XI.8 Impact of DOE Program Goals on Hydrogen Vehicles: Market Prospect, Costs, and Benefits

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Fiscal Year (FY) 2012 Objectives

- Project market penetrations of hydrogen vehicles under varied assumptions on processes of achieving the DOE program goals for fuel cells, hydrogen storage, batteries, motors, and hydrogen supply.
- Estimate social benefits and public costs under different program goals scenarios, including petroleum use reduction, greenhouse gas (GHG) reduction, zero-emission vehicle population, grid-connected vehicle population, public expenditure for infrastructure, and public expenditure for vehicle purchase subsidy.
- Compare cost-effectiveness of public expenditure among scenarios.
- Conduct market analysis by integrating output of various DOE-sponsored and other federal projects, including ORNL's Market Acceptance of Advanced Automotive Technologies (MA3T) model, Argonne National Laboratory's Autonomie model, National Renewable Energy Laboratory's H2A model, Energy Information Administration's Annual Energy Outlook projection, Department of Transportation's National Highway Traffic Safety database, and the Environmental Protection Agency's technology assessment.

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:

- Milestone 4: Complete evaluation of fueling station costs for early vehicle penetration to determine the cost of fueling pathways for low and moderate fueling demand rates. (4Q, 2012)
- Milestone 8: Determine economies of scale required for government ramp down of funding for RD&D. (4Q, 2013)
- Milestone 12: Complete an analysis of the hydrogen infrastructure and technical target progress for technology readiness. (4Q, 2015)

FY 2012 Accomplishments

- Constructed 42 different exogenous projections of technology status relative to program goals and projected corresponding sales of hydrogen vehicles using the MA3T model.
- Evaluated the social benefits of promoting hydrogen vehicle market in terms of petroleum use reduction, GHG emission reduction, and the stock penetration of zero-emission vehicles (for air quality) and grid-connected vehicles (for oil demand elasticity).
- Compared the cost-effectiveness of public expenditure among scenarios of program goal progresses.

Introduction

The Department of Energy's Hydrogen and Fuel Cell Program has established ambitious goals for hydrogen technologies, from production to delivery and end use [1]. Over the years, program goals have been modified in light of new information and using more advanced methods for establishing goals for an uncertain future. Very substantial progress had been made in recent years toward the

achievement of the DOE's hydrogen and fuel cell technology program goals, as illustrated by successive annual estimates of the cost of high-volume production of automotive fuel cells [2]. These estimates show that projected, high-volume fuel cell costs are very close to meeting program goals. Progress toward meeting goals for power density and stack energy efficiency has also been impressive [3].

This study aims at a better understanding of the hydrogen vehicle market prospect, the social benefits and the required public expenditure resulting from different level of progress in achieving the DOE's program goals on fuel cells, batteries, motors, hydrogen storage and hydrogen infrastructure.

Approach

To examine the impact of program goals on hydrogen vehicle market penetration, as well as the associated costs and benefits, the MA3T model, developed by ORNL, is adopted to project U.S. consumer demand for hydrogen vehicles, including hydrogen internal combustion engine vehicles, fuel cell electric vehicles, and fuel cell plug-in hybrid electric vehicles, in competition with other automotive powertrain technologies, including conventional gasoline and diesel vehicles, hybrid electric vehicles, plug-in hybrid electric vehicles, and battery electric vehicles. Using the MA3T model, 42 scenarios were designed to estimate the impact of program goals on market prospect, social benefits, required government support, and cost-effectiveness of light-duty vehicle market transition. These scenarios can be grouped into: 1) the Base case (with MA3T default assumptions); 2) all program goals met on time; 3) all goals met on time except one goal is delayed by 10 years; 4) all goals delayed by 10 years except one goal met on time; 5) all goals delayed to the Base case except one goal met on time.

Results

Program goals are important for hydrogen vehicle market success. In particular, the hydrogen delivered cost and the fuel cell system cost have the biggest impact in the long-term market and that infrastructure deployment is the key for the early market. The key findings of this study include:

- By achieving all or some of the program goals, hydrogen vehicle penetration will range from 20% to 70% by 2050 (see Figure 1).
- There appears to be a minimum level of infrastructure deployment to enable the emergence of the hydrogen vehicle market. With 5% hydrogen availability at local levels, hydrogen vehicles can reach 2%-7% of the total light-duty vehicle sales, depending on progresses on reaching other program goals (see Figure 1).
- The goals on fuel cell costs and hydrogen costs have the biggest impacts on the hydrogen vehicle market. With the 5% hydrogen availability at local levels by 2025, achieving only the fuel cell cost goal or only the hydrogen cost goal increases the hydrogen vehicle share by 2025 from 1.88% to 5.09% and 3.55%, respectively, assuming all other technologies following the baseline progresses (see Figure 1).

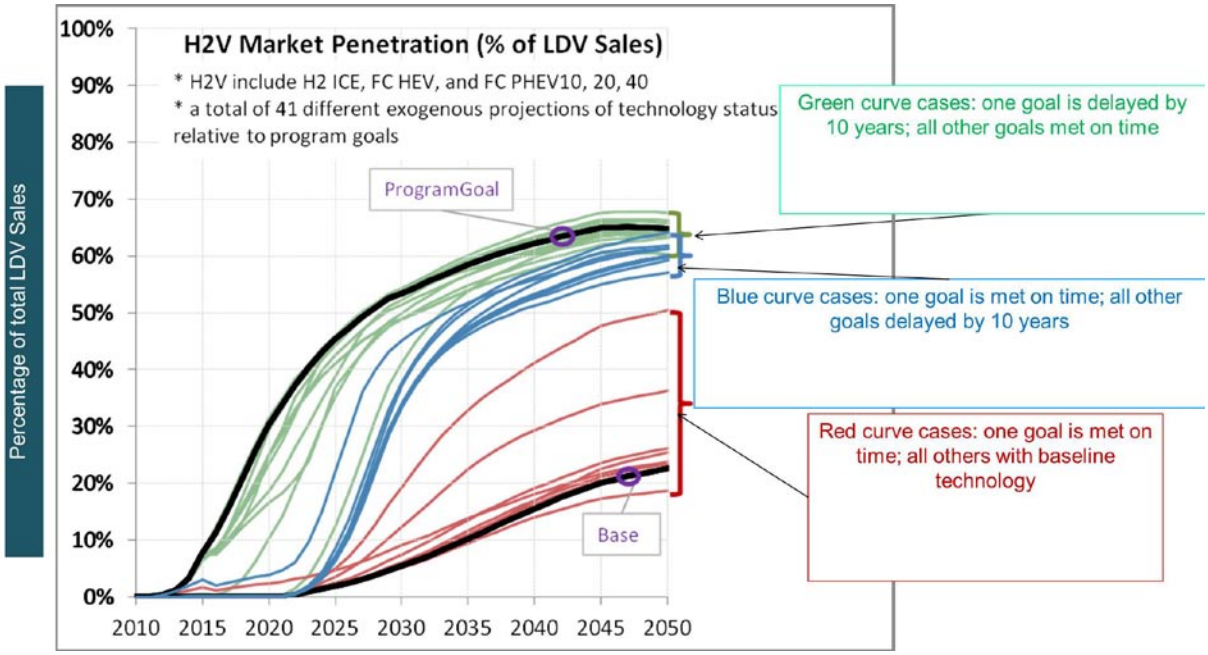

FIGURE 1. Hydrogen vehicle penetrations under varied technology progress, infrastructure and hydrogen price

- If all goals met, both hydrogen vehicles and plug-in hybrid electric vehicles could dominate the market. Fuel cell plug-in hybrid electric vehicles appear to have significant market potential (see Figure 2).
- The sooner the program goals are met, the larger the oil/GHG reduction benefits. Figure 3 shows that meeting all goals allow ~80% cut in petroleum use and ~60% cut in GHG by 2050. These cuts are robust against one goal being missed or delayed.
- The success of hydrogen technologies does not require all DOE program goals goals (fuel cells, batteries, motors, hydrogen storage and hydrogen infrastructure) to be met on time, but key goals need to be met without major delay, including fuel cell costs, delivered hydrogen costs, and the deployment of a basic hydrogen supply infrastructure.
- If most goals met on time, the transition requires 30-50 billion dollars of hydrogen subsidy and 10-20 billion dollars of vehicle subsidy through 2050 (see Figure 4).

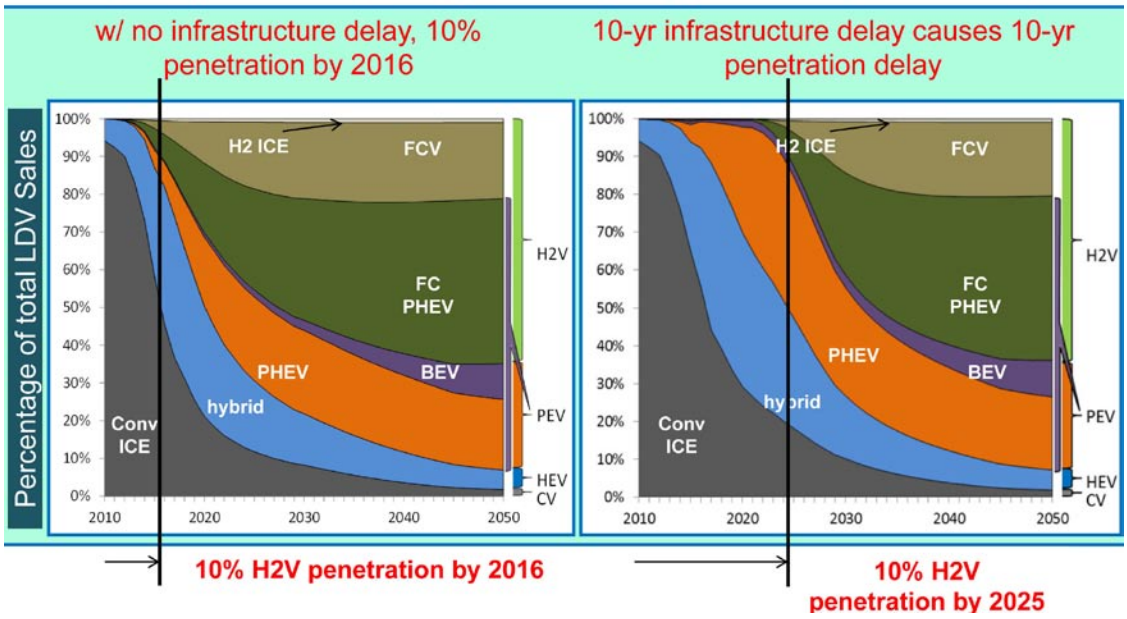

FIGURE 2. Hydrogen vehicle penetration when all program goals are met on time

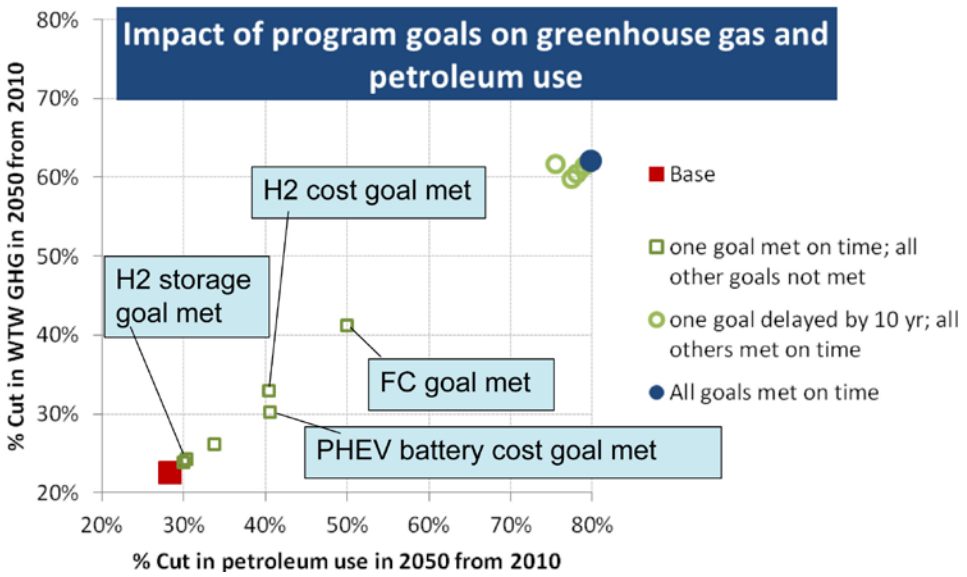

FIGURE 3. Impact of program goals on GHG emissions and petroleum use

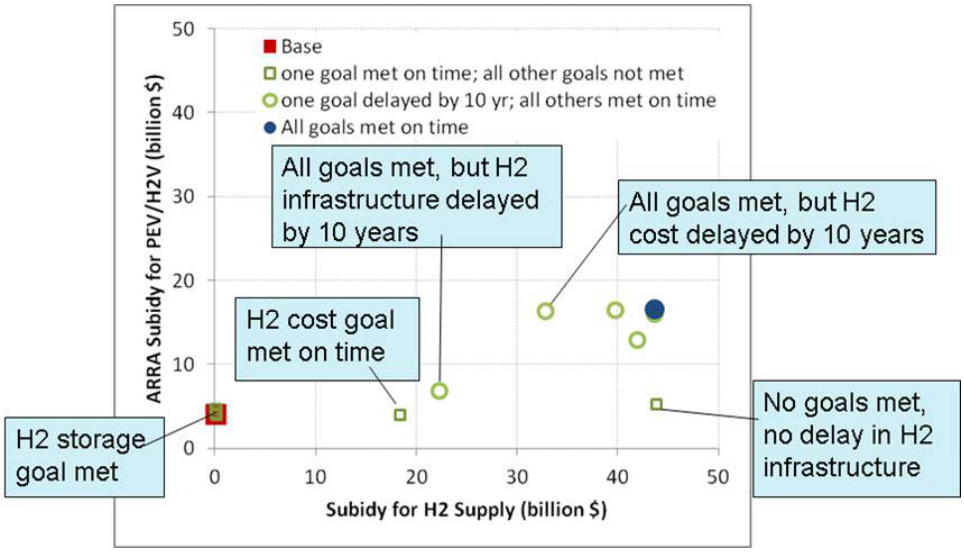

FIGURE 4. Required public support

Conclusions and Future Directions

ORNL has studied and quantified the importance of program goals for hydrogen vehicle market success and the resulting social benefits. The results suggest that a fast deployment of a basic refueling infrastructure (about 5% hydrogen availability at local levels) is required for hydrogen vehicles to penetrate the market noticeably. With such basic infrastructure and its continued expansion, hydrogen vehicles can reach 20%-70% of the market by 2050, depending on other progresses on other components. To bring more hydrogen vehicles to the road by 2050, low fuel cell costs and low hydrogen costs are the key drivers. With just A conference paper/journal publication will be prepared, as well as a final report summarizing all the results and research findings.

References

1. U.S. Department of Energy, Hydrogen and Fuel Cells Program (DOE/HFC), 2009. Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan.

2. (DTI) James, B.D., Kalinoski, J. and Baum, K. (2011). Manufacturing Cost Analysis Of Fuel Cell Systems, Directed Technologies Inc.

3. National Research Council, 2008b. Transitions to Alternative Transportation Technologies: A Focus on Hydrogen, National Academies Press, Washington, D.C.