IX.2 GPRA Analysis: Impact of Program Targets on Vehicle Penetration and Benefits

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Project Start Date: October 1, 2013
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- Quantify impacts of DOE Fuel Cell Technologies Office (FCTO) program targets on market penetration and societal benefits of fuel cell electric vehicles (FCEVs)
- Estimate FCEV market share and the resulting reduction in petroleum use and greenhouse gas (GHG) emissions
- Support United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) goals and FCTO activities

Fiscal Year (FY) 2015 Objectives

- Update fuel cell vehicle data and hydrogen cost data
- Construct appropriate hydrogen station roll-out scenarios
- Coordinate assumptions and data with program offices, national labs, and/or industry
- Report updated benefit analysis results

Technical Barriers

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

(A) Future Market Behavior

(C) Inconsistent Data, Assumptions and Guidelines

(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 FCTO Multi-Year Research, Development, and Demonstration Plan:

- Milestone 1.13: Complete environmental analysis of the technology environmental impacts for hydrogen and fuel cell scenarios and technology readiness. (4Q, 2015)
- 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)

FY 2015 Accomplishments

- Constructed 44 alternative scenarios to reflect uncertainty in fuel cell costs ($40/kW or $30/kW by 2020), hydrogen storage cost ($10/kWh or $8/kWh by 2020), oil prices, hydrogen station roll-out speed, and hydrogen prices
- Generated results of the above 44 scenarios on FCEV sales, petroleum consumption, and GHG emissions
- Found FCEV sales impact of program targets depends on oil price, infrastructure roll-out speed, and hydrogen price, but overall is significant
- Found FCEVs, battery electric vehicles (BEVs), and long-range plug-in hybrid electric vehicles (PHEVs) benefit the most from the program targets
- Found the $30/kW fuel cell target and the $8/kWh hydrogen storage target reduce petroleum use by 0.23 MMbpd by 2030, 1.1 MMbpd by 2050
- Found the $30/kW fuel cell target and the $8/kWh hydrogen storage target reduce GHG emissions by 12–31 $MMtCO_2e$ by 2030 and 29–163 $MMtCO_2e$ by 2050, depending on supply share of renewable hydrogen

INTRODUCTION

The Government Performance and Results Act (GPRA) is a United States law enacted in 1993, as one of a series of laws designed to improve management of government-funded projects. The GPRA requires agencies to engage in project management tasks such as setting goals, measuring results, and reporting progress. In order to comply with the GPRA, agencies are required to prepare annual performance plans that establish the performance goals for the applicable fiscal year and must prepare annual performance reports that review the agency's success or failure in meeting its targeted performance goals.

The DOE's Market Acceptance of Advanced Automotive Technologies (MA3T) model has been extensively used by the Vehicle Technologies Office (VTO) and FCTO to assess and analyze the potential market success of advanced automotive technologies. MA3T was used by the VTO in its GPRA analysis for FY 2012–FY 2014, and was used in FY 2013 in two studies for FCTO on the hydrogen fuel cell vehicle market, resulting in two articles published in International Journal of Hydrogen Energy.

This study aims at quantifying impacts of FCTO program targets (fuel cell costs and hydrogen storage costs) on FCEV sales, the light-duty vehicle (LDV) petroleum consumption, and GHG emissions, in both the near and long terms.

The objectives of this project are to:

- Construct appropriate scenarios to capture key transition uncertainties and reasonably reflect consensus understandings or assumptions.
- Generate simulation results to quantify the FCEV sales impact and LDV-related societal impacts of FCTO program targets.

APPROACH

The ORNL MA3T model was used to quantify FCEV sales, LDV petroleum use, and GHG emissions as a result of alternative assumptions. MA3T endogenously estimates market share of FCEVs among competing LDV technologies by including up to 300 vehicle choices and over 9,000 consumer segments. It explicitly considers range limitation, hydrogen refueling availability, technology learning, and vehicle make/model availability.

A total of 44 alternative scenarios were constructed to reflect the fuel cell (FC) cost targets of $40/kW or $30/kW by 2020, hydrogen storage (HS) cost targets of $10/kWh or $8/kWh by 2020, oil prices of Reference and High from Annual Energy Outlook (AEO) 2014 (a publication of the DOE Energy Information Administration), hydrogen station roll-out speed of Reference and Optimistic from the National Renewable Energy Laboratory's Scenario Evaluation, Regionalization and Analysis (SERA) model, and hydrogen prices of $8/kg, $4/kg, and $2/kg by assumption.

The Base case vehicle data in MA3T from the Low-Low scenario of the Argonne National Laboratory Autonomie output is modified to reflect the isolated effect of FCTO program targets on fuel cell and hydrogen storage costs. As in Figure 1, the FC and HS costs and capacity values in the Base case are used to calculate the FC and HS Base unit costs, which are compared to the FC and HS target unit costs. The comparison yields a vehicle cost difference that, when added to the Base vehicle cost, results in the target-adjusted vehicle cost in an alternative scenario.

This project also contributes to the broader DOE program benefit analysis, Baseline and Scenario Analysis (BaSce), by providing MA3T simulation results on two scenarios— "NoProgram" that assumes the "Low-Low" scenario of the most recent Autonomie vehicle simulation

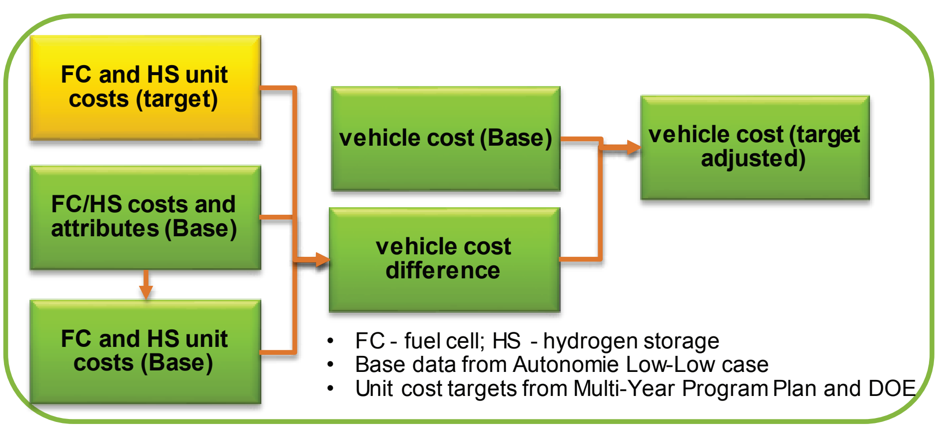


FIGURE 1. Target adjustment of vehicle costs

data on fuel economy and costs, representing no active pursuit of DOE VTO or FCTO program activities, and "ProgramSuccess" that assumes all DOE program targets are met on time plus an optimistic roll-out of both hydrogen refueling and electric vehicle charging infrastructure. Both scenarios assume AEO 2014 Reference energy prices.

RESULTS

Between the NoProgram and ProgramSuccess scenarios, the program targets seem to have greater positive impacts on market shares of powertrain choices that have a larger component targeted by DOE R&D activities. As shown in Figure 2, FCEVs, BEVs, and long-range PHEVs benefit the most from the program targets. As a result of program targets, FC hybrid electric vehicles (HEVs) have greater market shares both in the near and long terms. So do PHEV40s, while PHEV10s have smaller market shares both in the near and long terms and BEV100s have a larger near-term market share and a smaller long-term market share.

The FCTO program targets are found to result in significant reduction in LDV petroleum consumption. As shown in Figure 3, while the effect is much smaller by 2030, the long-term effect in 2050 is significant, especially when both FC and HS targets are combined. The FC \$30/kW and HS \$8/kWh targets are found to reduce petroleum use by 0.23 MMbpd by 2030 and 1.1 MMbpd by 2050.

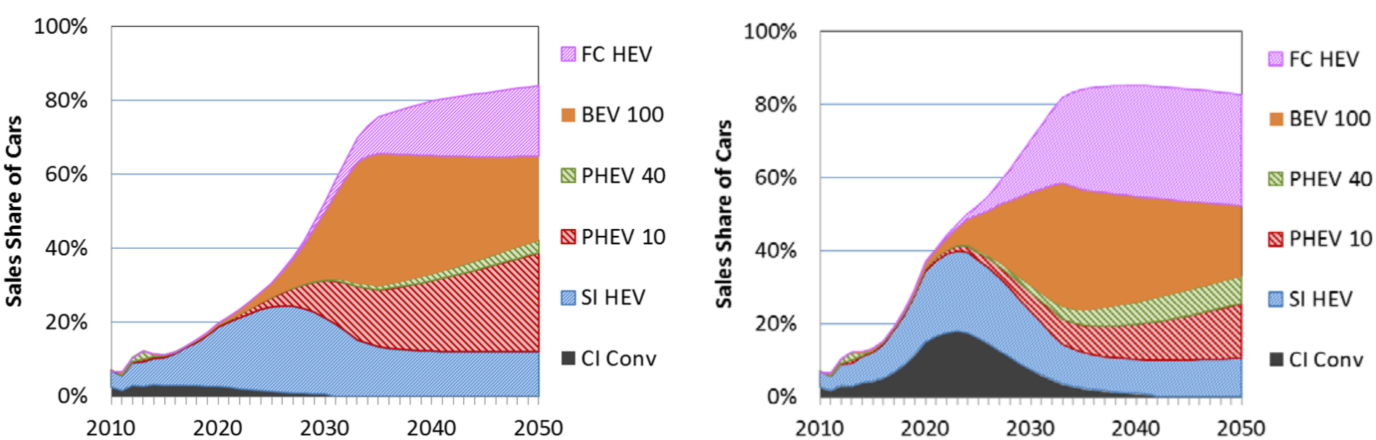
The GHG benefits of FCTO program targets are more uncertain. For simplification, we assume 0.51 kg CO_2/kWh electricity based on AEO estimated 2015 United States average grid carbon intensity and 9.22 kg CO_2/kg H_2 based on central reforming of natural gas at current technology without carbon capture and sequestration, but expect greater GHG benefits from deeper decarbonization of electricity and hydrogen supply. As shown in Figure 4, the FC \$30/kW and HS \$8/kWh targets reduce GHG emissions by 12–31 $MMtCO_2e$ by 2030 and 29–163 $MMtCO_2e$ by 2050, depending on supply share of renewable hydrogen.

CONCLUSIONS AND FUTURE DIRECTIONS

- FCEV sales impacts of program targets were found to be significant and dependent on oil price, station roll-out speed, and hydrogen price.
- The petroleum reduction benefit of program targets is significant, especially in the long run. The FCTO targets reduce petroleum use by 0.12 MMbpd or 2% by 2030, 0.68 MMbpd or 16% by 2050.
- The GHG reduction benefit of program targets is significant only in the long run and with decarbonization of hydrogen supply. The FC \$40/kW and HS \$10/kWh targets reduce GHG emissions by 0.8%–2% by 2030 and 3%–18% 2050, depending on supply share of renewable hydrogen.
- Recommended future work includes vehicle data updates to reflect recent views of future technology trends, cluster strategy to capture potential targeted markets, business model analysis to assist private sector investments, and consumer segmentation to understand niche and mass markets for FCEVs.

FY 2015 PUBLICATIONS/PRESENTATIONS

1. Zhenhong Lin, Changzheng Liu, GPRA Analysis: Impact of Program Targets on Vehicle Penetration and Benefits. Presented at the 2015 DOE Annual Merit Review meeting.



SI – spark ignition; CI – compression ignition; Conv – conventional

FIGURE 2. Technology market share impact of program targets (midsize cars and crossovers only)

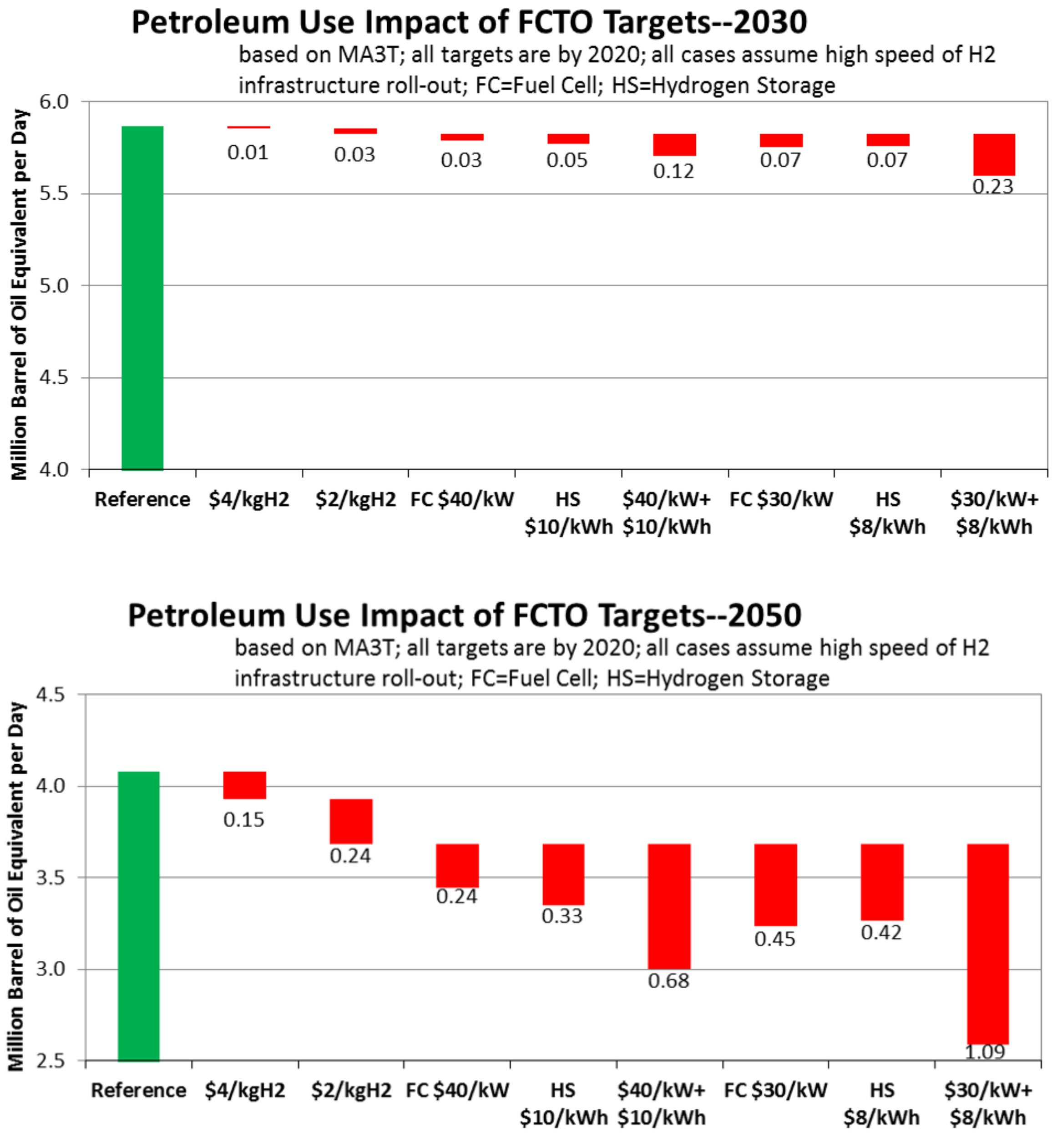


FIGURE 3. FCTO target impacts on LDV petroleum use

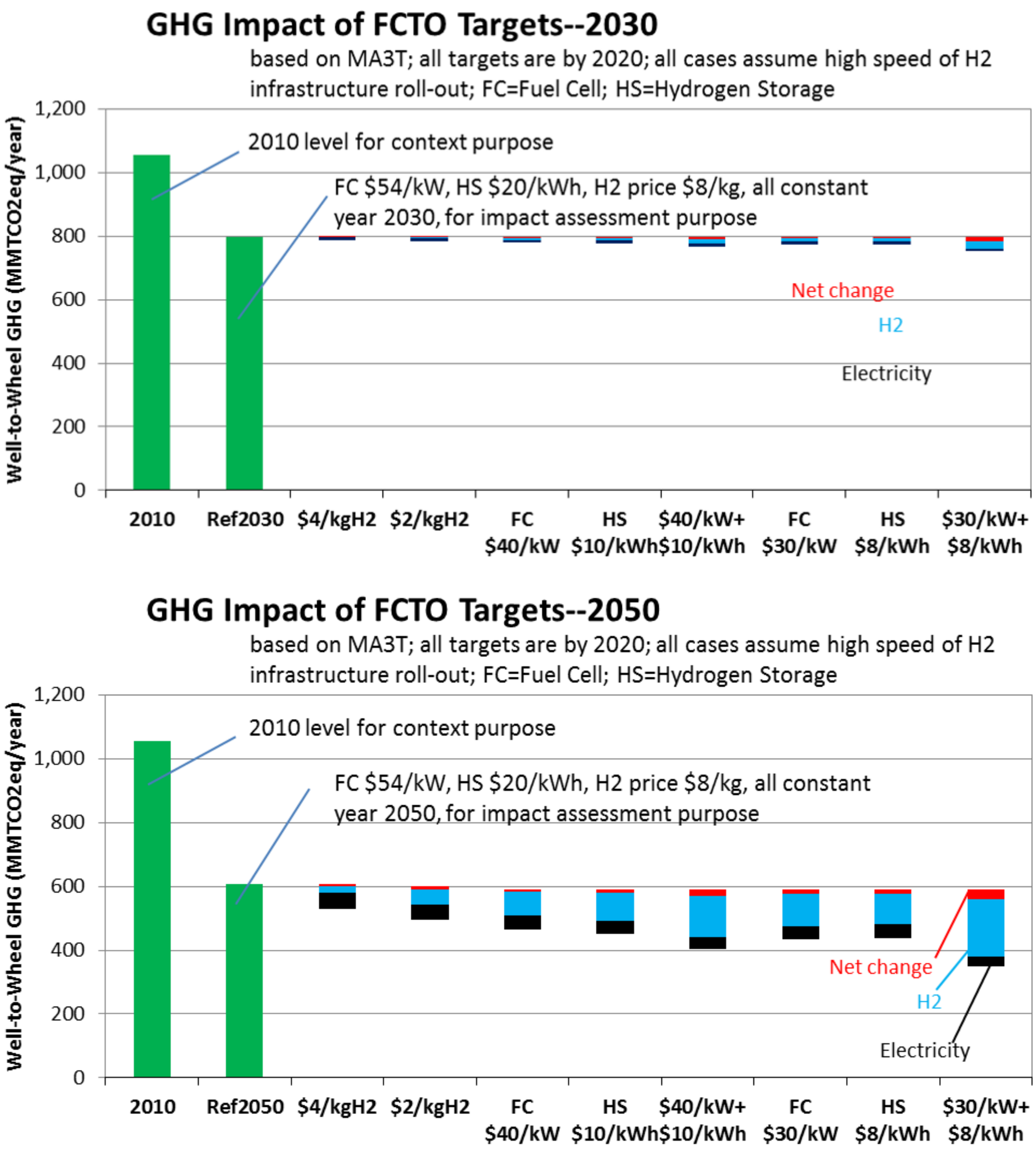


FIGURE 4. FCTO target impacts on LDV GHG emissions