Agent-Based Model of the Transition to Hydrogen-Based Personal Transportation: Consumer Adoption and Infrastructure Development Including Combined Hydrogen, Heat, and Power

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Project ID#
AN003

Overview

Timeline

- Project start date: March 2010
- Project end date: September 2010
- Percent complete: 15%

Challenges & Barriers

- Lack of understanding of future market behavior
- Lack of appropriate models and tools; stove-piped analytical capability
- Inconsistent data, assumptions, and guidelines

Budget

- Total project funding
  - $240,000
- Funding for FY10:
  - $240,000 (100% DOE)

Partners

- Lead: Argonne National Laboratory
- NREL: Fuel Cell Power Model
- Synovate

Relevance: Project Objectives

- Explore the **chicken-or-egg problem**: codevelopment of the hydrogen production and delivery infrastructure and the user base which supports it.

- **Understand how the system works** rather than provide one forecast of system development.
  - How do different policies affect the transition?
  - How sensitive is growth to factors beyond the control of policy makers?
  - What role do consumer attitudes and behavioral characteristics play?

- Consider in a complex adaptive system the **interactions** between:
  - Hydrogen fuel producers and suppliers
  - Consumers of hydrogen fuel and fuel cell vehicles (FCVs)
  - Manufacturers of FCVs

- Extend the current agent-based model to include limited-service **Combined Hydrogen, Heat and Power (CHHP)** facilities as well as the regular distributed production hydrogen fueling stations (HFSs) currently modeled

Relevance: Issues Illuminated

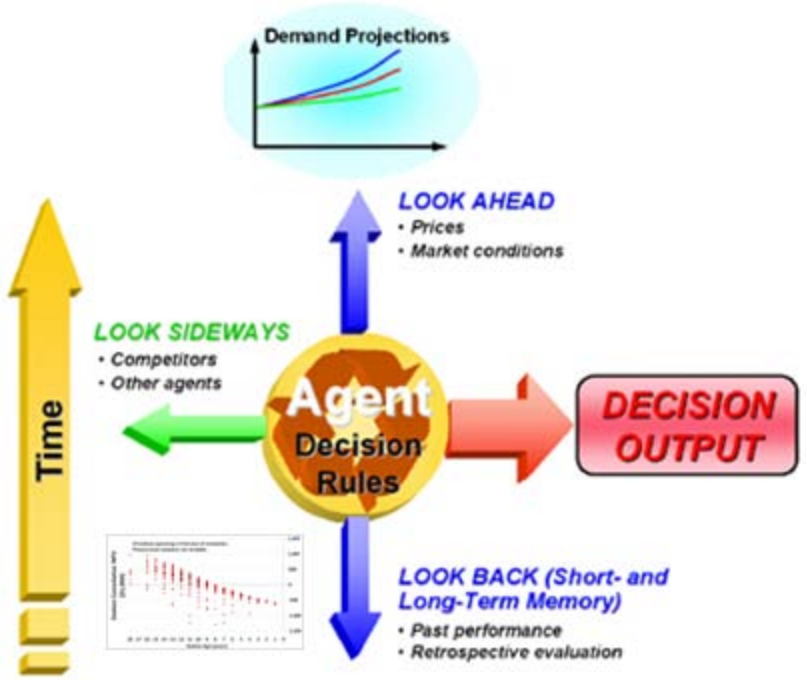
Premise: CHHP plant owners may sell limited amounts of hydrogen to consumers in hydrogen dispensing facilities (HDFs) as a way of obtaining additional revenue that can help to economically justify the plant.

- How might owners of CHHP facilities expand the hydrogen refueling infrastructure by adding HDFs, and **how might the presence of HDFs affect the overall transition?**
- Competition between HFSs and HDFs based on different consumer features: **convenience vs. selling price**
- Effect of driver agents becoming "locked in" to HDF purchases and reluctant to purchase from HFSs: **"Crossing the Chasm"**
- Effect of **different hydrogen production capacities** on both profits and the spread of hydrogen fueling facilities
- Effects of **temporal placement of HDFs** – do adding such facilities early on aid or hinder the purchase of FCVs? Can they be profitable once HFSs are widespread?

Approach: Summary of H2CAS Model

- Uses Agent-Based Modeling and Simulation (ABMS)
  - Simulates the decisions and actions of individual players in the system.
  - Models from the bottom up: **system behavior emerges** from the interactions of individuals.
  - Well-suited for our problem: thousands of players acting autonomously and interacting with one another.
  - Useful tool to help understand micro-factors that in combination drive the macro outcome.

- Agent Types:
  - Drivers
  - HFS Investors
  - CHHP Owners
  - Vehicle OEM



Approach: Description of Agents

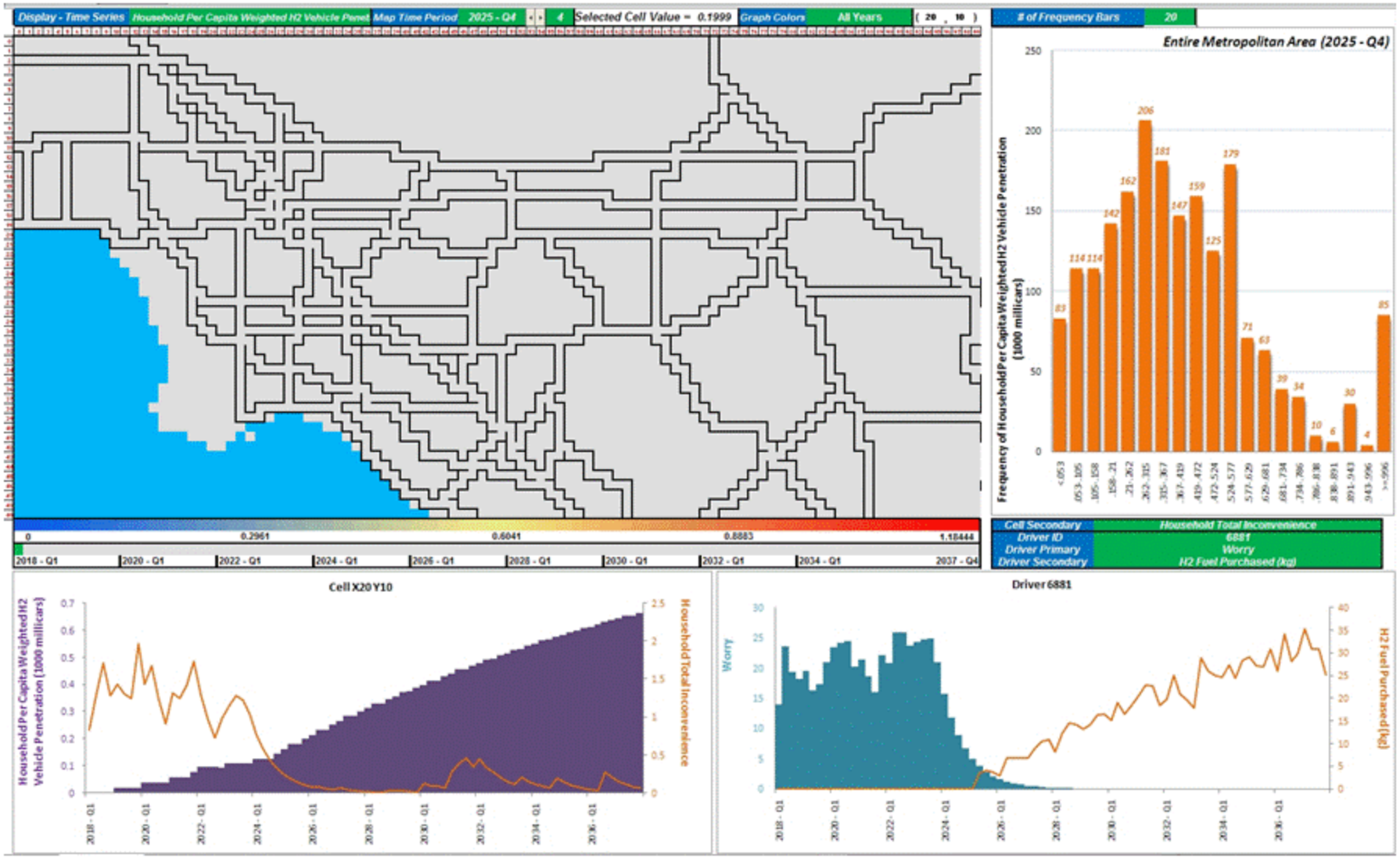
- Driver Agents
  - Represent consumers of vehicles and fuel.
  - Characterized by home and work locations, income level, and “personalities”.
  - **Make many trips** to work and other locations, noting exposure to refueling infrastructure.
  - **Make vehicle purchase decisions** (FCV vs. conventional vehicle)
    - Overall vehicle ages and mileage driven based on ORNL-compiled data.
    - High income drivers purchase vehicles more frequently.
    - Low income drivers purchase used vehicles.
  - Evaluate advantages and disadvantages of FCVs vs. conventional vehicles based on individual experience and personality
    - Sticker price
    - Price drop
    - Operational costs
    - Worry regarding availability of fuel & inconvenience in purchasing it
    - Social influence

Approach: Description of Agents

- HFS Investor Agents
  - Assess the suitability of various sites to locate HFSs based on FCV traffic past the site and their estimates of competition and future growth in hydrogen sales, and **build HFSs** accordingly.
- CHHP Owner Agents
  - Perform similar calculations in determining **whether to add HDFs to their plants**, but based on different cost structures and capacities.
- OEM Agent
  - May **limit the supply of FCVs** based on production capacity in the early years.
  - May decrease the selling price of FCVs relative to conventional vehicles as volume and experience are gained.

Approach: Study Area

- Los Angeles, CA area



Integration of CHHP

- Incorporate different characteristics of CHHP/HDFs and HFSs:
  - HDFs will have a **different cost structure** than dedicated HFSs; lots of federal and state incentives available
  - HDFs may **sell hydrogen "as available"** only, after meeting on-site stationary needs
  - HDFs may **sell to a limited group** of customers only, requiring pre-registration (at some cost in time and/or money to the consumer)
  - HDFs will likely have considerably **lower capacity** (kg/day) than HFSs
  - **Selling price** of HDF hydrogen may be different (lower) than HFS hydrogen
  - **Locations are restricted**: hospitals, large hotels, warehouses, etc.

Integration of CHHP (cont.)

- Model inputs
  - Use the results from NREL's Fuel Cell Power Model to develop a **simplified cost structure** for HDFs:
    - Incremental capital cost
    - Incremental fixed operating and maintenance costs
    - Marginal hydrogen production costs
  - **Locations** of HDFs (determined exogenously)
  - **Capacity** of HDFs (different from that of HFSs)
  - **Selling price** of HDF hydrogen (different from that of HFSs)
  - Switches to allow:
    - Preregistration requirement
    - HDFs to run out of fuel

Project Milestone	Date Due	% Complete
Document work plan for integrating CHHP into H2CAS and analyzing CHHP as a bridge to hydrogen transition	3/31/2010	100
Evaluation of candidate CHHP sites in the LA region	9/30/2010	10
Submit report summarizing analysis	9/30/2010	0

Technical Accomplishments and Progress

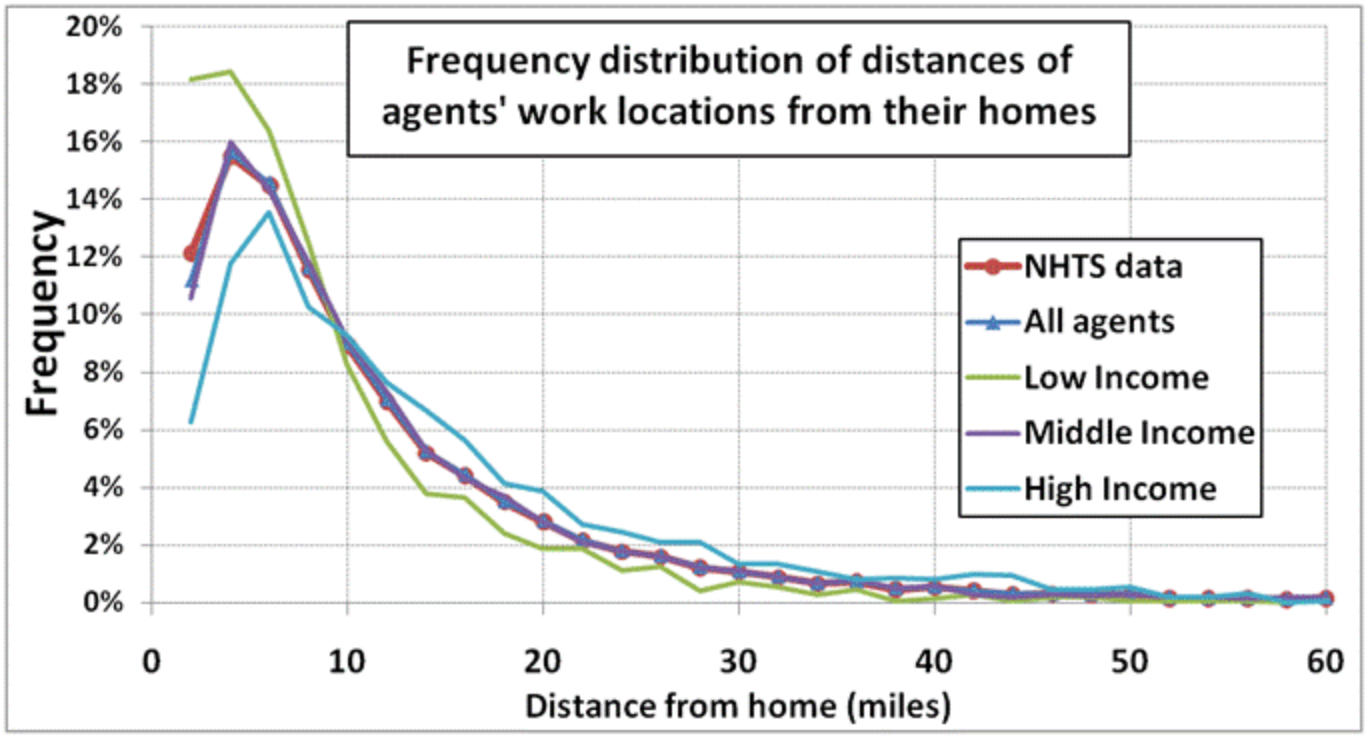
Work started March 2010 - No previous accomplishments to report.

- Increased the granularity of the roadway network topology to allow more refueling locations and more realistic trip routing.
- Added a simple OEM agent to limit the supply of vehicles during the early phase of the transition.
- Improved the calibration of driver "personalities" (attitudes towards new technology and "greenness") to the actual distribution in the population and stated willingness to pay.*
- Provided driver agents with multiple personalities to help the agents better reflect the diversity in a modeled population 1000 times larger.

* Based on literature estimates and discussions with Synovate, a market research firm specializing in the automotive market.

Technical Accomplishments and Progress (cont.)

- Calibrated driver trip distances to latest NHTS data.



Example showing correlation of agent trips with estimates based on NHTS data.

Technical Accomplishments and Progress (cont.)

Planned improvements/extensions:

- Improve investor agents' method of estimating and projecting hydrogen sales (ongoing).
- Further extend driver "personalities":
  - Incorporate attitudes towards FCVs based on time/money cost of registration and lack of full-service amenities.
  - Develop a mechanism to allow agent attitudes to change over time under social and other influences.
  - Calibrate to available market research and published literature.
- Develop algorithms for driver agents to register/purchase from HDFs based on their proximity to home/work, the agent's mileage driven, and perhaps other factors.
- Develop algorithms for driver actions in the event of a HDF running out of fuel, and the resulting costs to the driver in inconvenience.

Collaborations

Argonne NATIONAL LABORATORY

Prime

synovate
Research reinvented

Market research firm aiding in calibration of driver agent personalities

NREL National Renewable Energy Laboratory
Innovation for Our Energy Future

Fuel Cell Power Model used to develop cost structure for HDFs associated with CHHP facilities

Future Work

- Allow endogenous local competition on the selling price of hydrogen
- Explore transition failures
  - Expiration of subsidies
  - Improvements in conventional vehicle efficiency
  - Increased competition from other alternative fuel vehicles
- Expand geographic scope
  - Other metropolitan areas
  - Wider footprint: regional or interstate

Summary

- Relevance
  - Help to understand the hydrogen-based personal transportation chicken-or-egg problem, with particular examination of CHHP as a bridge
- Approach
  - Agent-Based Modeling and Simulation
- Technical Accomplishments & Progress
  - Improved realism of topology and calibrated travel patterns and consumer attitudes to available data
- Collaborations
  - NREL: Fuel Cell Power Model used to determine CHHP cost structure
  - Synovate: Consumer behavior research
- Future Work
  - Expand geographic scope and analyze competitive pricing