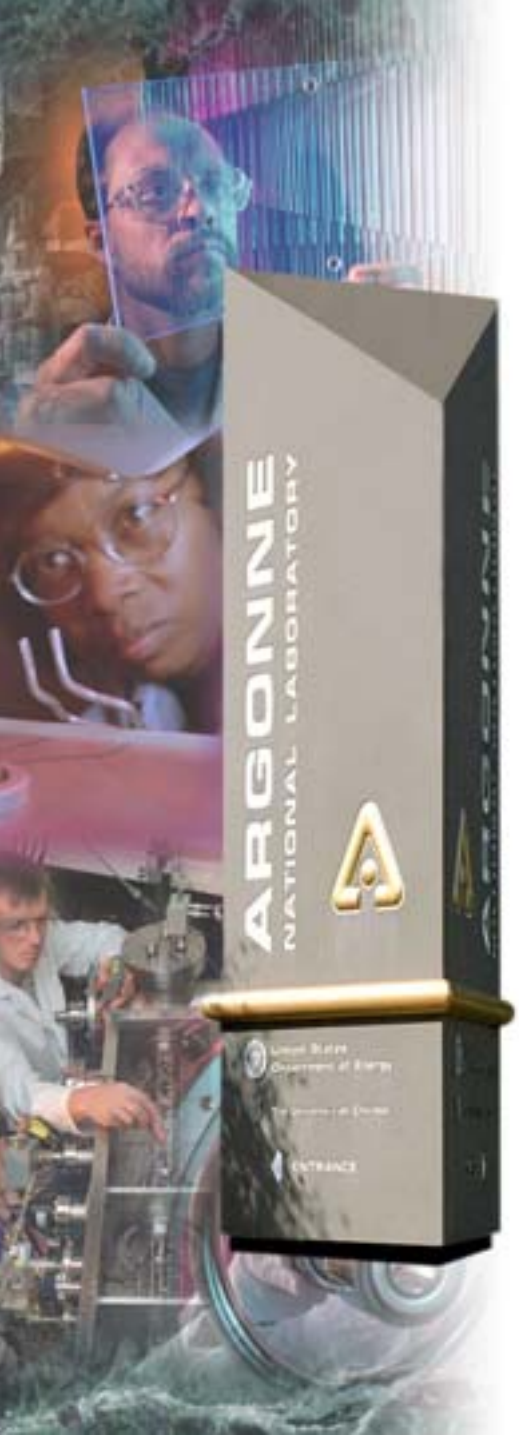

Agent-Based Modeling and Simulation (ABMS) for Hydrogen Transition Analysis

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Energy Efficiency and Renewable Energy

H2CAS

Objectives and Scope for Phase 1

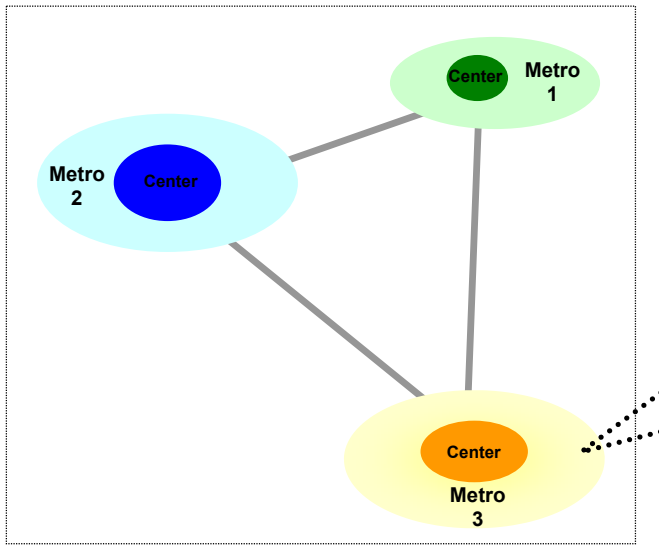
- Analyze the hydrogen infrastructure development as a complex adaptive system using an agent-based modeling and simulation (ABMS) approach
- Develop an ABMS model to simulate the evolution of that system, spanning the entire H2 supply chain from production to consumption
- Identify key factors that either promote or inhibit the growth of H2 infrastructure
- Apply ABMS to get new insights into transition, particularly early transition phase
  - Dynamic interplay between supply and demand
  - Chronological simulation of infrastructure build-up
  - Decentralized, independent decision-making
  - Agents maximize their own objectives and make decisions based on different expectations
  - Effects of uncertainties and different risk/strategy preferences
- Limited scope for FY06
  - Early transition
  - Stylized environment
  - Demand focused on transport

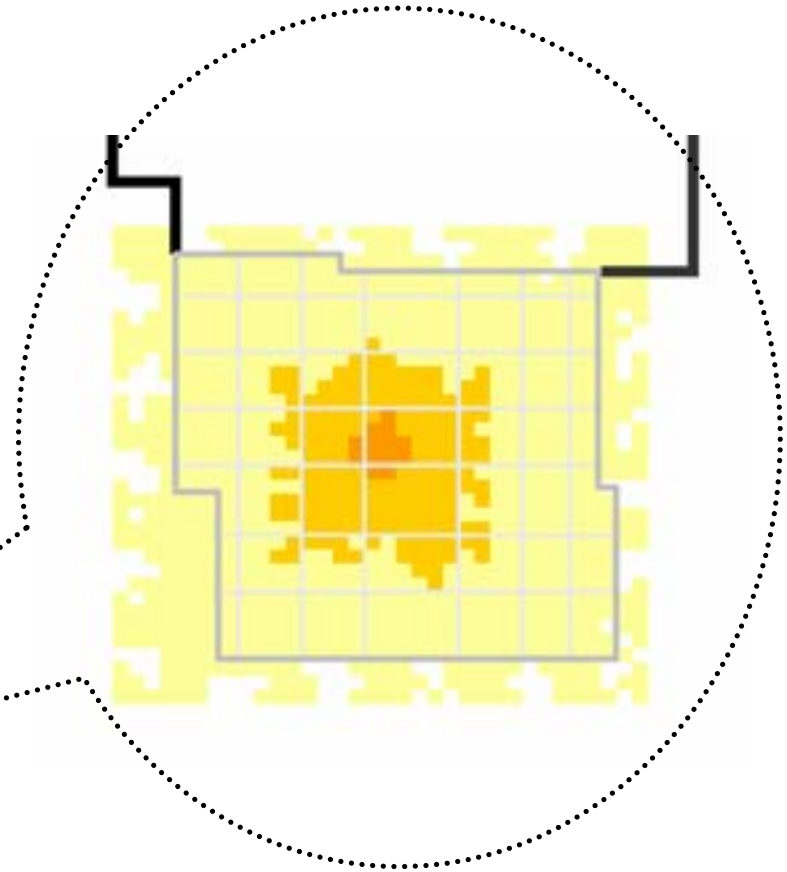
Phase 1 Model Will Include Several Agent Types

- Fuel production and delivery agents
  - 3 production options
    - *Decentralized (e.g., on-site reforming)*
    - *Medium centralized (e.g., centralized SMR)*
    - *Large centralized (e.g., coal or nuclear)*
  - 2 delivery options
    - *Low-volume, short-distance*
    - *High-volume long-distance*
- Retailing/refueling agents selling 2 products
  - H2
  - Gasoline
- Consumers
  - Transport demand
  - Purchasing and operating decisions
- Regulator
  - Passive agent; sets the market rules (e.g., level of tax credits)

The Initial Model Version Uses a "Stylized" Environment in which the Agents Interact

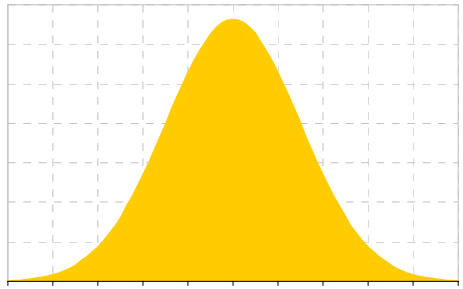
- 3 metropolitan areas with interconnecting transport corridors
- Ranges in population densities provide heterogeneous market environment
  - urban, sub-urban, rural
- Larger highway grid within metro areas connected to intra-city corridors
- Local roads considered ubiquitous
- Can be scaled up and populated in Phase 2 with data for real geographical region

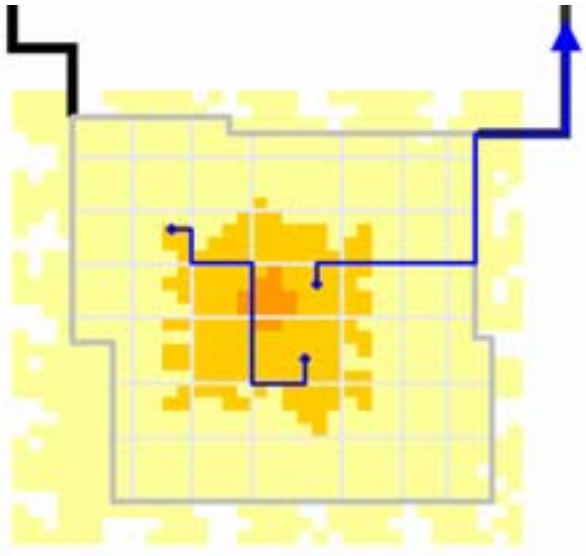




Consumer Agents

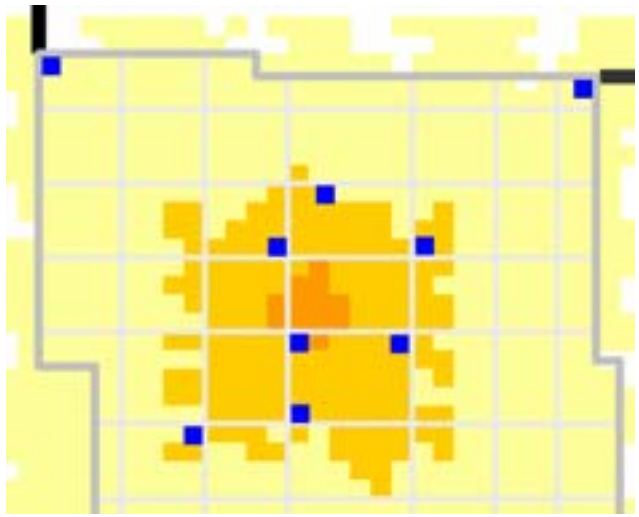
- Agents own and operate vehicles on road network
  - Number of agents: Low 1000s
  - Purchase car decision
    - *Initially, purchase options are limited to 2 vehicle choices (conventional, H2)*
    - *H2 vehicles assumed to meet DOE targets in performance and cost*
  - Vehicle operation and fuel purchase decision (price elastic demand)
- Randomly assigned locations (home, work)
- Have variety of attributes, such as income, income used for transportation, fuel price elasticity and lag, preferences, driving needs/patterns (randomly sampled)
    - *Short/medium-distance (commute, errands)*
    - *Long-distance (leisure)*
- Vehicle operation and purchase decisions try to maximize consumer utility with feedback on driving experience, word-of-mouth (social status), etc.





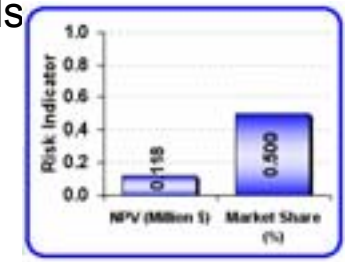
Retailing (Refueling Station Owner) Agents

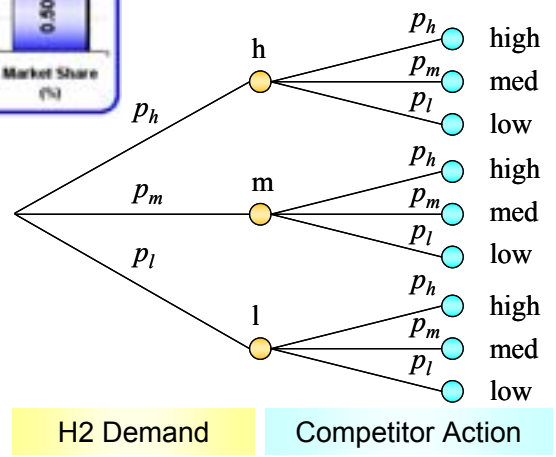
- Number of agents: Low 10s
  - Conventional fuel stations assumed to be universally available
- Initial seed
  - depending on volume/profitability, seed will either grow or decline
- Retailing agents monitor sales
  - Based on sales history, develop sales and profit expectations
  - If expectations meet targets, new stations will be added
  - If realized profits fall below threshold, station closes
- Model will allow to simulate the robustness and sustainability under various initial station seeds
  - Station density
  - Station dispersion

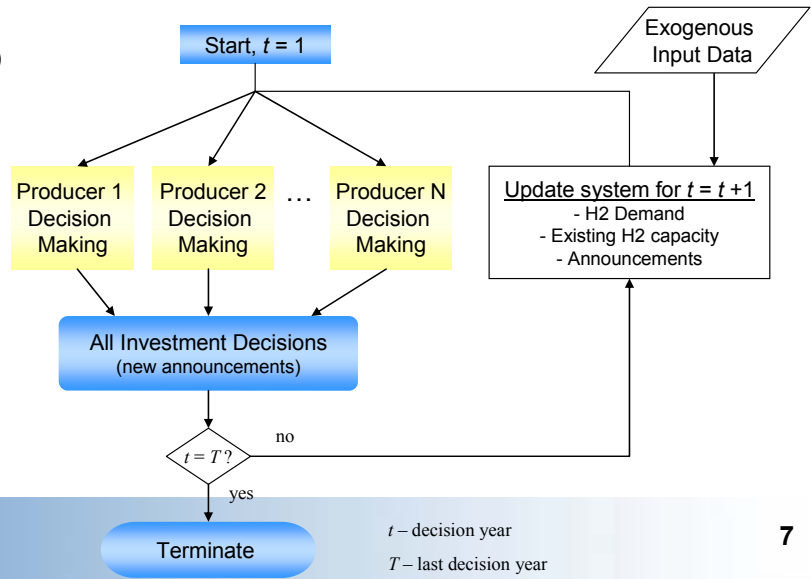


Production and Delivery Agents

- Producers make investment decisions at certain intervals
  - Each agent goes through its own decision making process by forecasting prices and profits for a number of years into the future
  - Choice of several production and delivery options
- Decisions can be based on multiple objectives
  - Profits, market share
- Decisions account for uncertainties, e.g.,
  - Demand/price of H2 (based on marginal production cost plus markup)
  - Action of competitors
- Decisions for all producers are aggregated and the system is updated before simulating the next time step
  - Producers first announce intended investments
  - Other agents learn this at the start of next decision interval and take into account in their decision routine
  - After construction delay, new facility comes online
  - The process is repeated for all simulation steps

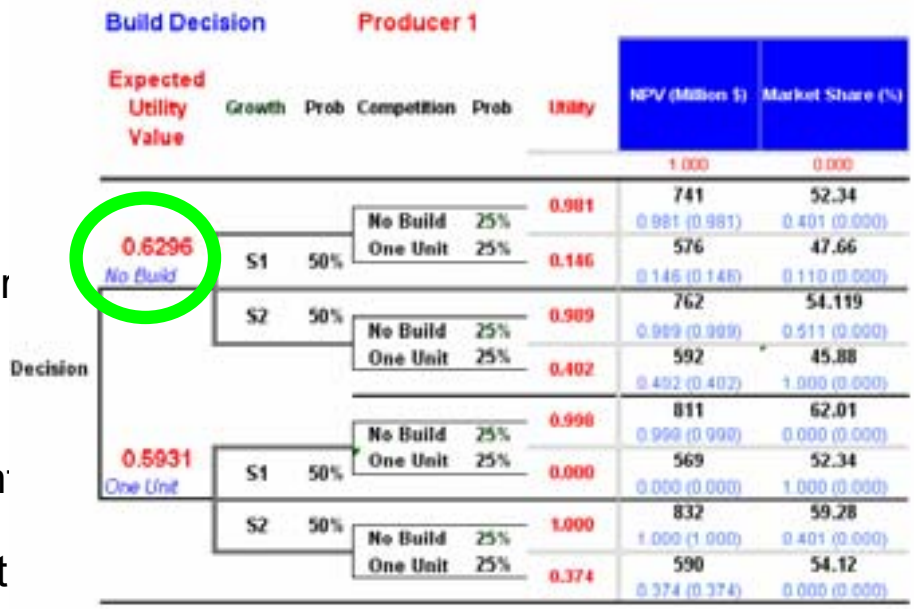


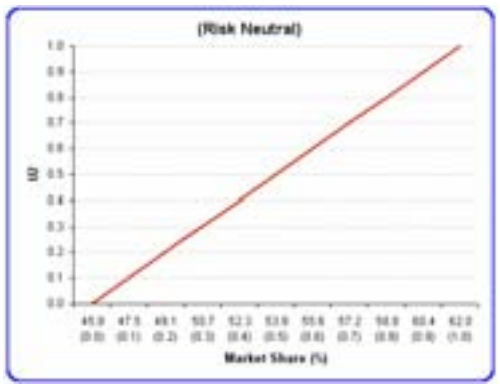


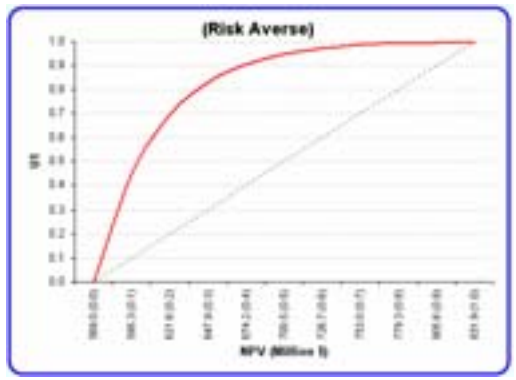


Production and Delivery Agents (cont'd)

- Number of agents: 2 – 5
- Agents have different preferences
  - Financial targets
  - Risk profiles
  - Time horizons
- Results for all decision criteria are computed for all possible combinations of scenarios over all forecast steps
  - Feeds into decision analysis that each agent uses to evaluate potential investment alternatives based on a producer's risk preferences and trade-offs among different decision criteria
- Initially, all producer agents use the same general decision model, differentiation occurs due to
  - Differences in risk and trade-off preferences
  - Available investment alternatives
  - Learning about competitors
- Producer agents look at portfolio profits (existing and potential new production)







Current Status

- Currently developing model environment
- Team is working on agent definitions
- Team has started reviewing and compiling model inputs