XI.1 Non-Automotive Fuel Cells: Market Assessment and Analysis of Impacts of Policies

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- ICF, International, Washington, D.C.
- Fuel Cell Today, Royston, UK

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

Fiscal Year (FY) 2011 Objectives

- Analyze the status and prospects of the fuel cell industry and impacts of policies.
- Simulate market transformation to hydrogen fuel cell vehicles in the United States.
- Conduct systems analysis of fuel cell technologies.

Technical Barriers

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

(A) Future Market Behavior

Understanding the behavior and drivers of the fuel and vehicle markets is necessary to determine the long-term applications. Another major issue is the hydrogen supply, vehicle supply, and the demand for vehicles and hydrogen are all dependent and linked. To analyze various hydrogen fuel and vehicle scenarios, models need to be developed to understand these issues and their interactions.

(D) Suite of Models and Tools

The program currently has a group of models to use for analysis; however, the models are not sufficient to answer all analytical needs. A macro-system model is necessary to address the overarching hydrogen infrastructure as a system. Improvement of component models is necessary to make them more useable and consistent.

(E) Unplanned Studies and Analysis

Every year, many analysis questions are raised that require analysis outside and, in some cases, instead of the plans made for that year. Many analysis questions need responses in brief periods of time particularly when they are driven by external requests or needs. A flexible capability to provide those results is necessary.

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:

Provide system-level analysis products to support hydrogen infrastructure development and technology readiness by evaluating technologies and pathways, guiding the selection of research, development and demonstration (RD&D) projects, and estimating the potential value of RD&D efforts:

- By 2015, analyze the ultimate potential for hydrogen and fuel cell vehicles. The analysis will address necessary resources, hydrogen production, transportation infrastructure, vehicle performance, and interactions between a hydrogen economic sector and other sectors.
- Provide milestone-based analysis, including risk analysis, independent reviews, financial evaluations and environmental analysis, to support the program's needs prior to technology readiness.
- **Milestone 26**: Annual model update and validation. (4Q, 2008; 4Q, 2009; 4Q, 2010; 4Q, 2011; 4Q, 2012; 4Q, 2013; 4Q, 2014; 4Q, 2015)
- **Milestone 39**: Annual update of Analysis Portfolio. (4Q, 2007; 4Q, 2008; 4Q, 2009; 4Q, 2010; 4Q, 2011; 4Q, 2012; 4Q, 2013; 4Q, 2014; 4Q, 2015)

FY 2011 Accomplishments

- Completed analysis of the status and outlook for the U.S. non-automotive fuel cell industry and quantified impacts of government policies on costs and production volumes.
- Completed analyses and assessments of markets, benefits and barriers to fuel cell deployment.

- Completed comparative lifecycle assessment of greenhouse gas emissions for fuel cell and internal combustion engine technologies.

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Introduction

Hydrogen fuels cells for both automotive and non-automotive applications are novel technologies with potentially enormous social benefits in terms of reduced environmental impacts, energy security and sustainability of global energy resources. To be successful, hydrogen fuel cell technologies must further reduce costs and improve durability while at the same time overcoming the "lock-in" of established technologies, such as the petroleum-fueled internal combustion engine. Because the chief benefits of these technologies are public goods (i.e., environmental quality, national security) public policy will play a key role in the market transformation that must take place if hydrogen and fuel cells are to be successful.

Models for analyzing the transition to hydrogen and fuel cells are essential to understanding how such a market transformation could occur, over what time frame, and the roles of government, industry and consumers in the transition. Analytical tools are needed to understand the technological and economical prerequisites for a successful transition, as well as its costs and benefits. This project assists the Department of Energy by developing integrated models for simulating and analyzing the market transformation to hydrogen and fuel cells and conducting special analyses to develop new information about critical aspects of that phenomenon.

Approach

ORNL developed the HyTrans model to simulate the transition of light-duty vehicle transportation to hydrogen and to analyze scenarios and policies to achieve such a transformation. HyTrans is a non-linear dynamic optimization model that integrates the supply of hydrogen fuel, fuel cell vehicle manufacturing, and consumer demand. It simulates market barriers such as the "chicken or egg" problem (lack of hydrogen fuel and lack of hydrogen-powered vehicles), lack of diversity of vehicle choices during the early market transition, learning-by-doing and scale economies. HyTrans has been used to construct comprehensive scenarios of the transformation of the light-duty vehicle market and to measure the costs and benefits of such a transition.

ORNL has also conducted assessments of the status of fuel cells for non-automotive applications. These assessments included in-depth interviews with foreign and domestic fuel cell manufacturers and observation of their manufacturing facilities, data collection and construction of a model for simulating the evolution of fuel cell markets over time, including competition with established technologies. The markets addressed include combined heat and power (CHP), uninterruptible and backup power, and materials handling.

Results

The most significant accomplishment of FY 2011 was the completion of an analysis of the status and prospect for the U.S. non-automotive fuel cell industry and the impacts of government policies. The non-automotive fuel cell industry, worldwide, has made impressive progress since a previous assessment in 2007 [1]. Still, the global industry is dependent on public policies and is likely to be for several years.

- Non-automotive fuel cell manufacturers are making progress in a limited number of markets: for proton exchange membrane (PEM) fuel cells, back-up and uninterruptible power (especially for telecommunications), material handling equipment (forklifts), micro-CHP; for larger phosphoric acid and molten carbonate fuel cells, CHP and grid-independent stationary power.
- All manufacturers have achieved large cost reductions of 50% or more over the past 2-5 years. Nonetheless, all manufacturers believe that costs must be further reduced by 40% to 50% in order to compete successfully in the marketplace without government support.
- In the current market, government incentives are essential to sustaining the U.S. fuel cell industry. This is likely to remain the case for the next five years. Given continued or enhanced incentives fuel cell manufacturers might achieve sufficient cost reductions to continue without government support sometime between 2015 and 2020.
- Most manufacturers believe that future cost reductions will come primarily though economies of scale and cost reductions in the supply chain, with technological advances playing a somewhat smaller role than in the past. Estimated scale elasticities (the percent reduction in cost for a 1% increase in annual production) are typically in the range of -0.2 to -0.3, implying that doubling output would reduce costs by 20% to 30%.
- Substantial improvements in the durability of fuel cells have also been achieved. PEM fuel cell stacks in backup power applications today are expected to operate under real-world conditions for 5,000 to 10,000 hour lifetimes. ENEFARM[1] systems have been operating for 20,000 hours in Japanese homes and are guaranteed for 40,000-hour lifetimes. Large-scale (>300 kW) fuel cells for CHP and stationary power already exceed 40,000 hours before requiring replacement. Still, manufacturers believe that durability must and can be further improved.
- Almost all of the manufacturers interviewed were operating well below their existing production capacity

[1] ENEFARM is the brand name of Japan's residential PEM fuel cell CHP product.

and all had the capability to expand capacity by 50% to 300% within one year.

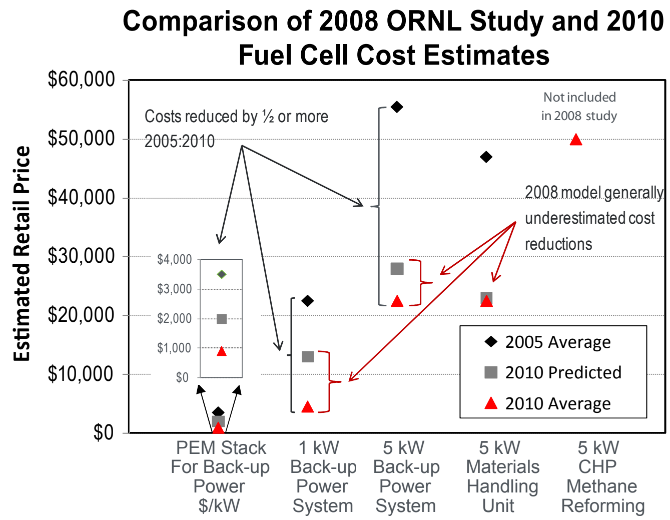
- Today, fuel cell manufacturers are dependent on government incentives or government procurements for viability. Without policies such as the investment tax credit, California's Self-Generation Incentive Program, research and development funding and government procurements, most companies' sales would be drastically reduced.
- For U.S. manufacturers, the key domestic markets are in California and the northeast states. South Korea is an important overseas market today, with sizable potential markets in the European Union. In the backup power area, manufacturers believe that developing countries represent large potential markets.
- For fuel cell CHP and micro-CHP manufacturers, both purchase incentives and high electricity prices (or feed-in tariffs) are essential to creating a viable market.
- For PEM fuel cells in back-up power and material handling, the cost and availability of hydrogen is a significant impediment to commercial success. While the American Recovery and Reinvestment Act of 2009 (ARRA) and other programs have provided important incentives for purchasing fuel cells, the problem of hydrogen availability for non-automotive applications has not yet been adequately addressed.

The 2008 report [1] estimated current costs for PEM fuel cell stacks and products and projected costs to 2010 based on assumed production levels, scale elasticities of approximately -0.2 and progress ratios of 0.95 for stack suppliers and 0.91 for manufacturers. These estimates, together with cost data gathered in the course of this study are shown in Figure 1. In every case, manufacturers have equaled or exceeded the manufacturing costs projected by the 2008 study. Large cost reductions have been achieved over the period 2005-2010:

- PEM stack costs have come down from roughly $4,000/kW to $1,000/kW.
- The cost of 1 kW backup power units have also been reduced by a factor of 4.
- The cost of 5 kW backup power units is down from about $55,000 to $22,000.
- The cost of 5 kW forklift systems has declined from $48,000 to about $22,000.

Similar cost reductions have been achieved by large, high-temperature fuel cell manufacturers. Fuel Cell Energy, for example, has reported cost reductions of a factor of five for its molten carbonate fuel cell product over the period 1996 to 2008 [2]. Foreign manufacturers whose governments have also supported fuel cell research, development and deployment have achieved similar cost reductions.

The model of the domestic fuel cell industry constructed for this study estimated that existing programs have important beneficial impacts on the industry, without which the industry might not become sustainable. The ARRA has contributed to reducing costs of fuel cell manufacturers in the material handling and backup power segments (Figure 2). Without either the ARRA or the investment tax credit, it is estimated that the cost of fuel cell material handling systems would be about $4,000 higher than the actual costs in 2010. Continuation of the investment tax credit through 2016 appears to be essential to sustaining a domestic fuel cell industry and could lead to a viable industry before 2020. The model's estimates suggest that continuing current policies could lead to growing markets in all three applications (Figures 3-4).



2005 and 2010 averagesbased on estimates supplied by manufacturers 2010 predicted assumed government procurements of 2,175 units per year, total for all market segments. Predictions assumed a progress ratio of 0.9 and scale elasticity of -0.2.

FIGURE 1. Comparison of 2008 ORNL Study and 2010 Fuel Cell Cost Estimates

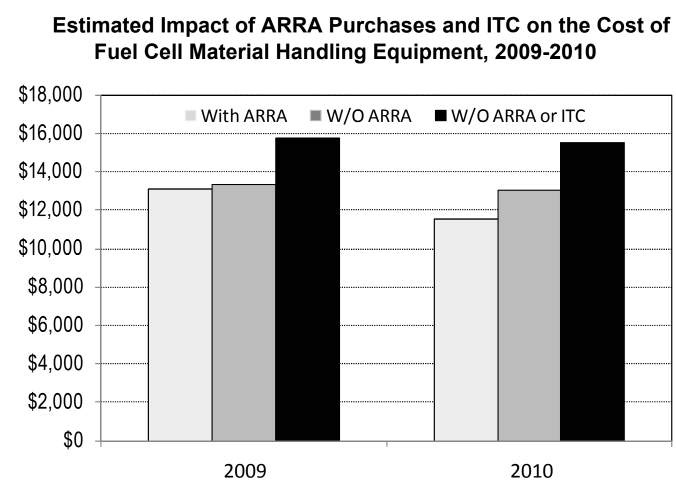
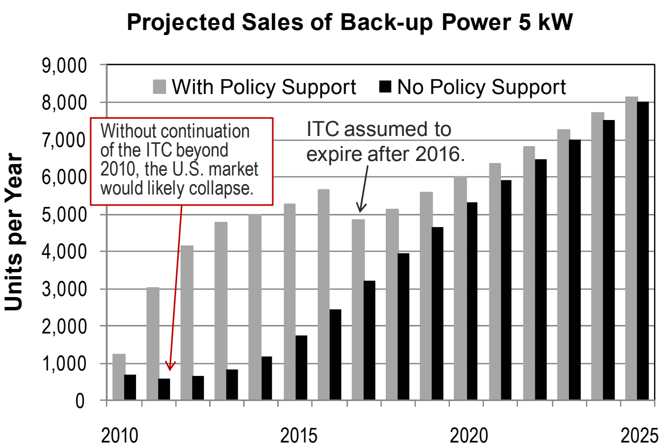


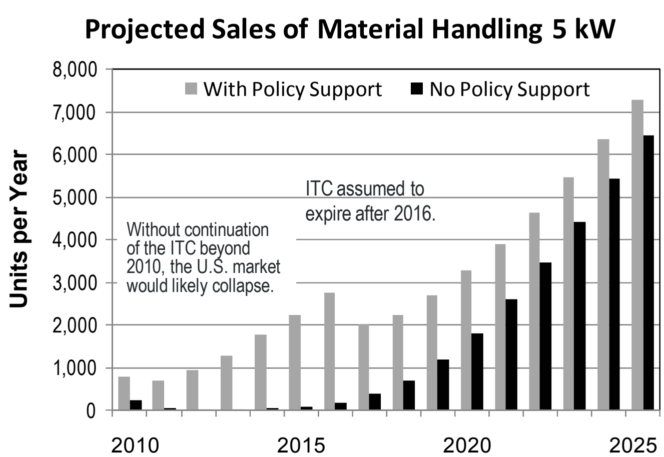
FIGURE 2. Estimated Impact of ARRA Purchases and Investment Tax Credit (ITC) on the Cost of Fuel Cell Material Handling Equipment in 2009 and 2010

However, production volumes, especially for material handling equipment but also for micro-CHP and large-scale CHP may not be sufficient to sustain manufacturers over the next 1-4 years. Enhanced incentives for fuel cell purchases should therefore be considered to increase the industry's chances for successful transition to viability. The most promising policy for all types of fuel cells appears to be conversion of the investment tax credit now capped at 30% of capital cost to an uncapped $3,000/kW tax credit. Feed-in tariffs are an especially attractive policy for large and small CHP.



Only ARRA purchases have been excluded from the "No Policy" case. Other government procurements prior to 2011 are included inboth cases. Progress ratioof 0.9 and scale elasticity of -0.2. Number of manufacturers is assumed to be 3. Government and private purchases for demonstrations are 100 units/yr. in the policy case.

FIGURE 3. Projected Sales of 5 kW Backup Power Units With and Without Current Policies



Only ARRA purchases have been excluded from the "No Policy" case. Other government procurements prior to 2011 are included inboth cases. Progress ratio of 0.9, scale elasticity of -0.2. Government and private procurements of 100 units/yr. for demonstrations continue in the policy case.

FIGURE 4. Projected Sales of 5 kW Material Handling Units With and Without Current Policies

Conclusions and Future Directions

The non-automotive fuel cell industry study documents the substantial progress domestic and foreign fuel cell manufacturers have made in reducing costs and improving performance over the past three years as well as the beneficial impacts of government policies. Still, the industry faces substantial barriers to market success, including further reducing costs via scale economies, learning by experience and for material handling applications, increasing the availability of moderately priced hydrogen.

Research in FY 2012 will focus on developing new scenarios of the potential transition to hydrogen, incorporating what has been learned about technologies and markets since the 2007 study. In particular, new scenarios will be developed to analyze the potential for hydrogen fuel cell, battery electric and grid-connected hybrid vehicles to compete in different market segments. In addition, the potential for maximum use of renewable energy in hydrogen and electricity production may be a focus. The HyTrans model will be used in these analyses but, in collaboration with the National Renewable Energy Laboratory (NREL), ORNL will explore the potential to combine ORNL's MA3T model with NREL's Scenario Evaluation, Regionalization and Analysis model to simulate the transitions at a much higher level of geographic detail and market segmentation.

FY 2011 Publications/Presentations

1. Greene, D.L., K.G. Duleep and G. Upreti, 2011. *Status and Outlook for the U.S. Non-Automotive Fuel Cell Industry: Impacts of Government Policies and Assessment of Future Opportunities*, ORNL/TM-2011/101, Oak Ridge National Laboratory, Oak Ridge, TN, May.

2. Greene, D.L., 2011. "Non-automotive Fuel Cells: Market Assessment and Analysis of Impacts of Policies", presented at the 2011 Hydrogen Program and Vehicle Technologies Program Annual Merit Review, Arlington, Virginia, June 10, 2011.

3. Greene, D.L., 2011. "National Security and Alternative Fuels: Observations on a Transportation Energy Transition", presentation to the Military Advisory Board of the Center for Naval Analysis, Alexandria, Virginia, March 8, 2011.

3. Greene, D.L., 2010. "Transportation's Energy Efficiency: What's Needed Today and by 2050", ACEEE: 30 Years of Energizing Efficiency, Washington, D.C., December 7, 2010.

4. Greene, D.L., 2010. "Transportation's Energy Challenges", Appalachian State University, Boone, NC, November 1, 2010.

5. Das, S., 2011. "Reducing GHG Emissions in the Transportation Sector", *Energy for Sustainable Development*, May, 2011.

6. Das, S., forthcoming, "Status of Advanced Light-Duty Transportation Technologies in the U.S.", submitted for publication in the Energy Policy journal, June'11.

References

1. Greene, D.L. and K.G. Duleep, 2008. *Bootsrapping a Sustainable North American PEM Fuel Cell Industry: Could a Federal Acquisition Program Make a Difference?*, ORNL/TM-2008/183, Oak Ridge National Laboratory, Oak Ridge, Tennessee, October.

2. Adamson, K., 2008. "2008 Large Stationary Survey", Fuel Cell Today, www.fuelcelltoday.com, August.