IX.9 Agent-Based Modeling of Consumer Behavior

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Project End Date: Subject to DOE

Overall Objectives

- Explore the role of consumer choice in the expansion and support of consumer-facing hydrogen fueling infrastructure.
- Understand how the system works rather than provide a single forecast of system development.
  - What role do consumer attitudes and behavioral characteristics play?
  - To what extent do social interactions influence purchasing behavior?
  - How do different offerings from original equipment manufacturers affect consumer adoption?
  - How sensitive and to what extent is growth affected by policy makers?
- Consider in a complex adaptive system the interactions between consumers of hydrogen fuel and fuel cell vehicles (FCVs), hydrogen fuel producers and suppliers, manufacturers of FCVs.

Fiscal Year (FY) 2017 Objectives

- Update zip code-level data on income, jobs, population density, etc.; augment it with national- and state-level data on fleet age, vehicle travel, etc.
- Expand spatial resolution from 1 mi square to 1/4 mi square zones.
- Expand study area to 100 mi x 60 mi and apportion it into a higher-resolution grid.
- Update "seed" data on existing FCVs and hydrogen fueling stations.
- Revise agent decision algorithms to reflect most recent behavioral research.

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

(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 achieving the following milestones for the Systems Analysis section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

- Milestones 2.3–2.6: Develop and maintain models and tools.

FY 2017 Accomplishments

- Upgraded model to 64-bit platform to enable more computationally demanding tasks (e.g., more agents, finer time scale, higher resolution space, more sophisticated algorithms).
- Completed spatial update and expansion. Expanded study area and spatial resolution to 1/4 mile square zones. Mapped zones to zip code-segmented data within study area.
- Acquired improved spatial data to seed the model with locations of existing FCVs and hydrogen fueling stations.
- Revised station characteristics to reflect tube-trailer delivery of gaseous hydrogen (in place of distributed hydrogen production as characterized in the earlier model). Began revising agent decision algorithms.

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INTRODUCTION

This project is updating and expanding an existing agent-based model that simulates the buildout of hydrogen fueling infrastructure in order to examine the effect of that buildout on FCV adoption. It relies on a complex adaptive systems framework and builds on earlier work by Argonne National Laboratory, Ford Motor Co., RCF Economic & Financial Consulting, and Synovate Motoresearch.

APPROACH

A complex adaptive systems framework is uniquely suited to examine the inter-relationship between supply and demand for new technologies like FCVs. Since vehicle adoption is affected by the availability (or lack) of fueling infrastructure, increases in the supply of that infrastructure may be expected to spur adoption which will produce further increases in infrastructure and, in turn, additional adoption. This "virtuous cycle" is the result of numerous decisions by individual agents who purchase vehicles, who invest in fueling stations, who manufacture vehicles, who develop policies to promote the technology, etc. For this application, the model simulates the behavior of consumer/driver agents living and working in a 60 x 100 mi study area roughly equivalent to the Los Angeles metropolitan area (Figure 1); investor agents who plan, develop and operate hydrogen fueling stations; original equipment manufacturer agents who produce and market vehicles; and government agents who enact policies affecting vehicle and infrastructure deployment.

RESULTS

For this new project, FY 2017 efforts focused on data acquisition to update and enhance the algorithms in the existing model and enhance spatial granularity, and coding to accomplish those updates and enhancements. Table 1 shows some of the parameters that were updated using new or revised data or findings from the literature.

Spatial Enhancement

In order to increase the model's geographic scope and resolution, each 1 mi square travel zone was split into sixteen 1/4 mile square zones, and mapped to zip codes and to locations of seed drivers and stations; the road network was expanded to add major arterials; and travel patterns were reconfigured to reflect more realistic trip routes. The updated, higher-resolution model now has more precise location information for seed drivers and stations, permitting investors to consider additional potential fueling locations and consumers to utilize them.

TABLE 1. Parameters updated or added to agent-based model in FY 2017

Parameter or Set of Parameters	Data Update (FY 2017)	Modeling/ Sensitivity (FY 2018)
Investor planning horizon	○	●
Fueling station capital & O&M cost	○	●
Station salvage value	○	
Station debt financing	○	●
Station capacity, delivery option[A]	○●	●
Augmenting station capacity	○●	●
H_2 price (production, tax, retail, etc.)	○●	●
FCV purchase price	○●	●
FCV tank capacity, mi/kg, etc.	○●	●
FCV age, VMT distribution	○	●
FCV driver VMT	○	●
FCV driver fueling preferences	○	
FCV driver worry	○	

○ = Updates with more recent, more complete, and/or more robust research/reports.
● = Updates with observed data.
A = New parameter added.
O&M – operation and maintenance
VMT – vehicle miles travelled

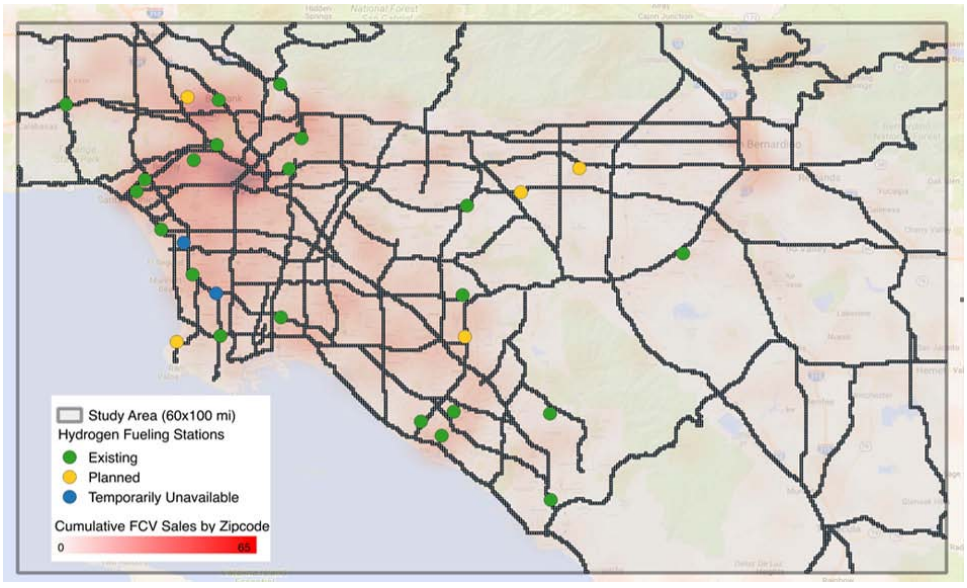

FIGURE 1. Study area

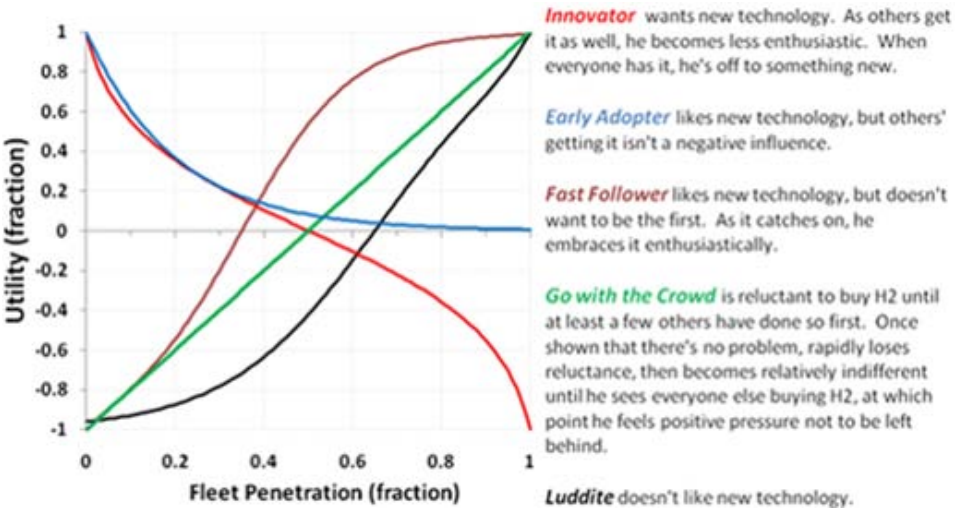

FIGURE 2. Consumer preferences for new technology and how those preferences influence adoption

Agent and Choice Representation

Along with spatial enhancement, FY 2017 efforts used new and improved research results to update the representation of hydrogen fueling stations and the behavior of the consumer, driver, investor, and original equipment manufacturer agents. While some of the parameters required for that update (see Table 1) are straightforward, others (e.g., driver worry, fueling preferences) involve complex relationships that can vary across populations or even within the same population over time. Given this heterogeneity, the model incorporates not only an initial distribution of preferences for new technology adoption (e.g., innovator, early adopter, fast follower, crowd follower, or Luddite, see Figure 2), but also memory and experience-based costs. The latter include the driver agent's most recent on-road experience or exposure, the rate of decay in operational memory of that recent experience or exposure, variations in personal preferences for when to refuel (remaining tank level), the extent of social influence on vehicle selection, etc.

Model Seeding

To initiate the simulation, a set of existing FCVs and hydrogen fueling stations (termed seeds) must be located within the study area. When the original, circa 2007, version of the model was developed, there were only a limited number of pre-commercial FCVs and hydrogen fueling stations. Thus seeding could not reflect a true market response. According to the California Fuel Cell Partnership, over 1,300 FCVs are on the road in California and 29 retail stations are in operation today. Most of the vehicles and 17 of the stations are in the Los Angeles metropolitan area. In addition to mapping the locations of these 17 retail stations, FCVs were mapped to analysis zones within the study area based on cumulative FCV sales by zip code.

CONCLUSIONS AND UPCOMING ACTIVITIES

This project is a two-year effort with FY 2017 activities focused primarily on refreshing and updating the circa 2007 model. In FY 2017, we expanded the model's geographic scope and resolution, augmented the types of stations represented, obtained new data to seed the model, and began work on integrating state-of-the-art consumer decision-science algorithms. Planned FY 2018 activities include representing different vehicle categories, allowing consumers to choose between different FCV types, and modeling additional methods of vehicle adoption (e.g., leases, rentals, fleets). However, in light of anticipated funding, work on FY 2018 planned activities is unlikely to occur.

FY 2017 PUBLICATIONS/PRESENTATIONS

Guo, W. Behavioral Modeling of the Adoption and Use of Fuel Cell Electric Vehicles, submitted to the 2017 Behavior, Energy and Climate Change Conference, ACEEE, Sacramento, CA, October 15–18, 2017.