IX.12 Benefits Analysis of Multi-Fuel/Vehicle Platforms with a Focus on Hydrogen Fuel Cell Electric Vehicles

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Project Start Date: October 1, 2015
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- Estimate potential future benefits attributable to the Hydrogen and Fuel Cells Technologies Office (FCTO) program, including:
  - Petroleum use reduction
  - Greenhouse gas emissions reduction
  - Economic impacts

While considering synergies and interactions with the Vehicle Technologies Office (VTO) program.

- Examine the sensitivity of estimated benefits to input assumptions.

Fiscal Year (FY) 2017 Objectives

- Issue report documenting results and methods of the analysis of program benefits.
- Present results to FCTO and VTO analysts.
- Assess sensitivity of benefits estimates to assumptions about technology progress.

Technical Barriers

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

(B) Stove-piped/Siloed Analytical Capability

(C) Inconsistent Data, Assumptions and Guidelines

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 3.1: Annual update of Analysis Portfolio (4Q, 2011 through 4Q, 2020)

FY 2017 Accomplishments

- Produced estimates of petroleum use reduction attributable to hydrogen fuel cell vehicle and storage technologies ranging from 0.3 to 1.0 million barrels per day (MMbpd) by 2050, and a reduction in greenhouse gas emissions ranging from 59–148 million metric tons CO_2 equivalent by 2050.
- Estimated that successful achievement of FCTO research and development program goals and commercialization of FCTO technologies could lower the cost of fuel cell vehicle ownership, as measured by a levelized cost of driving metric to be competitive with conventional gasoline-powered vehicles by 2035.
- Documented these analysis methods and results in a technical report (Stephens et al., 2017 [1]).

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INTRODUCTION

Potential future benefits resulting from successful achievement and deployment of technologies being developed under the FCTO and VTO research and development programs were estimated out to the year 2050. These benefits include:

- Petroleum use reduction
- Greenhouse gas emissions reduction
- Economic impacts

These benefits are estimated under assumed future conditions, and the sensitivity of the estimates to these assumptions is being evaluated.

APPROACH

Scenarios were developed and analyzed to estimate benefits of successful development and deployment of advanced vehicle technologies, comparing a case with completely successful deployment of FCTO and VTO technologies ("Program Success" case) to a future in which there is no contribution after FY 2017 by the FCTO or VTO to these technologies ("No Program" case). Benefits were disaggregated by individual program technology areas, which included the FCTO and VTO research and development programs.

RESULTS

Projections for the Program Success case indicate that by 2035, the average fuel economy of on-road, light-duty vehicle (LDV) stock could be 24% to 30% higher than in the No Program case[1]. The resulting petroleum savings in 2035 were estimated to be as high as 1.5 MMbpd, and reductions in greenhouse gas (GHG) emissions were estimated to be as high as 250 million metric tons of CO_2 equivalent per year. Such petroleum reductions result in significant reductions in fuel expenditure for light-duty vehicles, totaling $62–85 billion annually by 2035.

Figure 1 shows the projected petroleum consumption by LDVs (entire on-road stock) in years 2035 and 2050 under both the No Program and Program Success scenarios, with uncertainty bars showing the range of projected values. Projections were made using four different vehicle market penetration models. Savings for LDVs are shown in the plot on the left. Figure 1 also shows the range of projected cumulative petroleum savings since 2019 attributed to FCTO and VTO technology programs in the plot on the right.

[1] The Program Success case represents a future in which FCTO (and VTO) R&D programs successfully reach all technology targets and these technologies are successfully commercialized. The No Progam case represents a future in which no further R&D investments are made by FCTO or VTO, and technological progress advances more slowly.

FCTO and VTO technologies are projected to improve fuel economy by 35–62% for new LDVs sold in 2035, and by as much as 73% by 2050, relative to improvements in the absence of DOE funding. These increases, due in part to market penetration by fuel cell vehicles, are shown in Figure 2.

Projections of LDV adoption indicate that although advanced-technology vehicles may be somewhat more expensive to purchase, the fuel savings result in a net reduction of consumer cost. As shown in Figure 3, in 2035, projections of decreases in annual fuel expenditures for LDVs range from $62–85 billion, while the projected increase in new LDV expenditures in the same year ranges from $3–1 billion (both in 2015$). By 2050, annual fuel savings for LDVs reach $94–184 billion, while vehicle purchases are projected to be $27–$32 billion more expensive.

Benefits were disaggregated by individual program technology areas, which included the FCTO program and the VTO research and development programs of electrification, advanced combustion engines and lubricants, and materials technology. Benefits to medium-duty vehicles and HDVs were attributed to advanced combustion engines and lubricants, the program which funds most of the heavy-duty technologies. Ranges of projected petroleum savings and greenhouse gas reductions attributed to these programs are plotted in Table 1.

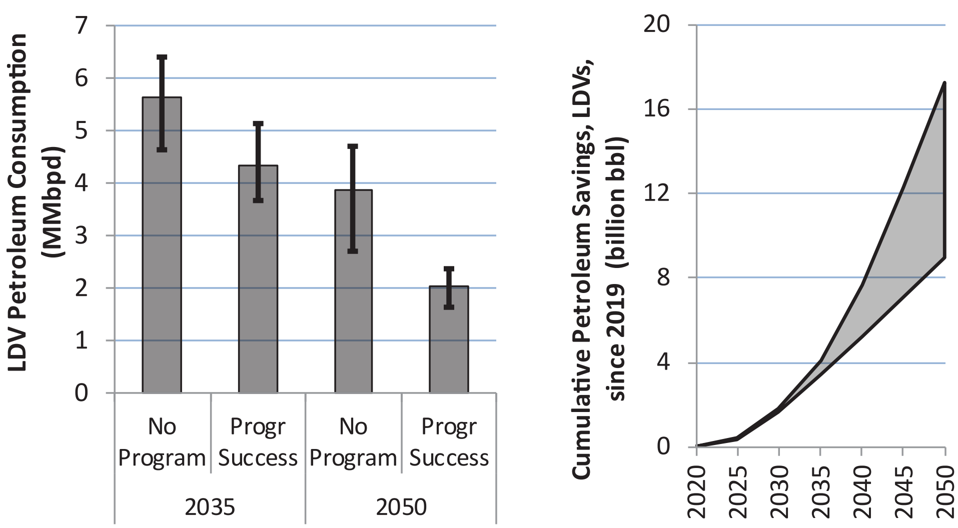

FIGURE 1. Projected on-road petroleum consumption by light-duty vehicles under the No Program and Program Success scenarios in 2035 and 2050 (left), and cumulative petroleum savings since 2019 attributed to FCTO and VTO technology programs (right). Projections made using four vehicle market penetration models.

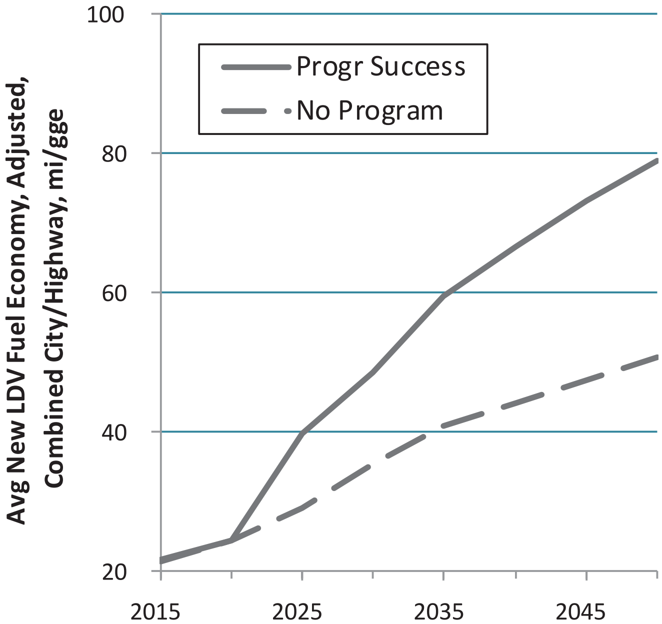

FIGURE 2. Projected fleet-averaged fuel economy (adjusted, combined city/highway) through 2050 for light-duty for Program Success and No Program scenarios. Harmonic average of four projections from different market penetration models).

CONCLUSIONS AND UPCOMING ACTIVITIES

A Program Success scenario and a No Program scenario were analyzed to estimate the combined benefits of successful FCTO and VTO technology programs. Projections for the Program Success case indicate that by 2035, the average fuel economy of on-road, LDV stock could be 24% to 30% higher than in the No Program case, and by 2050, the increase could be 39% to 68%. The resulting petroleum savings were estimated to be as high as 1.5 MMbpd in 2035 and up to 2.7 MMbpd in 2050, and reductions in GHG emissions were estimated to be as high as 250 million and 390 million metric tons of CO_2 equivalent per year in 2030 and 2050, respectively. Petroleum savings in 2035 and 2050 attributable to the FCTO program range from 0.11 MMbpd to 0.45 MMbpd in 2035 and from 0.35 MMbpd to 0.96 MMbpd in 2050. Projections of LDV adoption indicate that although advanced-technology vehicles may be somewhat more expensive to purchase, the fuel savings result in a net reduction of consumer cost. In 2035, reductions in annual fuel expenditures for LDVs are projected to range from \$62–\$85 billion, while the projected increase in new vehicle

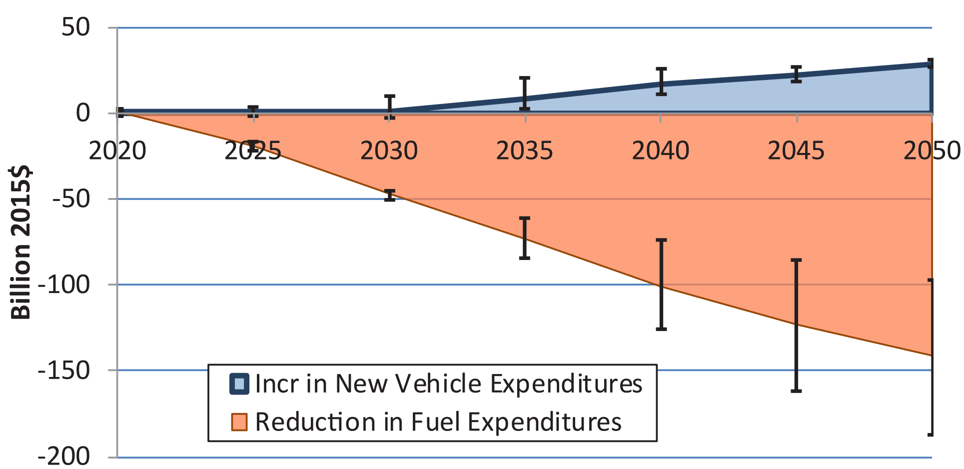

FIGURE 3. Differences in annual national consumer costs of vehicle purchases and fuel costs for on-road light-duty vehicles through 2050, between the No Program and Program Success scenarios. Increased expenditures shown as positive; decreased expenditures shown as negative.

TABLE 1. Projected Ranges of Petroleum Savings and Emissions Reductions in 2025, 2035, and 2050 by VTO and FCTO Technology Programs

Program Area	Petroleum savings (MMbpd)			Annual GHG reduction (million tons CO_2-eq)		
	2025	2035	2050	2025	2035	2050
Electrification	0.03–0.19	0.28–0.61	0.38–1.44	5–29	57–123	74–272
Combustion & Fuels	0.25–0.32	0.66–1.01	0.85–1.01	46–62	122–194	151–182
Materials	0.02–0.03	0.06–0.12	0.06–0.08	4–7	11–24	10–15
Hydrogen Fuel Cells	0.00–0.05	0.11–0.45	0.35–0.96	0–6	14–46	59–148

TABLE 2. Side Cases (Scenarios) to be Analyzed

Case	H_2 storage cost	Fuel Cell System cost	H_2 price	H_2 availability	Fuel Cell Vehicle configuration
H_2 price medium	Progr Success	Progr Success	Medium	Progr Success	Progr Success
H_2 storage cost accel	Accel	No Program	No Program	No Program	No Program
FC system cost accel	No Program	Accel	No Program	No Program	No Program
H_2 price, availability	No Program	No Program	Accel	Progr Success	No Program
All accel	Accel	Accel	Accel	Progr Success	Accel

expenditures in the same year ranges from \$6–\$21 billion (both in 2015\$).

In addition to the two scenarios analyzed to provide estimated future program benefits, several side cases will be developed and analyzed (Table 2). The sensitivity of projected benefits to different input assumptions about hydrogen price, costs of fuel cell systems, and hydrogen storage will provide insight into which technology area might provide the most benefit if accelerated beyond FCTO program plans. It is recommended to include medium- and heavy-duty fuel cell vehicles to the scenarios to account for future benefits of FCTO technologies in these applications.

FY 2017 PUBLICATIONS/PRESENTATIONS

1. Stephens, T.S. *Benefits Analysis of Multi-Fuel/Vehicle Platforms with a Focus on Hydrogen Fuel Cell Electric Vehicles*. U.S. Department of Energy Hydrogen and Fuel Cells Program 2017 Annual Merit Review and Peer Evaluation Meeting, Washington, D.C., June, 2017, https://www.hydrogen.energy.gov/pdfs/review17/sa068_stephens_2017_o.pdf.

2. Stephens, T.S., A. Birky, and D, Gohlke. *Vehicle Technologies and Fuel Cell Technologies Office Research and Development Programs: Prospective Benefits Assessment Report for Fiscal Year 2018*. Argonne National Laboratory, Argonne, IL, in review.

REFERENCES

1. Stephens, T.S., A. Birky, and D, Gohlke. *Vehicle Technologies and Fuel Cell Technologies Office Research and Development Programs: Prospective Benefits Assessment Report for Fiscal Year 2018*. Argonne National Laboratory, Argonne, IL, in review.