XI.6 Sensitivity Analysis of H2-Vehicles' Market Prospects, Costs and Benefits

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Project Start Date: October, 2010
Project End Date: Project continuation and direction determined annually by DOE

Fiscal Year (FY) 2012 Objectives

- Project market shares of hydrogen fuel cell vehicles (FCVs) under varying market conditions using the Market Acceptance of Advanced Automotive Technologies (MA3T) model.
- Analyze the sensitivity of projected market shares of hydrogen FCVs to alternative assumptions about consumers' preferences and behavior.

Technical Barriers

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

(A) Future Market Behavior
(B) Stove-piped/Siloed Analytical Capability
(D) Insufficient Suite of Models and Tools
(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:

- 1.15 Complete analysis of program milestones and technology readiness goals – including risk analysis, independent reviews, financial evaluations, and environmental analysis – to identify technology and risk mitigation strategies. (4Q, 2015)
- 1.16 Complete analysis of program performance, cost status, and potential use of fuel cells for a portfolio of commercial applications. (4Q, 2018)
- 2.2 Annual model update and validation. (4Q 2011 through 4Q, 2020)

FY 2012 Accomplishments

- Produced 48 scenarios with alternative assumptions about technological progress and market conditions.
- Tested sensitivity of scenario results to alternative assumptions about consumers' preferences and behavior.
- Published refereed journal article describing FY 2011 research on markets for non-automotive fuel cells.

Introduction

The future market potential of hydrogen vehicles and the challenges to achieving market success depend partly on technological factors and partly on market behavior. The Hydrogen and Fuel Cells Program has formulated program goals for hydrogen production, storage and fuel cell technologies that are a function of the theoretical potential of the technologies and what is believed to be necessary for success in the market place. There is uncertainty both with respect to what can be achieved technologically and how the market is likely to respond.

As hydrogen and fuel cell technologies progress and more is learned about the cost and performance that is achievable, it is important to re-evaluate the likelihood of market success and the resulting impacts on economic, energy security and environmental benefits. But there is also substantial uncertainty about how markets will respond to novel automotive technologies and how hydrogen and fuels cells may compete in the market with other advanced automotive technologies. This study makes use of a state-of-the-art market penetration model, the MA3T model, to assess the sensitivity of the market success of hydrogen FCVs to alternative scenarios of technological progress and alternative assumptions about consumer behavior.

Approach

Scenarios of technological progress for FCVs and competitive/synergistic advanced technologies were constructed based on simulations developed by the Argonne National Laboratory's Autonomie model. The Autonomie model simulations are generally consistent with DOE's program goals for advanced vehicle technologies. These were combined with projections of energy prices and light-duty vehicle sales from the 2011 Annual Energy Outlook (AEO). The scenarios were input to the Department of Energy's MA3T model. The MA3T model is a nested discrete choice model that estimates future market shares of 20 powertrain technologies, separately for automobiles and light trucks, and produces projections to the year 2050. The technology sets include plug-in versions of both internal combustion engine and fuel cell-powered vehicles. MA3T includes a detailed market segmentation to better represent heterogeneity in consumer demand. Its 1,458 segments account for differences among regions, degree of urbanization, housing types, risk preferences, and distributions of daily vehicle use.

Variants to a baseline scenario were developed to reflect uncertainties along the following four dimensions:

- Technology status
- Energy prices
- Consumers' preferences
- Policies

The baseline scenario assumed automotive fuel cell systems would cost $60/kW and onboard hydrogen storage would cost $10/kWh; it assumed batteries for battery electric vehicles would cost $450/kWh. More successful technology scenarios were constructed, including fuel cell system costs down to $25/kW and on-board storage at $5/kWh; battery success scenarios included costs down to $150/kWh and accelerated progress. Three energy price scenarios were used, based on the AEO 2011 High, Reference and Low oil price cases. Alternative policies focused on early infrastructure provision and subsidies for fuels and vehicles. Sensitivity to four key aspects of consumer behavior were explored: 1) sensitivity of choices to price, 2) cost of limited refueling availability, 3) cost of limited vehicle range and long refueling time, 4) the extent to which consumers factor future fuel costs into their new vehicle purchase decisions.

Results

The results of the sensitivity analysis suggest that the market success of hydrogen vehicles (H2Vs), given appropriate policies, is relatively robust to both the evolution of fuel cells and competing/synergistic technologies and to consumers' preferences. Figure 1 illustrates the outcomes of scenarios in which the key factors varied were technological success and the provision of infrastructure (the dip in shares around 2015 is due to the expiration of tax credits). Given adequate provision of early infrastructure, the ultimate market success depends most strongly on the progress of automotive fuel cell technology. The effects of the progress of other advanced technologies are reflected in the dispersion among curves of the same color (green, blue and red). Assuming successful development of fuel cell technology, it appears that fuel cells could achieve market shares in the range of 60-70% of new light-duty vehicle sales by 2050. Interestingly, lower battery costs produce a slight increase in the estimated FCV market share because the benefits of lower battery costs to FCVs appear to outweigh the effect of greater competition from lower-cost plug-in electric vehicles (PEVs).

Given technological success, H2Vs appear to be competitive under a range of prices for hydrogen and petroleum. DOE program goals are aimed at hydrogen prices between $2 and $4 per kilogram, in the long run. As Figure 2 illustrates, hydrogen prices do affect sales but raising the long-run, high-volume delivered hydrogen price from $2.50 to $4.00 reduces sales of hydrogen vehicles by less than 15%. The price of petroleum will also have an impact: the range from the Low to High Oil Price cases is about +/-20% of the Reference Case estimate if fuel cell technology is successful but +/- 50% if the base assumptions are used.

The sensitivity of the market success of hydrogen vehicles to consumers' preferences was also tested. Figure 3 illustrates the effect of greater or lesser sensitivity of consumers' choices to price (Beta). In discrete choice models, such as the MA3T, sensitivity to price reflects the degree to which consumers consider the alternatives to be close substitutes for one another. Insensitivity to price indicates that there are many attributes of the vehicles about which consumers have widely different evaluations. At low levels of market penetration less price sensitivity favors hydrogen vehicles. However, in the technology success case in later years greater price sensitivity increases H2V sales. This result is not seen in the Base case; less price sensitivity uniformly favors H2V's market share. In the Technology Success case FCVs eventually become less expensive to own than alternatives and so greater sensitivity to price favors them.

Other consumer preference factors that had similar impacts (approximately +/-20%) on hydrogen vehicles' market success were the degree to which consumers consider future fuel costs in new car purchase decisions and the perceived cost of limited fuel availability. Consumers' perception of the value of fuel availability matters greatly when the market shares of hydrogen vehicles are small but has only a small effect as market shares approach 50%. The cost of limited range and long refueling times affects PEVs more than H2Vs and has a very minor impact on the market success of H2Vs. Based on this result and the beneficial effect of lower battery costs on FCVs' market share, it appears that there is little competition between PEVs and FCVs for market share.

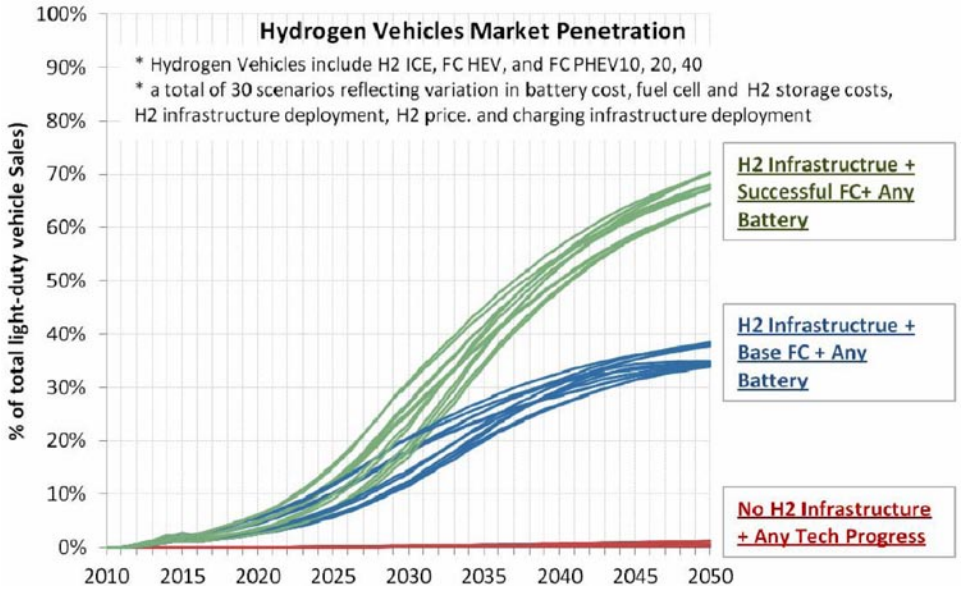

FIGURE 1. Hydrogen Vehicles Market Penetration: Sensitivity to Technological Progress

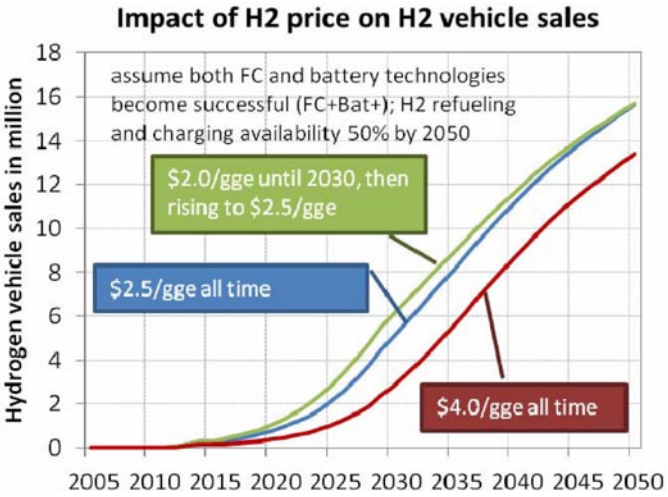

FIGURE 2. Impact of Hydrogen Price on Hydrogen Vehicle Sales

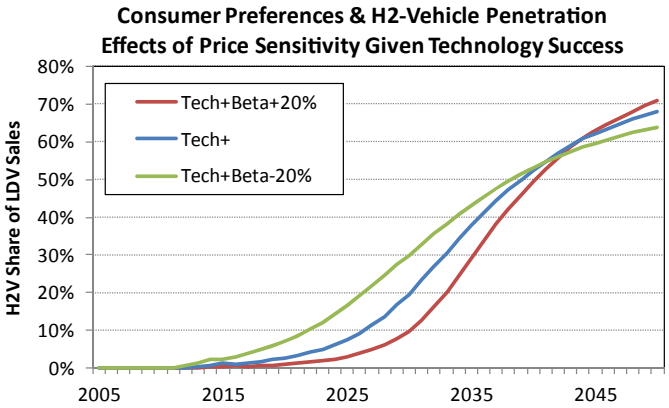

FIGURE 3. Effect of Consumer Price Sensitivity on Hydrogen Vehicle Sales

Conclusions and Future Directions

This analysis suggests that, given appropriate transition policies, particularly the early provision of refueling infrastructure, FCVs are likely to achieve substantial market success. If the technology goals for FCVs are achieved, the market share of H2Vs could well be in the range of 60% to 70% by 2050. Furthermore, given technology success, the market acceptance of H2Vs seems to be robust to a range of external market conditions and assumptions about consumers' preferences. However, this analysis represents a first attempt to comprehensively analyze the sensitivity of hydrogen vehicle market success to a wide range of uncertainties. Not all relevant uncertainties have been included in the analysis and a full experimental design has not been carried out due to the complexity of the MA3T model and limited time and resources to execute potentially thousands of model runs. Future research may address these issues depending on the evaluation of this initial analysis, availability of funding and program priorities.

The analysis will be documented in the form of an article that will be submitted for consideration for publication in an appropriate refereed journal. Based on the referees' comments the analysis may be revised.

FY 2012 Publications/Presentations

1. Upreti, G., D.L. Greene, K.G. Duleep and R. Sawhney, 2012. "Fuel cells for non-automotive uses: Status and prospects", *International Journal of Hydrogen Energy*, vol. 37, no. 8, pp. 6339-6348.

References

1. Lin, Z., 2012. MA3T Model: Modeling the Market Acceptance of Advanced Automotive Technologies, Center for Transportation Analysis, Oak Ridge National Laboratory, http://cta.ornl.gov/ma3t/.

2. Energy Information Administration, 2011. *Annual Energy Outlook 2011*, DOE/EIA-0484(2011), U.S. Department of Energy, Washington, D.C.