Transition to a Hydrogen Transportation Economy

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Purpose, Objectives, and Work Scope

Funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy

Main project partners include:
- Argonne National Laboratory
- Ford Motor Company
- RCF Economic and Financial Consulting, Inc.

Objective is to analyze the potential emergence of a new hydrogen infrastructure as a complex adaptive system using an agent-based modeling and simulation (ABMS) technique

Use ABMS to address a number of limitations of traditional simulation and optimization techniques. Advantages offered by ABMS include
- Ability to analyze non-optimal outcomes
- Use of profit motive rather than least-cost minimization
- Representation of diversity of actors and business models (differences in tastes, resources, strategies, risk preferences, and objectives; conflicting objectives)
- Representation of independent decision-making (each stakeholder maximizes its own objectives or utility function, rather than economic welfare)
- Ability to represent decisions made based on imperfect knowledge (uncertainty)
- Ability for stakeholders to learn and adapt to real or perceived changes in behavior of others or operating environment
- Ability to look at transitory behavior, rather than only the final equilibrium stage

Identify key factors that either promote or inhibit the development of a new infrastructure

Use ABMS to explicitly deal with the chicken-or-egg problem between hydrogen fuel production and purchase of hydrogen vehicles

What is Agent-Based Modeling?

Agent-based modeling is a micro-simulation technique grounded in the biological, social, and other sciences

An agent-based system is made up of agents that sustain themselves while interacting with other agents and adapting to a changing environment

ABMS simulates the behaviors and interactions of a large number of individuals (7,000 to 70,000 agents) and studies the macro-scale consequences of these interactions

An agent has the following characteristics
- Represents a discrete entity with its own goals and behaviors
- Acts autonomously (most important) and independently
- Heterogeneous with diverse characteristics
- Has the capability to learn/adapt and modify its behaviors

Key assumptions in agent-based modeling include
- Some key aspect of agent behaviors can be credibly described
- The mechanisms by which agents interact can be credibly described
- Complex social/economic processes can be built "from the bottom up"

Infrastructure Investor Agents

Make investment decisions under uncertain demand and competition

Investors want to maximize return (profit motive)

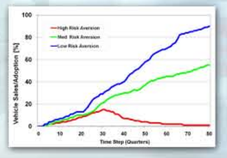
Build facilities based on expectations about complicated situations (satisficing rather than optimizing)

In each period, investors learn from experience/mistakes and revise their expectations using the difference between "actual" and "expected" demand in revising future investment plans

As refueling infrastructure becomes available, driver agents respond by purchasing vehicles and fuels

Allows for non-optimal decisions

Infrastructure performance will vary and some assets may be abandoned (stranded assets)



Under what conditions/assumptions do we see sales/adoption taking off?

How does the system emerge assuming one investor only versus multiple investors?

Under what circumstances could we see the system stagnate or collapse?

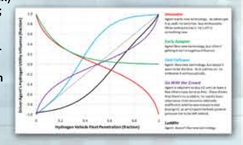
Consumer/Driver Agents

Endogenous vehicle adoption and fuel purchases on a GIS platform

Agents are defined by different income levels, home and work locations, personal preferences and tastes, and personality types; agent densities match actual population/job densities; agents take various types of trips with trip lengths corresponding to actual patterns

Consumer/driver agents decide whether to buy a hydrogen vehicle or a conventional vehicle and when and where to refuel

Agents use a "utility function" to reach their vehicle purchase decision; this function considers the following factors:
- Cost (capital plus operating)
- Inconvenience of refueling
- Worry of running out of fuel
- Social influences (global, neighborhood, work, mix)
- Attitude toward hydrogen (based on personality; model includes five different personality types)



Driver agents gather these data and compute their discounted utility either as actual or as potential hydrogen vehicle owners; positive utility results in hydrogen vehicle purchase

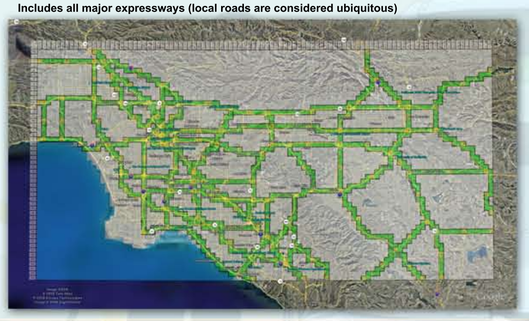
Model tracks vehicle stock and distinguishes between new-car sales and used-car sales

GIS-Based Agent Environment

Scope of the current model configuration is the Los Angeles area (100 miles by 50 miles)

Includes a 25-mile-wide "buffer zone" outside the main region

Includes all major expressways (local roads are considered ubiquitous)



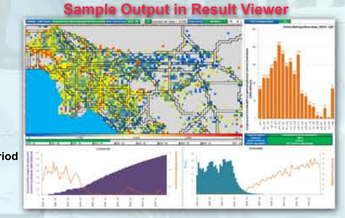
Sample Parameters We Are Testing

Drivers
- Personalities and the weights placed on social interactions
- Risk avoidance of running out of fuel
- Taste and imitation factors
- Number of trips / trip lengths / distance driven per year
- Ratings for income and greenness
- Driver memory (weight on most recent events)
- Years to consider savings of variable benefit
- Fueling window
- Costs applied to worry, inconvenience, and special fueling trips
- Vehicle age distributions and scrap rates for different income levels
- Used car market interaction distributions for different income levels

Vehicles
- Tank capacity
- Fuel efficiency
- Fixed benefit (or cost)
- Variable benefit
- Vehicle lifetime
- Travel vs. age distribution

Investor
- Station size
- Traffic observation method
- Production/sales price of H_2
- Planning horizon/payback period
- Discount rate
- Station capital cost
- Annual maintenance cost

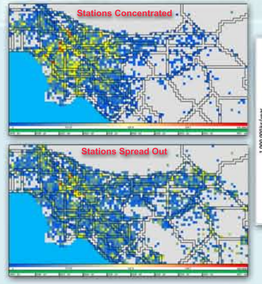
Sample Output in Result Viewer

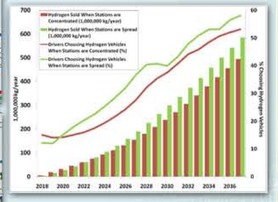


Results

When siting a limited number of stations, what are the consequences of concentrating supply resources in the most heavily populated and trafficked area, as compared to spreading the supply over the entire region?

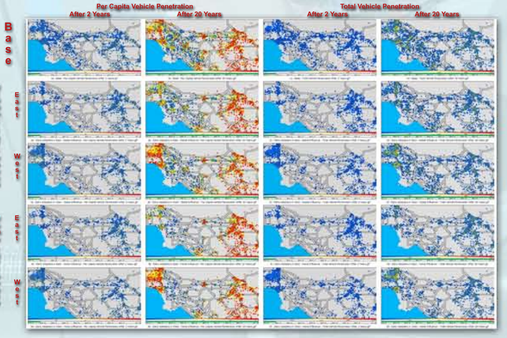
For the same number of stations rolled out over the same time frame, spreading the stations ultimately results in a higher total sales volume





Results

Examining hydrogen vehicle fleet penetration as a function of the location of early adopters and the type of social interaction used (note, results below are for hypothetical placements)



Background images courtesy of BP p.l.c. and National Hydrogen Association

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