IX.7 Hydrogen Analysis with the Sandia ParaChoice Model

Todd West (Primary Contact), Dawn Manley, Rebecca Levinson
Sandia National Laboratories
7011 East Avenue
Livermore, CA 94550
Phone: (925) 294-3145
Email: thwest@sandia.gov

DOE Manager
Fred Joseck
Phone: (202) 586-7932
Email: Fred.Joseck@ee.doe.gov

Project Start Date: October 1, 2014
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- ParaChoice captures changes to the light-duty vehicle (LDV) stock through 2050 and its dynamic, economic relationship to fuels and energy sources
- Model occupies a system-level analysis layer with input from other DOE models to explore the uncertainty and trade space (with 10,000s of model runs) that is not accessible in individual scenario-focused studies
- Model dynamics and competition among LDV powertrains and fuels using regional-level feedback loops from vehicle use to energy source
- Identify set of conditions that must be true to reach performance goals and sensitivities and tradeoffs between technology investments, market incentives, and modeling uncertainty

Fiscal Year 2015 Objectives

- Add hydrogen production and fuel cell electric vehicles (FCEVs) to existing Sandia ParaChoice model to further the Fuel Cell Technologies Office (FCTO) mission
- Determine how FCEVs compete in the fleet with conventional and other alternative energy vehicles
- Determine effects of FCEV and hydrogen adoption on petroleum usage and greenhouse gas (GHG) emissions
- Evaluate hydrogen production and consequences for hydrogen pricing, FCEV adoption, and GHG emissions

Technical Barriers

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

(A) Future Market Behavior

(B) Stove-piped/Siloed Analytical Capability

(C) Inconsistent Data, Assumptions and Guidelines

(D) Insufficient Suite of Models and Tools

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 MYRDD 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 1.16: Complete analysis of program performance, cost status, and potential use of fuel cells for a portfolio of commercial applications. (4Q, 2018)
- Milestone 1.18: Complete life cycle analysis of vehicle costs for fuel cell electric vehicles compared to other vehicle platforms. (4Q, 2019)

Specifically, this project models the life cycle costs of fuel cell electric vehicles compared to conventional and alternative LDVs. Sensitivity analyses were performed to identify where FCEVs can successfully compete with current and potential future LDV options.

FY 2015 Accomplishments

- Added FCEVs and a range of hydrogen production pathways to the existing Sandia ParaChoice model
- Updated ParaChoice model to use most recent Annual Energy Outlook and Autonomie projections as well as the most recent vehicle registration data and state incentives for FCEVs and hydrogen production
- Completed initial analysis of FCEV adoption, hydrogen production pathways, and sensitivity analysis
- Presented initial analyses at DOE Annual Merit Review

INTRODUCTION

In the coming decades, light-duty vehicle options and their supporting infrastructure must undergo significant transformations to achieve aggressive national targets for reducing petroleum consumption and lowering greenhouse gas emissions. Hydrogen FCEVs, battery and hybrid electric vehicles, and biofuels are among the promising advanced technology options. In addition, natural gas vehicles, fueled with domestically produced natural gas, have significant potential to displace petroleum use in the light-duty vehicle mix.

The parametric analysis of factors that influence adoption of hydrogen vehicles and infrastructure for light duty transportation is assessing the evolving market penetration potential of FCEVs. Specifically, this analysis is examining options for the evolving light duty vehicle mix from the present to 2050 to include FCEVs, conventional internal combustion engines (ICEs), battery electric vehicles (BEVs) of various ranges, plug-in hybrid electric vehicles which have an electric range of either 10 or 40 miles (PHEV-10 or PHEV-40), natural gas vehicles (both dedicated and bi-fuel vehicles), as well as E85 flex fuel vehicles.

APPROACH

ParaChoice captures changes to the LDV stock through 2050 and its dynamic, economic relationship to fuels and energy sources. The model occupies a system-level analysis layer with input from other DOE models to explore the uncertainty and trade space (with 10,000s of model runs) that is not accessible in individual scenario-focused studies. By conducting parametric analyses, this sensitivity study identifies the set of conditions that must be true to reach performance goals and tradeoffs between technology investments, market incentives, and modeling uncertainty.

In particular, this project is examining the market penetration of FCEVs as a function of (1) various hydrogen production and distribution pathways, as well as public infrastructure availability; (2) fuel (gasoline, natural gas, hydrogen) and electricity cost; (3) vehicle cost; (4) home filling (natural gas) or charging (BEV, PHEV) cost; and (5) fuel economy.

RESULTS

The parametric approach taken in this analysis allows exploration of broad range of scenarios and tradeoffs. Analysis of which factors have the greatest impact on FCEV adoption and GHG emissions is ongoing, but preliminary results are highlighted below.

Using baseline input parameters, we find that FCEVs are a significant fraction of fleet sales by 2050 (Figure 1). These results however are sensitive to specific assumptions on future costs of FCEVs from the Argonne National Laboratory *Autonomie* model. Initial results using an updated version of *Autonomie* show much less adoption of FCEVs by 2050.

ParaChoice models vehicle adoption and use at the state and urban/suburban/rural level. For example, model outputs show the effects of different state incentives on 2050 FCEV sales (Figure 2). State incentives and fuel prices appear to drive regional variation in FCEV adoption.

Hydrogen pump fuel prices drop with increasing demand, ultimately becoming competitive with gasohol prices on a per mile basis (Figure 3).

For baseline inputs, hydrogen is provided by industrial sources until mid-2030s (Figure 4). Hydrogen production then transitions to distributed production via steam methane

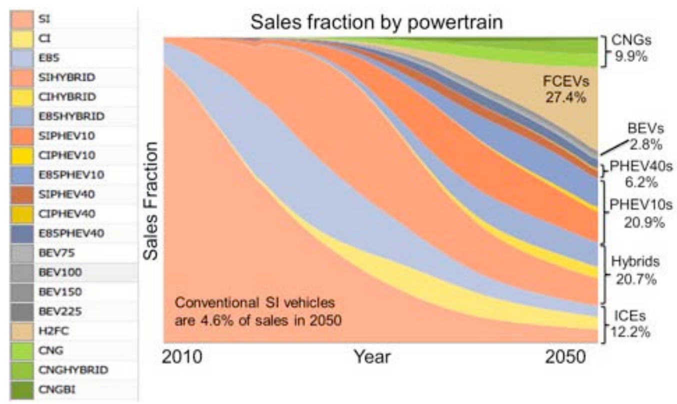

FIGURE 1. Sales fraction by powertrain for baseline scenario, using costs and efficiencies from Autonomie 2011

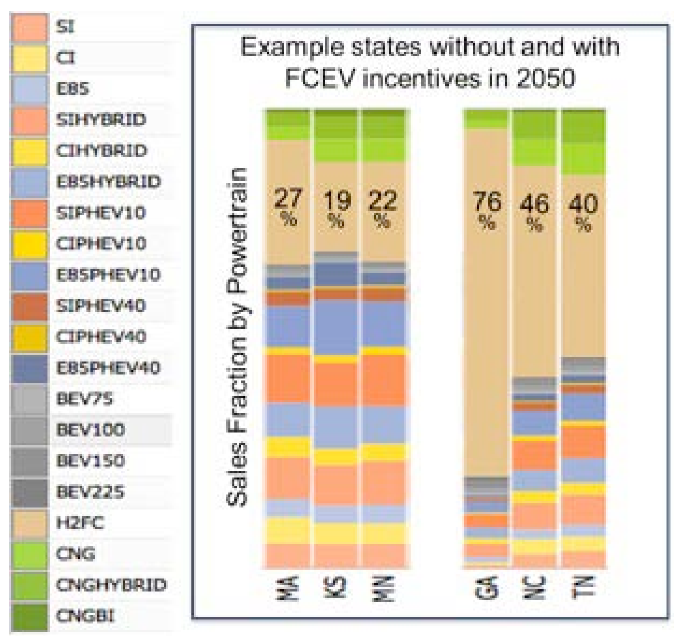

FIGURE 2. FCEV adoption differs between states with and without incentives

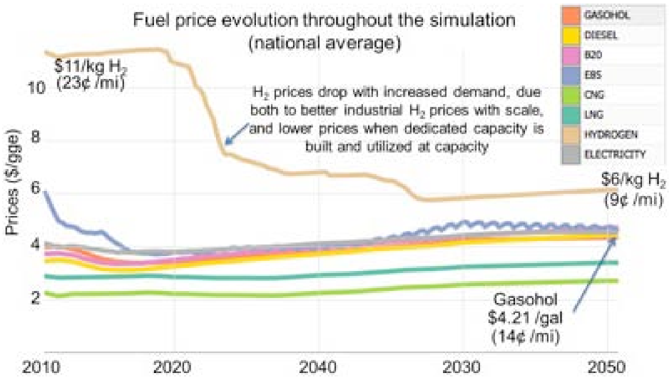

FIGURE 3. National average fuel prices through 2050 for baseline scenario

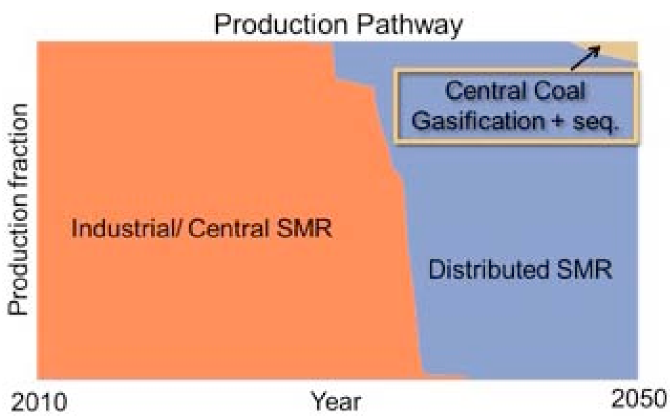

FIGURE 4. Hydrogen production pathways through 2050 in the baseline scenario

reforming (SMR). By 2045, centralized production using coal plus sequestration becomes the cheapest option for some states. Consequently, greenhouse gas emissions are not strongly affected by the substantial FCEV adoption in the absence of low carbon mandates or other incentives.

CONCLUSIONS AND FUTURE DIRECTIONS

FCEVs and hydrogen fuel production are now part of the Pathways ParaChoice model. This model's parametric approach allows exploration of a broad range of scenarios and tradeoffs. Initial findings include the following.

- Hydrogen can play a large role in the 2050 fleet.
- If market forces are the only drivers of hydrogen production pathways, FCEVs will have a carbon neutral effect on the fleet out through 2050.
- FCEVs have the potential to reduce GHG emissions if carbon taxes, technology improvements, or incentives steer hydrogen production towards low-carbon pathways.

Future work will expand on this analysis of FCEVs in the vehicle fleet and on the pathways used to produce hydrogen as a vehicle fuel. In particular, the analysis will examine the market penetration of FCEVs in a range of specific market segments to determine under what conditions FCEVs can best compete with other alternative fuel vehicles.

FY 2015 PUBLICATIONS/PRESENTATIONS

1. Levinson, Rebecca. "Hydrogen Analysis with the Sandia ParaChoice Model." 2015 Annual Merit Review. Crystal City Marriott, Arlington, VA. 9 June 2015.