

Analysis Of Energy Infrastructures And Potential Impacts From An Emergent Hydrogen Fueling Infrastructure

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Project ID # ANP4
June 9, 2008

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Overview

Timeline

- Start – Dec. 2007
- Finish – Sep. 2015
- 2% complete

Budget

- Total project funding
 - DOE \$200K
- Funding received in FY07
 - \$0K
- Funding for FY08
 - \$150K

Barriers

- A. Future Market Behavior
- B. Stove-piped/Siloed Analytical Capability
- E. Unplanned Studies and Analysis

Targets

- Analyze issues and long term impacts related to infrastructure evolution, hydrogen fuel, and vehicles (Task 1)

Partners

- Looking to partner with UC-Davis and UC-Berkeley as program grows



Objectives

- **Use dynamic models of interdependent infrastructure systems (natural gas, coal, electricity, petroleum, water, etc.) to analyze the impacts of widespread deployment of a hydrogen fueling infrastructure**
- **Identify potential system-wide deficiencies that would otherwise hinder infrastructure evolution, as well as mitigation strategies and unintended collateral effects on supporting systems**



Milestones

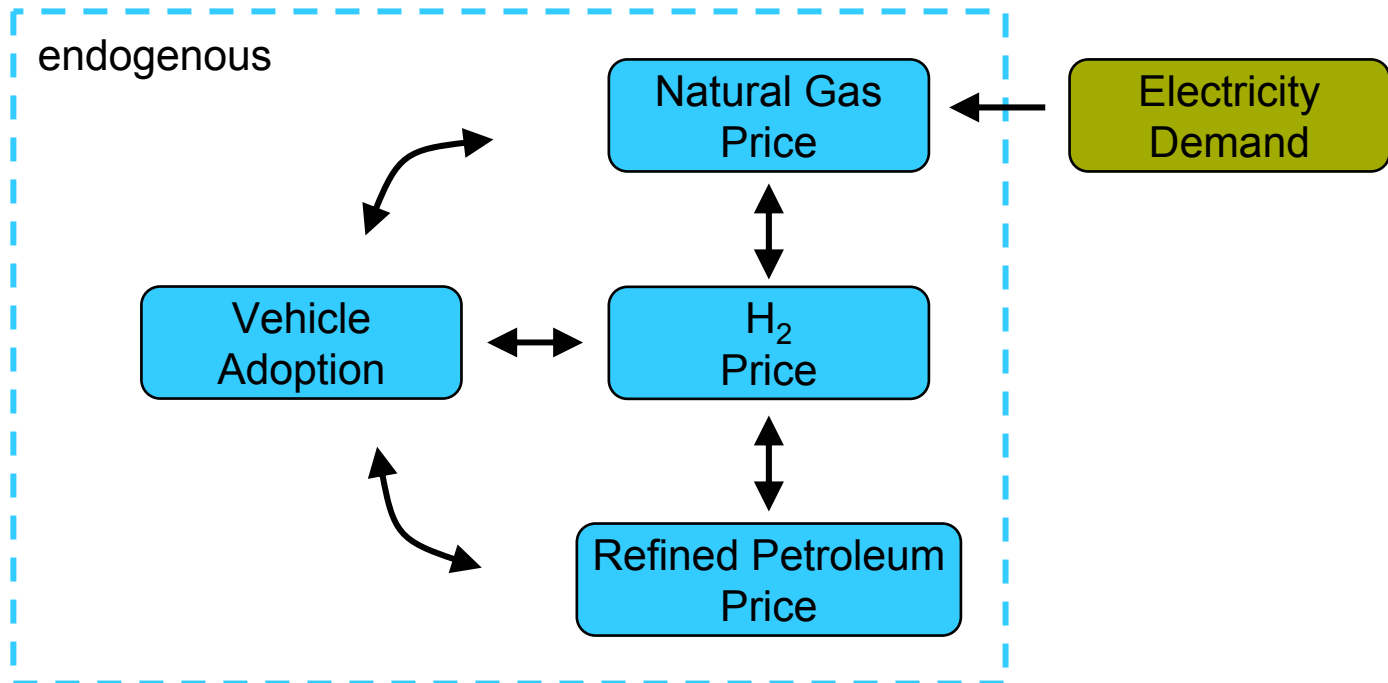
MM / YYYY	Milestone
Apr / 2008	Build a SD model of the CA natural gas distribution system coupled to refined petroleum and electricity generation systems in order to execute a regional analysis of the impacts of SMR-derived hydrogen fuel on the natural gas infrastructure.
Sep / 2008	Extend the SD model to include refined details of the electricity generation sector in order to resolve key interdependencies and complex behaviors that may result from non-linear feedback effects. Complete the analysis for CA.



Approach

- **Analysis-driven approach defined by programmatic needs**
 - Provide analysis and insight into the dynamic behavior of complex systems
- **System dynamics: Methodology**
 - Pose detailed questions
 - Will the demand for SMR-derived H₂ negatively impact NG distribution and short circuit vehicle roll-out?
 - Is there a potential for infrastructure interdependency issues to become problematic?
 - Are there means to mitigate negative or amplify positive consequences?
- **System dynamics: Analysis**
 - Formulate SD models of infrastructure components and interrelations to a sufficient level of detail
 - Use Vensim software to quickly and efficiently generate code
 - Dedicate resources to analysis not model formulation








Model California Energy Infrastructures

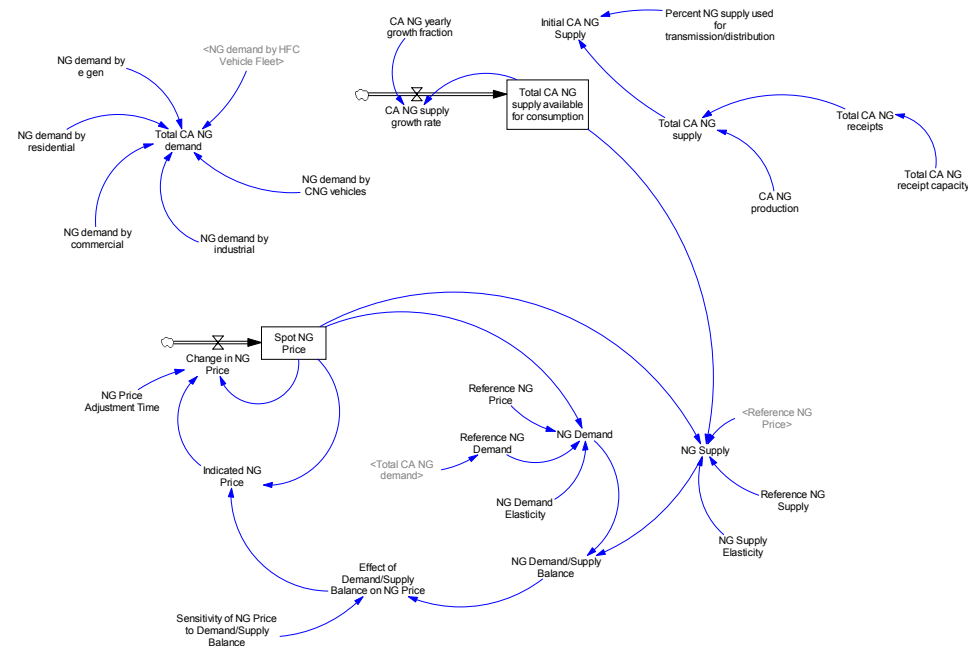


- **Natural Gas and Refined Petroleum distribution dynamics**
 - Governed by supply/demand market theory
- **Vehicle adoption dynamics**
 - Bass technology diffusion model
- **Electricity distribution dynamic not yet coupled**

CA Aggregate Natural Gas Distribution Model

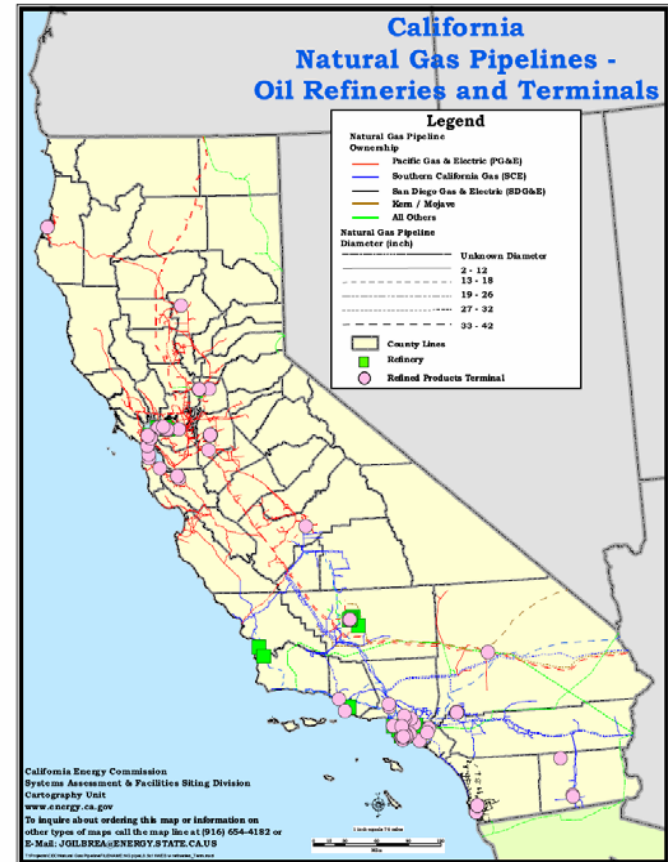
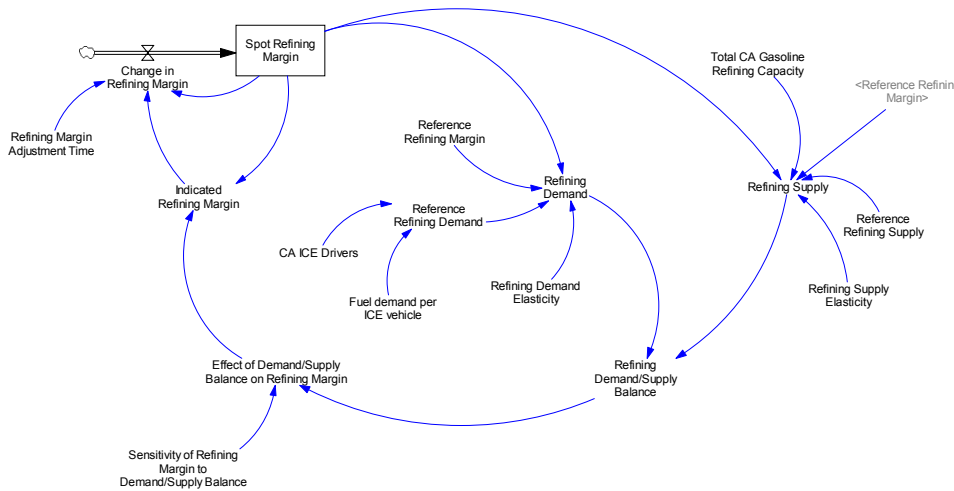
California — Natural Gas 2006
*California Energy Commission Report

	Million Cu. Feet	Percent of National Total		Million Cu. Feet	Percent of National Total
 Total Net Movements:	1,987,018	—	 Industrial:	732,054	11.27
 Dry Production:	301,153	1.63	 Vehicle Fuel:	10,247	41.12
Deliveries to Consumers:			 Electric Power:	770,836	12.39
 Residential:	491,777	11.26	Total Delivered:	2,249,347	11.28
 Commercial:	244,432	8.62			



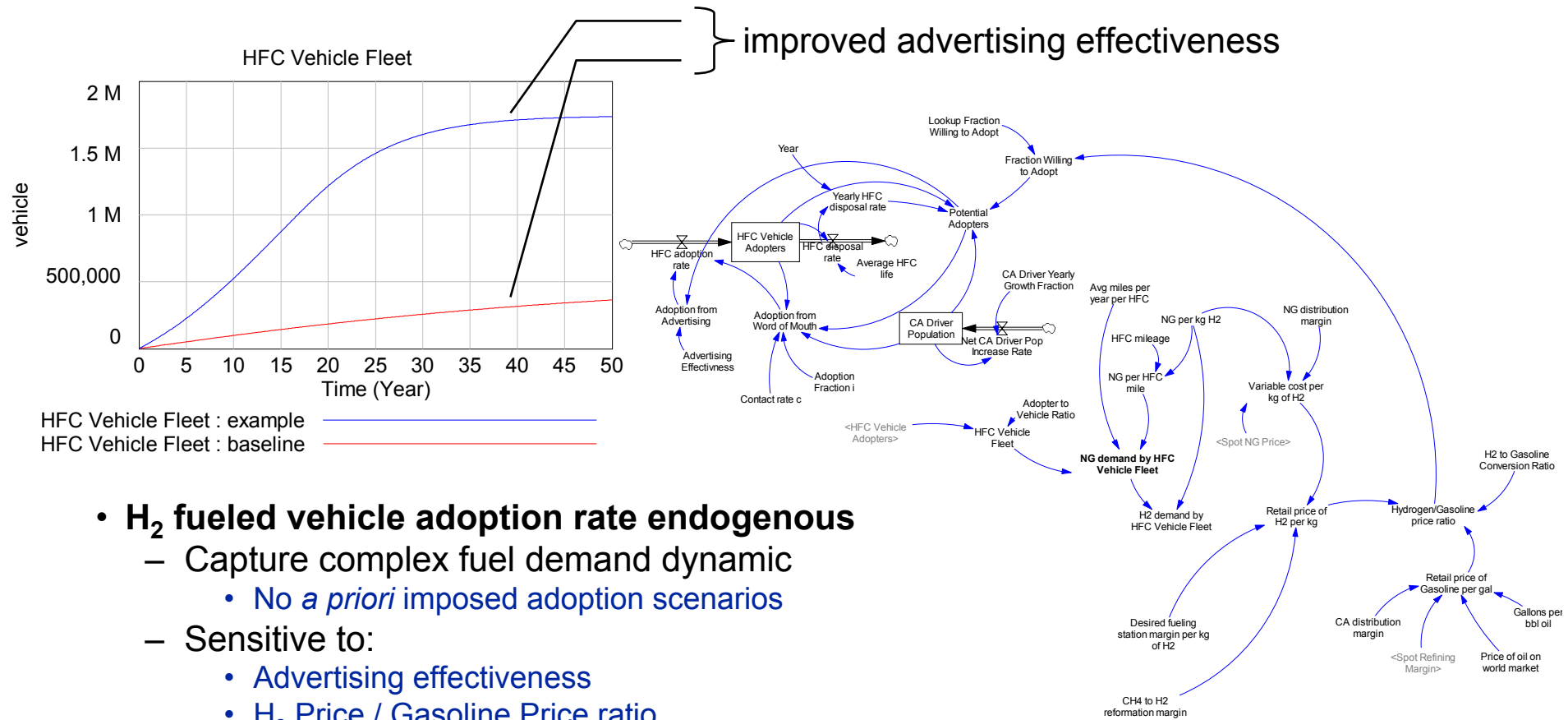
- **Supply side dynamic accounts for:**
 - NG receipts, in-state production
- **Demand side dynamic accounts for:**
 - Electric power, industrial, commercial, residential, and CNG vehicle fleet (currently static variables)
 - H₂ fuel via steam methane reforming (dynamic variable)
- **NG spot price determined by:**
 - Market latency and elasticity (both supply and demand)
 - Power law relationship between the demand and supply balance
- **H₂ fuel price a function of NG price, market forces, conversion efficiency, and distribution margins (consistent with H2A)**

CA Aggregate Refined Petroleum Distribution Model



- **Supply side dynamic accounts for:**
 - Refining capacity (fixed variable)
 - Spot refining margins (dynamic variable)
- **Demand side dynamic accounts for:**
 - Gasoline demand by ICE drivers
- **Gasoline price determined by:**
 - Market latency and elasticity (both supply and demand)
 - Price of oil on world market

Bass Technology Adoption Model



HFC Vehicle Fleet : example (blue line)
 HFC Vehicle Fleet : baseline (red line)

- **H₂ fueled vehicle adoption rate endogenous**
 - Capture complex fuel demand dynamic
 - No *a priori* imposed adoption scenarios
 - Sensitive to:
 - Advertising effectiveness
 - H₂ Price / Gasoline Price ratio
- **Easily modified to incorporate NREL Discrete Choice Analysis Dynamic**

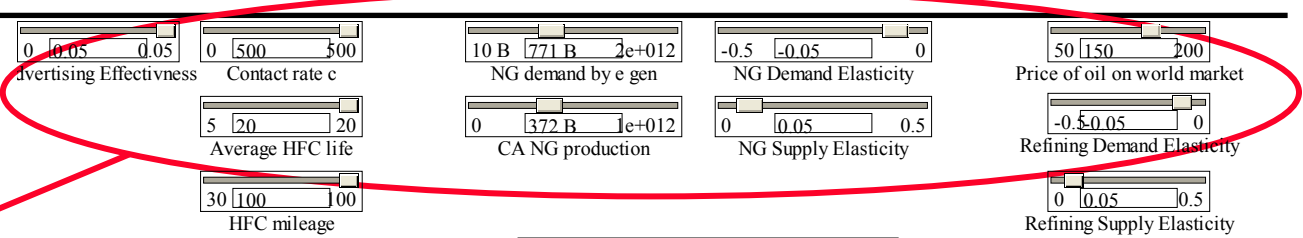


Model Assumptions

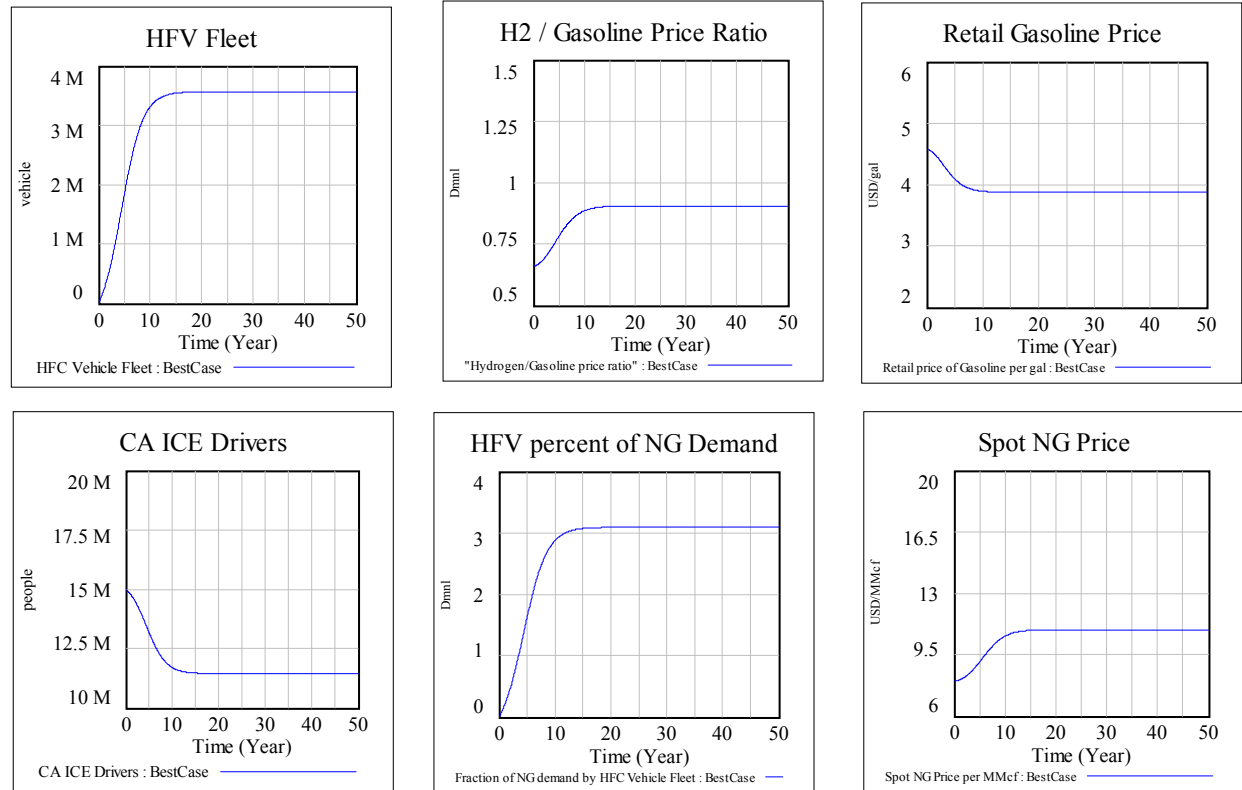
- **Endogenous variables**
 - Rate of vehicle adoption
 - Price and demand (NG, H₂, and gasoline)
- **Analysis constrained by fixed or exogenous variables (an incomplete list)**
 - NG demand other than H₂, market elasticity factors, crude oil price, CA population or economic growth, NG or electricity import constraints, +others...
 - Sensitivity analysis can be used to capture the range of dynamic behavior for each of these and infer critical behavior
- **Model does not resolve geospatial features of the infrastructure but can be addressed if necessary**

Impact Of Large H₂ Fueled Vehicle Market Penetration

sliders used to dynamically adjust parameters



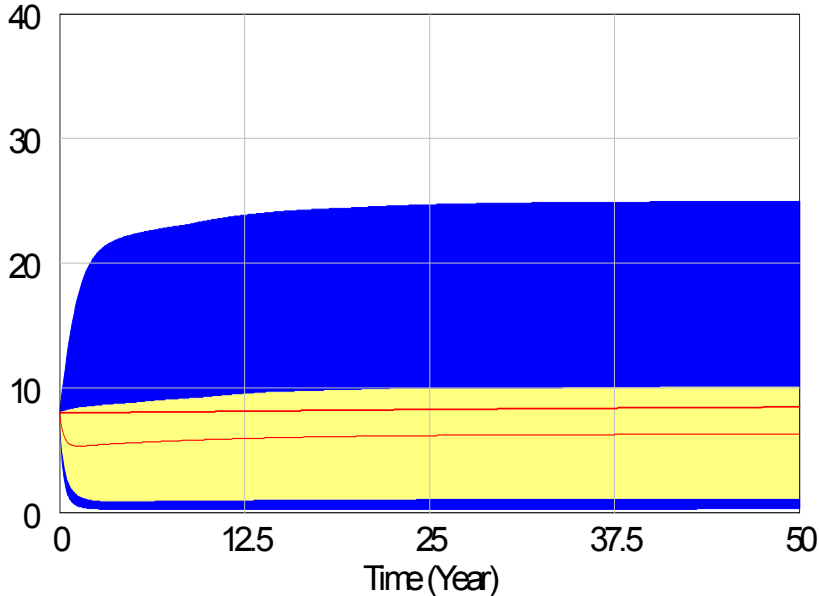
screen shot of example output



Example Sensitivity Analysis

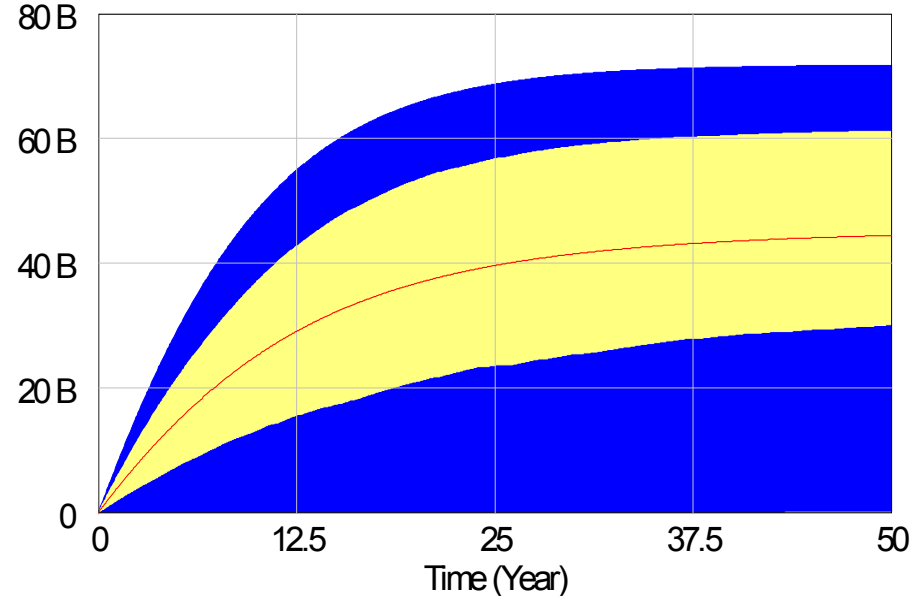
50%  100% 

Spot NG Price per MMcf



50%  100% 

NG demand by HFV Fleet



- Model runs quickly and efficiently on PC
- 1000's of scenarios used to execute sensitivity analysis (stochastic sampling of variables)



Preliminary Findings

- **A successful H₂ fueled vehicle rollout in CA represents a small amount of new demand**
 - 3.5MM vehicles total about 3% of current NG demand
 - NG infrastructure may have time to adapt over a long time period
 - Increase import capacity

HOWEVER

- 3.5MM vehicles added tomorrow would be a different matter
 - If NG import capacity does not grow then HFV would stress an already stressed system
 - NG and electrical generation in CA today is at capacity



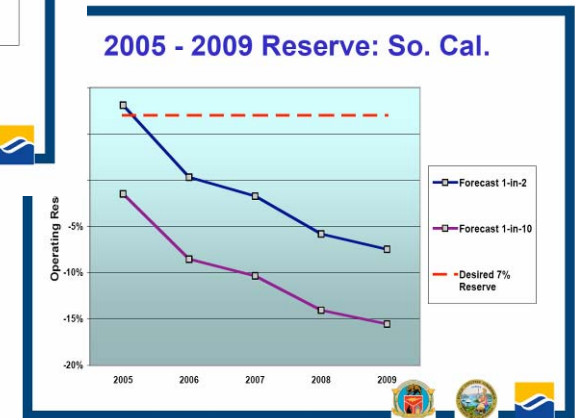
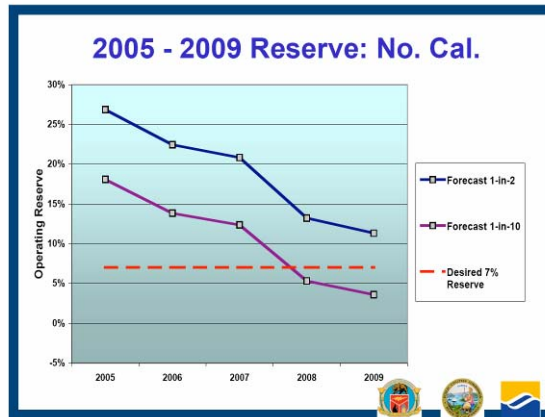
Preliminary Findings

- **Gasoline prices would likely drop as H₂ fueled vehicles penetrate market**
 - Refining capacity in CA is at its limit; decreasing gasoline demand would free up capacity thereby decreasing refinery margins
 - Falling gasoline prices would make HFV less attractive relative to liquid hydrocarbon ICE vehicles
- **The prospect of increasing NG prices and falling gasoline prices due to the H₂ vehicle rollout poses an original question: **could HFV become a victim of their own success?****

Future Work

2006 gross system power (GWhr)

Fuel Type	In-State	NW	SW	GSP	GSP %
Coal	17,573	5,467	23,195	46,235	15.7%
Large Hydro	43,088	10,608	2,343	56,039	19.0%
Natural Gas	106,968	2,051	13,207	122,226	41.5%
Nuclear	31,959	556	5,635	38,150	12.9%
Renewables	30,514	1,122	579	32,215	10.9%
Biomass	5,735	430	120	6,285	2.1%
Geothermal	13,448	0	260	13,708	4.7%
Small Hydro	5,788	448	0	6,236	2.1%
Solar	616	0	0	616	0.2%
Wind	4,927	244	199	5,370	1.8%
Total	230,102	19,804	44,959	294,865	100.0%



- **Imperative to include the dynamic behavior of CA electricity generation**
 - Relies heavily on the NG infrastructure
 - System already operates at capacity with projected peak power deficits by end of decade



Future Work

- **Complete analysis for questions posed against CA infrastructures**
 - Integrate electricity and water distribution dynamic
 - Resolve key dynamical behaviors resulting from infrastructure interdependencies
 - Identify system vulnerabilities that may hinder HFV rollout
 - Use a resource utilization metric to quantify system perturbations induced by H₂ fuel demand
- **Assess and analyze other US regions**
 - Investigate issues stemming from coal-to-hydrogen in regions dependent on coal-derived electrical power



Summary

- **System dynamics approach used to analyzing CA energy infrastructures**
 - Developed SD model that describes the complex market behavior of interconnected infrastructures
 - Natural gas, refined petroleum, electricity
 - HFV market adoption endogenous to SD model
 - Bass technology diffusion approach
- **Vensim software used for code development**
 - Fast and flexible model development
 - Dedicate resources to analysis not model building
- **Preliminary results suggests that a successful rollout of HFVs in CA does not dramatically increase demand for natural gas, however...**
 - Natural gas and electricity systems running at capacity in CA
 - Small perturbations in supply/demand dynamics could have significant consequences