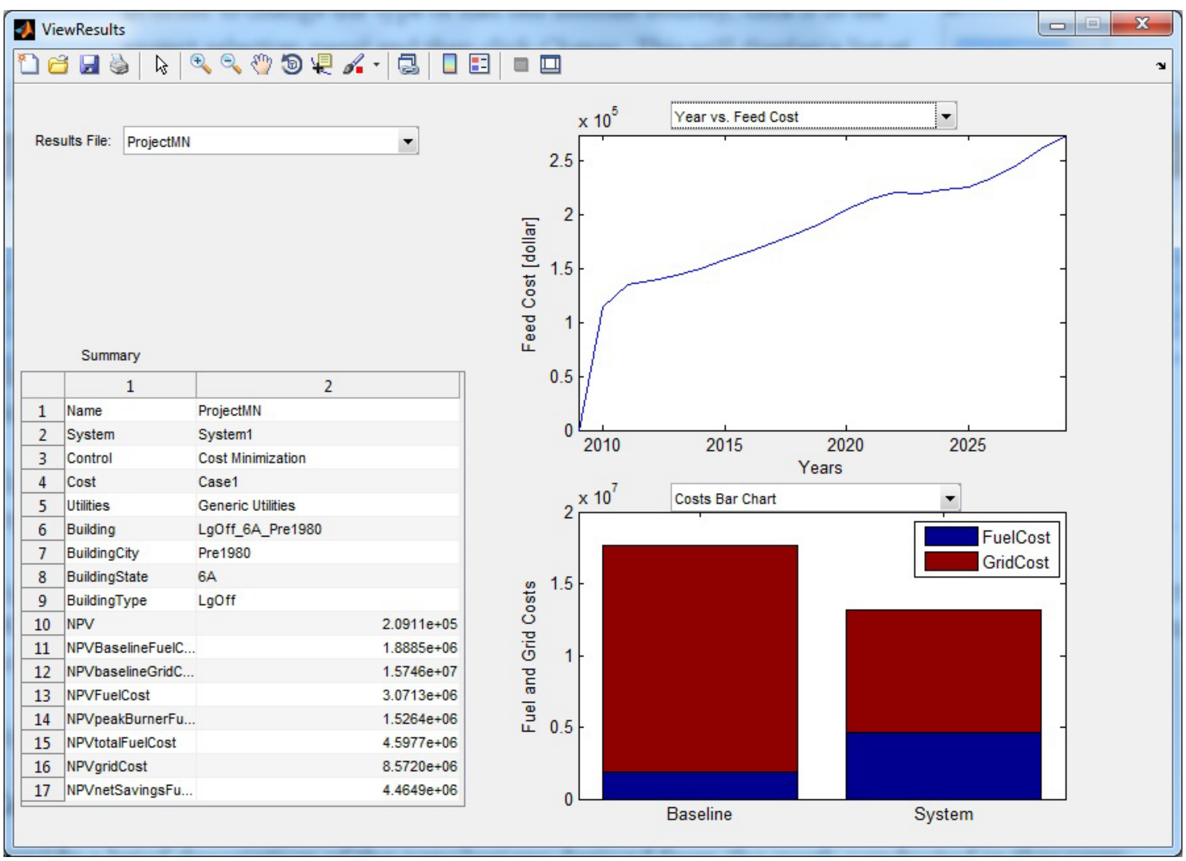

FIGURE 4. The model output screen allows users to quickly evaluate the viability of a fuel cell installation relative to the existing building baseline