IX.8 Evaluation of Technology Status Compared to Program Targets

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Overall Objectives

- Quantify the potential impact of fuel cell electric vehicle (FCEV) research and development under the U.S. Department of Energy's (DOE's) Fuel Cell Technologies Office technology program.
- Estimate how competitive FCEVs could become in the future.
- Identify the most influential parameters for FCEV success.

Fiscal Year (FY) 2016 Objectives

- Estimate how competitive FCEVs could become in the future using two approaches:
  - Comparing the cost of equivalent vehicles using different powertrains.
  - Evaluating the market adoption of FCEVs introduced among all currently existing vehicle options.
- Understand the influence of meeting, exceeding, or falling short of DOE Fuel Cell Technologies Office program goals on future market adoption of FCEVs.

Technical Barriers

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

(A) Future Market Behavior

(B) Stove-piped/Siloed Analytical Capability

(D) Insufficient Suite of Models and Tools

Contribution to Achievement of DOE Systems Analysis Milestones

This project contributes to achievement of the following DOE milestones from the Systems Analysis section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

- Milestone 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)
- Milestone 1.17: Complete analysis of program technology performance and cost status, and potential to enable use of fuel cells for a portfolio of commercial applications. (4Q, 2018)

FY 2016 Accomplishments

- In all scenarios that assume similar vehicles using different powertrains, the combined energy and component costs of future FCEVs were found to be lower than those of conventional vehicles and comparable to those of hybrid electric vehicles (HEVs).
- The market share analysis was completed and shows FCEVs could gain as much as one-third of new vehicle sales by 2050. The market analysis improved on past approaches by expanding on the scenarios reviewed and using a model that includes all existing vehicles rather than model-created representations, evolves the vehicle powertrains based on market conditions, and validates with historical sales.
- For some scenarios, HEVs and plug-in hybrid electric vehicles (PHEVs) had greater market share than FCEVs because they can combine their engine and battery power to the wheels for better acceleration, whereas fuel cell and battery power is delivered through a larger and more expensive electric motor.
- Some scenarios found significant FCEV sales, assuming only FCEV technical targets are met, oil prices are high, and either the accelerated FCEV targets are met in 2025 or the FCEV incentives are extended to two million vehicles per manufacturer.

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INTRODUCTION

The DOE's Fuel Cell Technologies Office technology program focuses on research and development to overcome technical barriers related to hydrogen production, delivery, and storage technologies as well as fuel cell technologies for transportation, distributed stationary power, and portable power applications. These research and development activities could result in significant benefits as more hydrogen and fuel cell technologies are deployed. The main goal of this project is to show the effects on FCEV market adoption of meeting, exceeding, or falling short of Fuel Cell Technologies Office program goals. In this study, both techno-economics and consumer choice analyses were conducted to assess the competitiveness of FCEVs in the future.

APPROACH

To achieve the objective of the study, a novel analytic approach is adopted that integrates vehicle simulation (techno-economics) with market adoption potential (consumer choice). In addition, distinct technology trends (based on trends from the Government Performance and Results Act, National Research Council, and other sources) were developed to explore a wide range of potential vehicle technology progress outcomes.

For techno-economic analysis, conventional vehicles (CVs), HEVs, and FCEVs with the same acceleration, range, and battery-to-total-power ratio were simulated and compared in a powertrain simulation model, Future Automotive Systems Technology Simulator (FASTSim). FASTSim is a user-friendly powertrain simulation model, validated against hundreds of existing vehicles. The FASTSim model takes vehicle component parameters as input and simulates efficiency, performance, and cost of vehicles on standard time-versus-speed drive cycles.

The market adoption analysis expanded on the techno-economic analysis perspective of FASTSim using the vehicle choice model, Automotive Deployment Option Projection Tool (ADOPT). It replaced the representative vehicles in the techno-economic approach with all of the existing vehicle options to capture how FCEVs will compete given a realistic variety of vehicle acceleration rates, sizes, and efficiencies. Additionally, through ADOPT's vehicle evolution process, it captured how FCEVs compete when all of the powertrains are optimized to take advantage of their unique characteristics and market conditions.

RESULTS

Techno-Economic Analysis: The total vehicle costs in a 2035 showroom of a CV, HEV, and FCEV with the same acceleration performance, range, and battery-to-total-power ratio are compared under Low, Base, and Accelerated scenarios (Figure 1). The total vehicle cost to the consumer equals the manufacturing cost multiplied by a retail markup factor (1.5) plus net present value of lifetime fuel cost. The gasoline price is assumed to be \$3.53 per gallon, and the hydrogen price is assumed to be \$4.40 per gallon gasoline equivalent. A discounting factor of 4.1% is used to calculate net present values, based on the 20-year median real annual return of the S&P 500 [1]. The results show that under any of the technology development scenarios, total costs of FCEVs are lower than those of CVs, but comparable to those of HEVs. A detailed look at reductions in normalized total FCEV cost attributed to technology improvements is shown in Figure 2. It shows that the largest reductions in normalized total FCEV cost come from vehicle mass reduction (5.7%) and fuel cell system cost (2.2%). It is also worth noting that the third largest reduction is attributed to the combination effect, which is achieved when all technology improvements are combined.

The market share analysis shows that HEVs and PHEVs can be more marketable than FCEVs when each powertrain is optimized for its unique strengths. Specifically, HEVs and PHEVs could provide very fast acceleration and low fuel cost at a relatively low price because their fuel converters and motors can provide power to the wheels in parallel. The FCEV requires a larger, more expensive electric motor to achieve the same acceleration because the fuel cell cannot directly power the wheels. The improved HEVs and PHEVs prevent significant FCEV market share in the base and accelerated scenarios. However, significant FCEV sales can be achieved by modifying the scenarios, assuming only FCEV technical targets are met, oil prices are high, and either the accelerated FCEV targets are met in 2025 or the

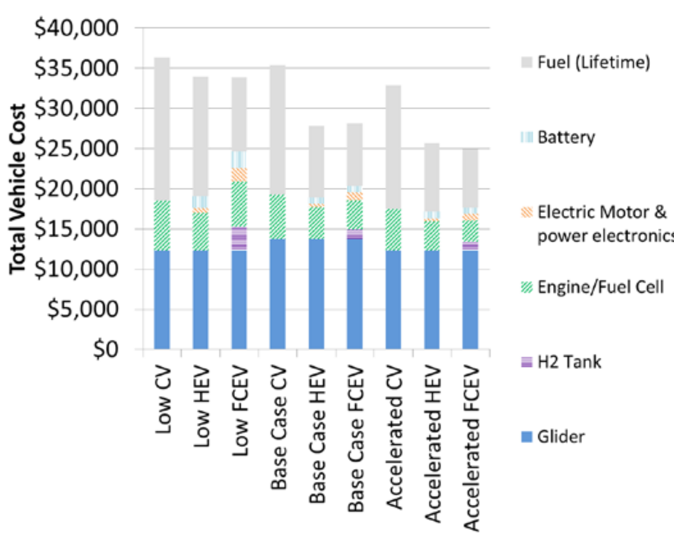
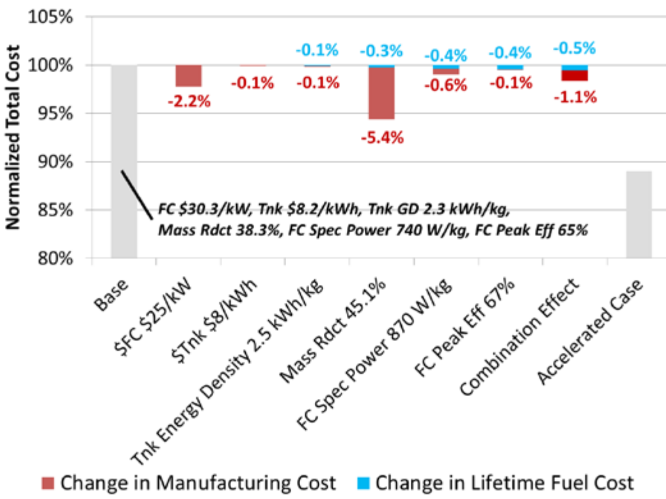


FIGURE 1. Component costs comparison of CVs, HEVs, and FCEVs in 2035 showroom under different scenarios



FC – Fuel cell, Tnk – Tank, Rdct – Reduction, Spec – Specific, Eff – Efficiency

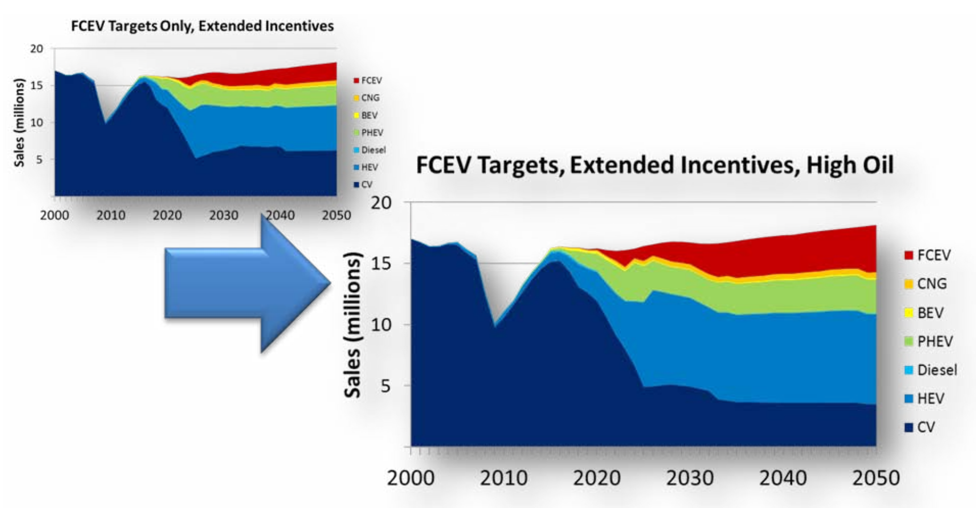
FIGURE 2. Reductions in normalized total FCEV cost attributed to technology improvements

FCEV incentives are extended from 200,000 to two million vehicles per manufacturer (Figure 3 and Figure 4).

CONCLUSIONS AND FUTURE DIRECTIONS

This study investigates the impacts of technological improvements on vehicle features, efficiency, performance, manufacturing cost, and operating cost in 2035 in the U.S. In addition, it simulates the market penetration of FCEVs and other vehicle types under various scenarios. Key observations from the analysis include the following:

- In all scenarios, the FCEV's manufacturing cost is higher than the CV's and HEV's. However, when combining the manufacturing cost and lifetime fuel cost, the CV is the worst economic choice, and the HEV and FCEV costs are comparable.
- In the base scenario, the FCEV's consumer-perceived price (manufacturer's suggested retail price plus first four years of fuel costs) is lower than the CV's but higher than the HEV's. This suggests that this level of technological advancement alone cannot guarantee FCEV success and that additional policies would be needed to promote FCEV consumer acceptance.
- Fuel cell stack cost, hydrogen tank cost, and mass-reduction targets have major impacts on FCEV manufacturing cost and price to consumers. Fuel cell engine peak efficiency influences fuel cost but not component costs. The combined effects of technological improvements play an important role in reducing FCEV costs and consumer prices.
- Assuming battery prices drop significantly, market share analysis shows that HEVs and PHEVs can be more marketable than FCEVs when each powertrain is optimized for its unique strengths. The improved HEVs and PHEVs prevent significant FCEV market share in the base and accelerated scenarios. However, significant FCEV sales can be achieved by modifying the scenarios: assuming only FCEV technical targets are met, oil prices are high, and either the accelerated FCEV targets are met in 2025 or the FCEV incentives are extended to two million vehicles per manufacturer.



BEV - Battery-electric vehicle, CNG - Compressed natural gas vehicle

FIGURE 3. Market share due to achieving only FCEV-related targets, extending FCEV incentives to two million vehicles per manufacturer, and assuming high oil prices

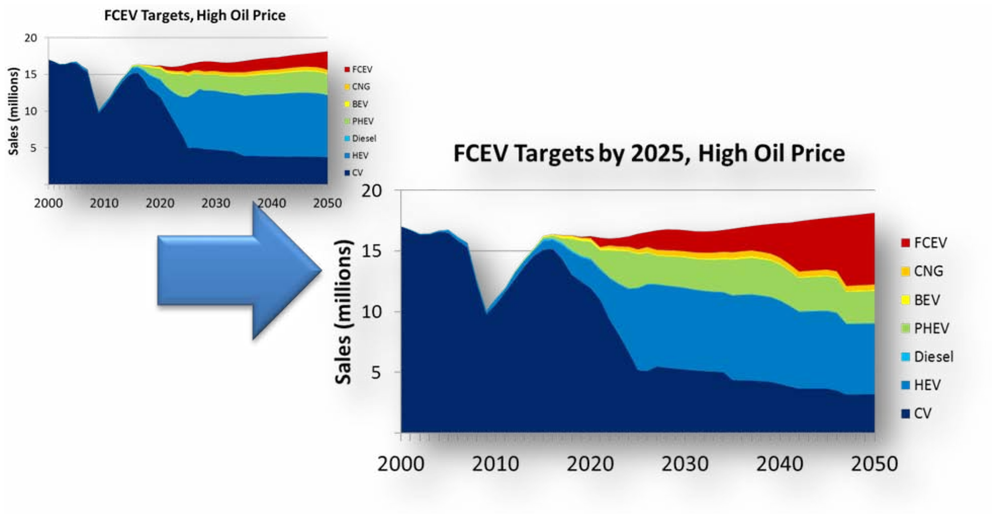


FIGURE 4. Market share due to achieving only FCEV-related targets by 2025 and assuming high oil prices

Suggested future research based on this study includes the following:

- Develop improved mass reduction cost curve to better represent tradeoffs in component sizes and acceleration.
- Incorporate zero-emission vehicle mandate influence by simulating credit system.
- Consider the learning-curve effect in relation to FCEV technology. In the present analysis, FCEV costs decline as U.S. FCEV sales increase. However, because automakers manufacture and sell vehicles globally, the impact of global FCEV sales could be considered in the analysis.

FY 2016 PUBLICATIONS/PRESENTATIONS

1. Melaina, M., Y. Chen, and A. Brooker. "Evaluation of Technology Status Compared to Program Targets." Presented at the DOE Hydrogen and Fuel Cells Program 2016 Annual Merit Review and Peer Evaluation Meeting, Washington, D.C., June 8, 2016.

REFERENCES

1. New York Times. 2011. "In Investing, It's When You Start and When You Finish." New York Times, 2011. http://www.nytimes.com/interactive/2011/01/02/business/20110102-metrics-graphic.html?_r=1&.