

VII.9 Adapting the H2A Hydrogen Production Cost Analysis Model to Stationary Applications

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Technologies Program Multi-Year Research,
Development and Demonstration Plan:

- **Milestone 5:** Complete analysis and studies of resource/feedstock, production/delivery and existing infrastructure for various hydrogen scenarios. (4Q, 2009)
- **Milestone 26:** Annual model update and validation. (4Q, 2009)
- **Milestone 39:** Annual update of analysis portfolio. (4Q, 2009)

Accomplishments

- Completed all modifications and additional functionality identified in the scope of work.
- Published Version 1.1 of the H2A Power Model.
- Used case studies to demonstrate the enhanced functionality of Version 1.1 and its value for modeling systems in various geographic locations and building types.



Objectives

- Expand the H2A Power Model's capabilities to enhance modeling and evaluation of stationary combined production of electricity, heat, and hydrogen.
- Use case studies to demonstrate the enhanced H2A Power Model's functionality and value for modeling systems in various geographic locations and building types.

Technical Barriers

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

- (B) Stove-piped/Siloed Analytical Capability
- (C) Inconsistent Data, Assumptions and Guidelines
- (D) Suite of Models and Tools
- (E) Unplanned Studies and Analysis

Contribution to Achievement of DOE Systems Analysis Milestones

This project is contributing to achievement of the following DOE milestones from the Systems Analysis section of the Hydrogen, Fuel Cells and Infrastructure

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 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. As a result, the H2A platform was adapted to create the H2A Power Model.

The H2A Power Model analyzes the technical and economic aspects of high-temperature fuel cell-based tri-generation systems. 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 demand priority (i.e., whether the system follows electricity or heat demand) and can accept default H2A 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 internal rate of return. It also determines the amount and type of energy input and output and the associated greenhouse gas emissions. Version 1.0 of the H2A Power Model was completed in Fiscal Year 2008. A second fuel cell system (molten carbonate) was added in Version 1.1. Version 1.1 also expands the input options and enhances energy and cost output information for tri-generation systems.

Approach

The potential advantages of a fuel cell-based tri-generation system depend on numerous variables, including the type of building 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 H2A Power Model analyzes energy supply and demand for each hour over the course of a year. The enhancements to Version 1.1 enable the model to perform this hourly analysis more accurately and with more flexibility with regard to fuel cell and renewable electricity technologies used, building energy demand, costs, and revenues. Case studies evaluated

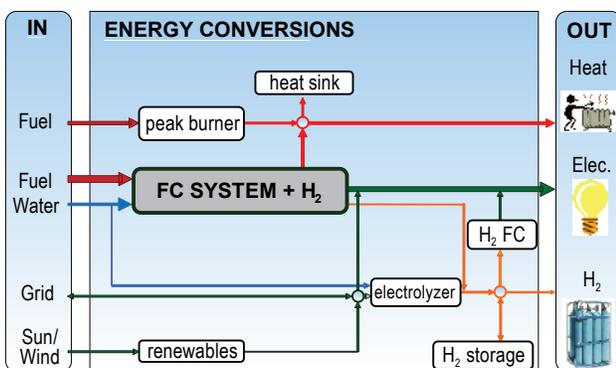


FIGURE 1. H2A Power Model tri-generation system component selection diagram. The user need not use all energy conversion technologies; for example, a standalone fuel cell system can be evaluated.

using Version 1.1 demonstrate the model's functionality and value for modeling systems in various geographic locations and building types.

Results

The following enhancements were added to Version 1.1 of the H2A Power Model:

- Standard building load profile import capability
- Solar and wind resource data import capability
- Individual depreciation for all components
- Economic incentives analysis
- Detailed grid power purchase structure
- Net metering functionality
- Greenhouse gas tables from GREET 1.8b
- Financial summary sheet
- Sensitivity analysis/tornado charts
- Choice of phosphoric acid or molten carbonate fuel cell system

In addition, a user guide was produced and training was provided for an initial group of users. Feedback from a first round of peer review was incorporated into the model. A second round of peer review is ongoing.

Version 1.1 was used to analyze the influence of building type and geographic location on the economics of tri-generation systems. Electricity and heat demand profiles from the National Renewable Energy Laboratory's building systems model were entered for high schools, hospitals, large office buildings, large hotels, and supermarkets in six U.S. cities representing six climate zones. The buildings' electricity demand included air conditioning, and heat demand included space and hot water heating.

These analyses provided insight into the optimal size of the fuel cell system as a function of building type and location; Figure 2 shows an example analysis. Climate was shown to influence the cost of energy because of its effect on fuel cell utilization; Table 1 and Figure 3 show an example analysis. The impacts of electricity and natural gas prices on the cost of hydrogen were also shown: when electricity prices are high, electricity produced by the fuel cell can be "priced" higher, thus reducing the cost of hydrogen; when natural gas prices are low, the fuel cell tri-generation system produces electricity, heat, and hydrogen for a lower cost.

Conclusions and Future Directions

Version 1.1 of the H2A Power Model was developed. Improvements over the previous version enable more accurate and flexible analysis of hourly energy supply and demand and the resulting cost of

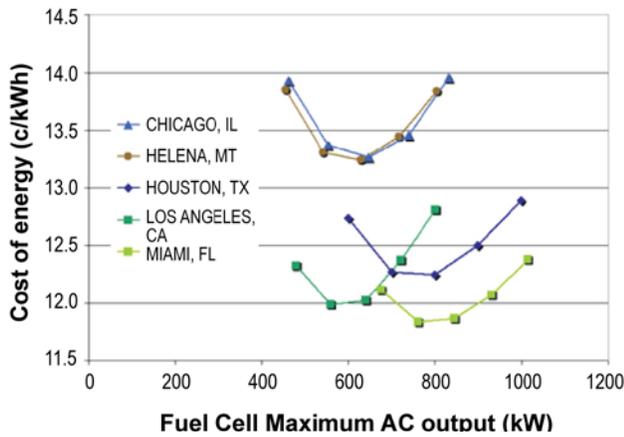


FIGURE 2. H2A Power Model results showing the cost of energy from a tri-generation system as a function of fuel cell maximum electricity output for hospitals in different cities/climate zones.

TABLE 1. H2A Power Model comparison of fuel cell size, hydrogen delivered, and fuel cell utilization for hospitals in different cities/climate zones showing higher fuel cell utilization in warmer climates.)

	Fuel Cell Size (kW)	Hydrogen Delivered (kg/day)	Fuel Cell Utilization (AC Output/Max AC Output)
MIAMI	846	328	81.2%
HOUSTON	799	296	78.0%
LOS ANGELES	640	236	77.4%
HELENA	629	225	75.3%
BALTIMORE	684	244	75.2%
CHICAGO	646	230	74.9%

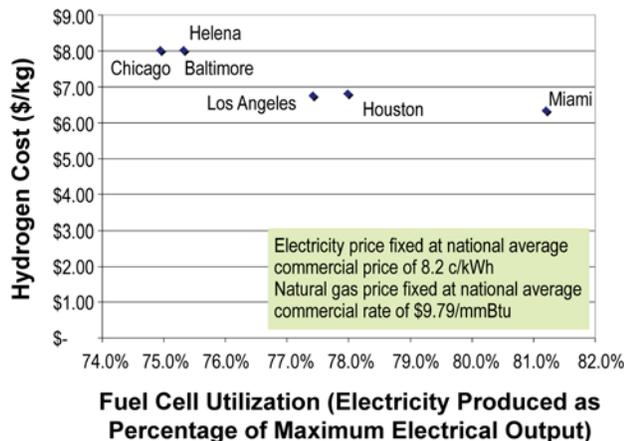


FIGURE 3. H2A Power Model results showing lower hydrogen cost for cities in warmer climates with higher fuel cell utilization.

hydrogen, heat, and electricity. Version 1.1 was used to analyze the influence of building type and geographic location on the economics of tri-generation systems. This information can be used to evaluate where and for what building applications tri-generation systems would be most economic.

Future work includes continuing to improve the functionality of the H2A Power Model: results from an extensive second round of peer reviews will be incorporated into the model, and the ability to model absorption chillers will be added. Model training and documentation will be made available, and ongoing support and maintenance will be performed.

The H2A Power Model will continue to support DOE analysis of hydrogen infrastructure implementation scenarios and market transformation strategies. The model also will be integrated with DOE’s Macro Systems Model.

FY 2009 Publications/Presentations

1. H2A Power Model Presentation, presented at the Transportation and Stationary Power Integration Workshop, Phoenix, Arizona, November 27, 2008.
2. H2A Power Model Presentation, presented at the CHBC General Meeting, Diamond Bar, California, December 11, 2008.
3. H2A Power Model Presentation, presented at the Association of Energy Engineers Southern California Chapter Meeting, March 12, 2009.
4. The Influence of Building Location on Combined Heat and Power/Hydrogen (Tri-Generation) System Cost, Hydrogen Output and Efficiency, presented at the National Hydrogen Association Meeting, Columbia, South Carolina, March 30 – April 3, 2009.
5. H2A Power Model Presentation, presented at the National Hydrogen Association Meeting, Columbia, South Carolina, March 30 – April 3, 2009.
6. Adapting the H2A Hydrogen Production Cost Analysis Model to Stationary Applications, presentation at the DOE Hydrogen Program Annual Merit Review and Peer Evaluation, Washington, D.C., May 19, 2009.
7. H2A Power Model Startup Guide, April 2009.