HyTrans Model:
Analyzing the Transition to Hydrogen-Powered Transportation

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Overview

Timeline

- Start: October, 2005
- End: September, 2008
- % Complete: 60%

Budget

- Total project funding: $1M
  - DOE share = 100%
- Funding in FY06: $200K
- Funding for FY07: $400K

Barriers

- Lack of understanding of the Transition of a Hydrocarbon-Based Economy to a Hydrogen-Based Economy.
- Lack of an integrated market model of all major components of the Hydrogen Fuel and Vehicle System

Partners

- NREL, ANL, DTI
- GM, Ford, D-C
- Collaboration with U.C. Davis Hydrogen Pathways Program
- Project management by ORNL

HyTrans Objectives for FY 2007

- Complete development of an integrated market model of the hydrogen transition.
  - Incorporate reduced form representations of the H2A production and delivery models.
  - Develop new fuel cell vehicle cost model in cooperation with industry partners.
  - Add regional detail sufficient for DOE early transition scenarios.
  - Additional enhancements.
  - Complete and publish model documentation.
- Use the HyTrans model to describe & analyze DOE's early transition scenarios (2012 to 2025) and publish a report on their:
  - Costs
  - Benefits in GHG and oil reduction
  - Sustainability beyond 2015

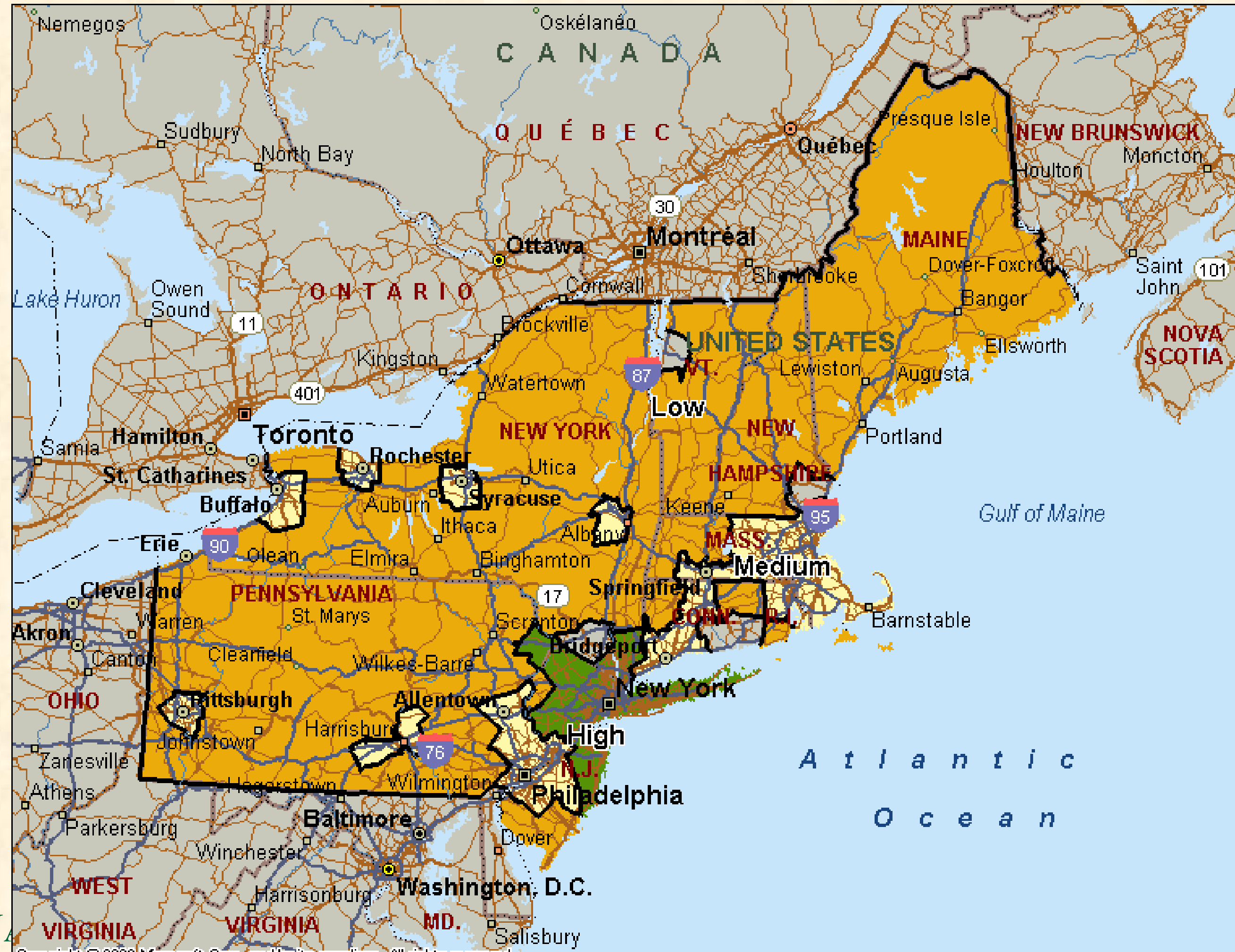
HyTrans draws on or incorporates models and data from a variety of sources.

- H2A
  - Hydrogen Production
  - Hydrogen Delivery
- PSAT & ASCM
  - Fuel economy
  - 2010/2015 cost & performance goals
- ORNL Vehicle Choice Model
  - Fuel availability
  - Make & model diversity
  - Price, fuel economy, etc.
- Vehicle Manufacturing Cost Estimates (assisted by OEMs)
  - Scale Economies
  - Learning-by-doing
- GREET GHG emissions
- **Calibrated to** NEMS AEO 2006 **through 2030, the extrapolated to 2050 & beyond.**

Several key assumptions are essential to interpreting the model's results.

- Markets function efficiently.
- Agents accurately anticipate future conditions.
- DOE 2010 & 2015 technology goals are met.
- There are no key resource constraints.
- Rest of world hydrogen and fuel cell activities are not explicitly taken into account.
- Sales of FCVs and use of hydrogen during scenario period (2012-2025) imposed by constraints. HyTrans estimates costs & consequences.

The U.S. is divided into 3 geographical regions and each region is divided into three fuel demand density subregions. Regions & subregions may have different hydrogen production and delivery pathways & different vehicle technology choices.



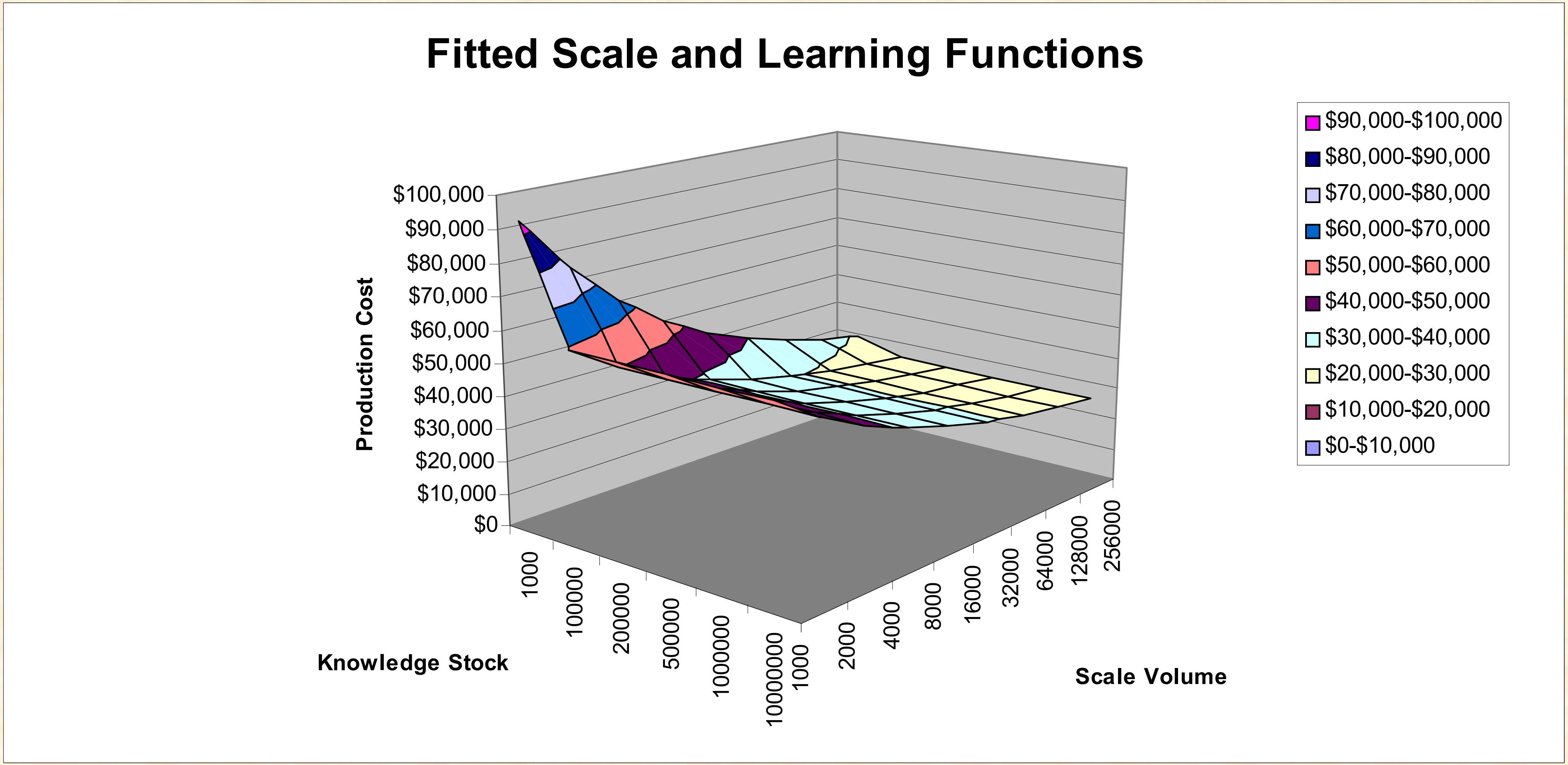
A new vehicle cost model was calibrated with data provided by OEMs.

- **Three multiplicative factors:**
  - Independent tech-progress,
  - Learning-by-doing and
  - Scale economies.
- **Vehicle Price** =

  Glider Cost +

  Long-run Drivetrain Cost x Technology(time) x Learning-by-doing(stock) x Scale(volume)
- **Independent Technology progress**
  - calibrated to DOE goals
- **Learning & Scale**
  - calibrated to central tendency of manufacturers' cost estimates.

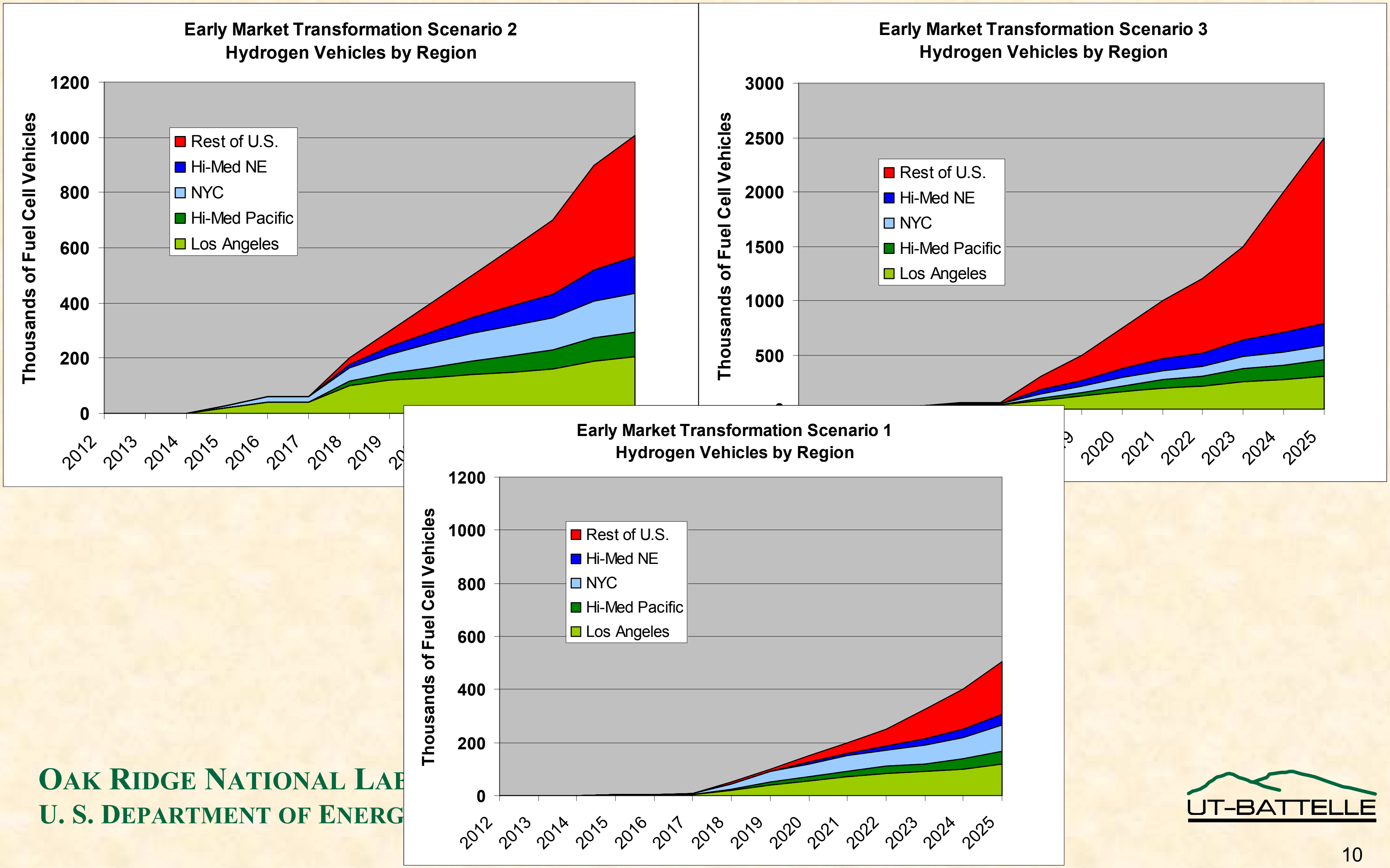
Learning is exponential and asymptotic to the program goals (not usual functional form), scale has a constant elasticity of approximately -0.25.



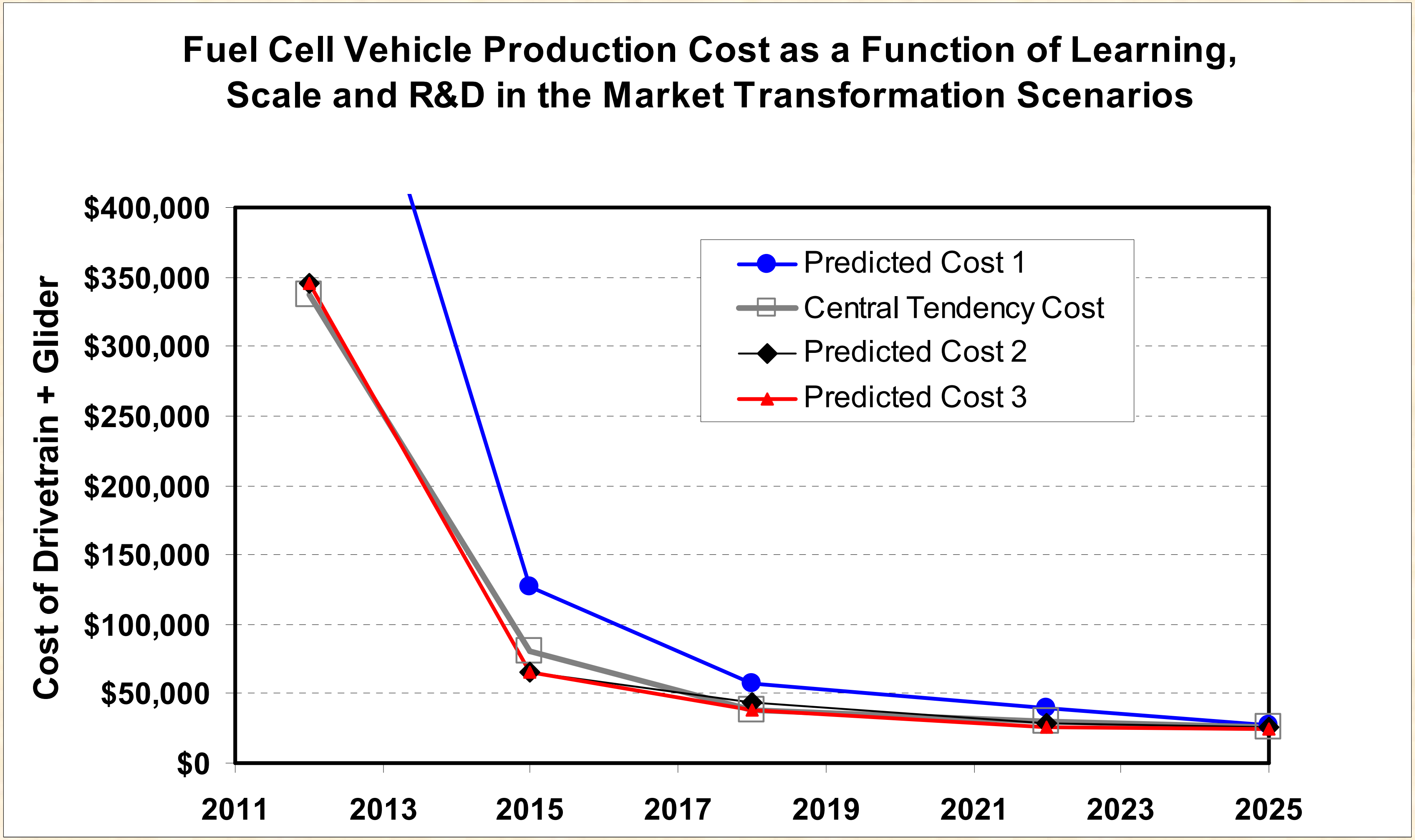
HyTrans was used to evaluate the impacts of early transition scenarios.

- In the early transition the model is constrained to meet the scenario vehicle sales targets.
  - **Estimates costs of vehicles and hydrogen, infrastructure investments and implicit subsidies.**
  - **Estimates benefits of learning-by-doing, scale economies, fuel availability and market diversity.**
  - **2010/15 DOE targets met.**
- In the later period (2025-2050) no vehicle and fuel subsidies are assumed. Are they needed?
  - **Impacts of achieving program goals, or not**
  - **Competition with other advanced technologies**
  - **"Cost out" the transition, to government & industry**
  - **Benefits: reduced oil dependence, GHG emissions**

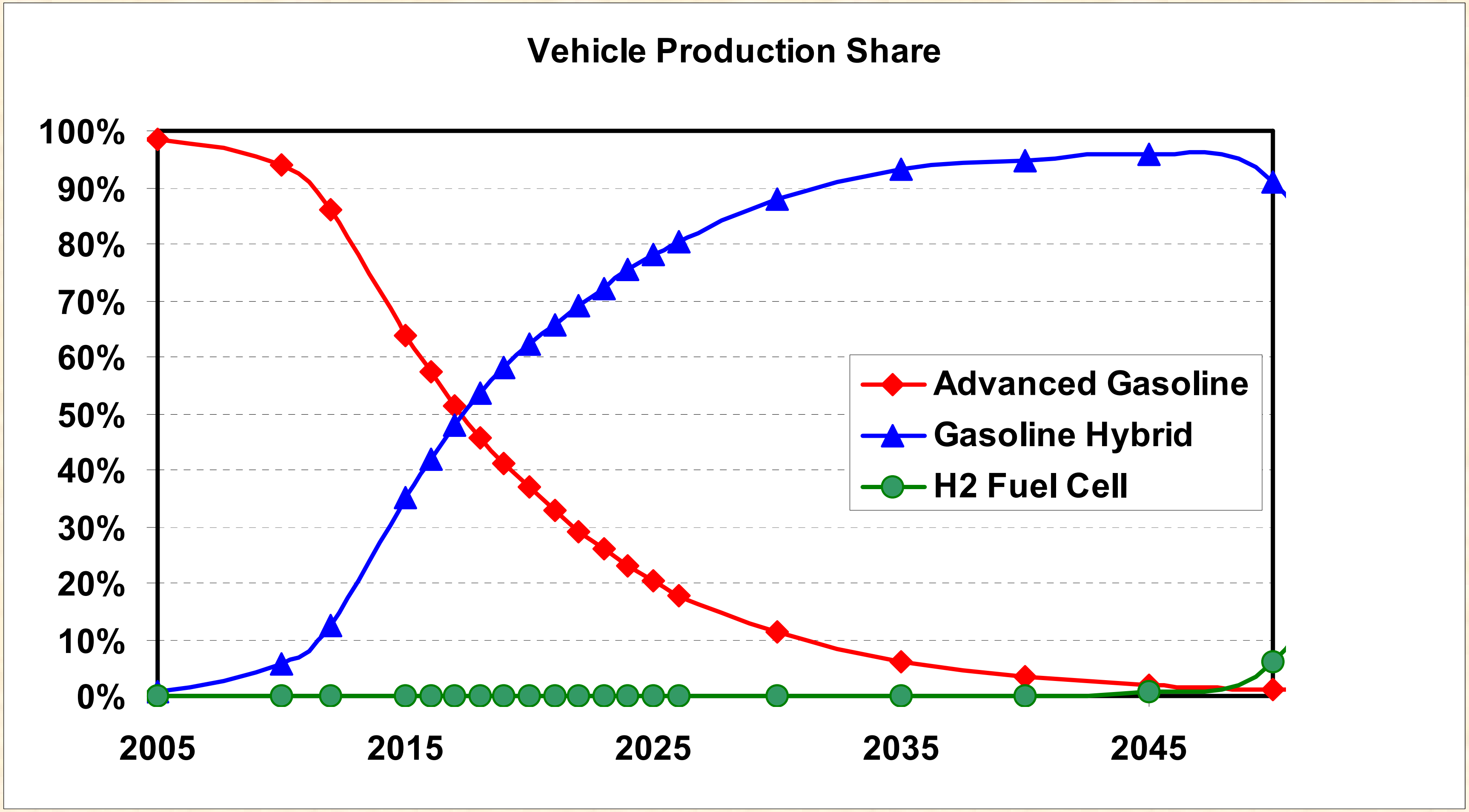
3 scenarios were analyzed requiring 2, 5 and 10 million hydrogen FCVs on the road by 2025, respectively. In all, 12 scenarios with differing technology and policy assumptions were run.



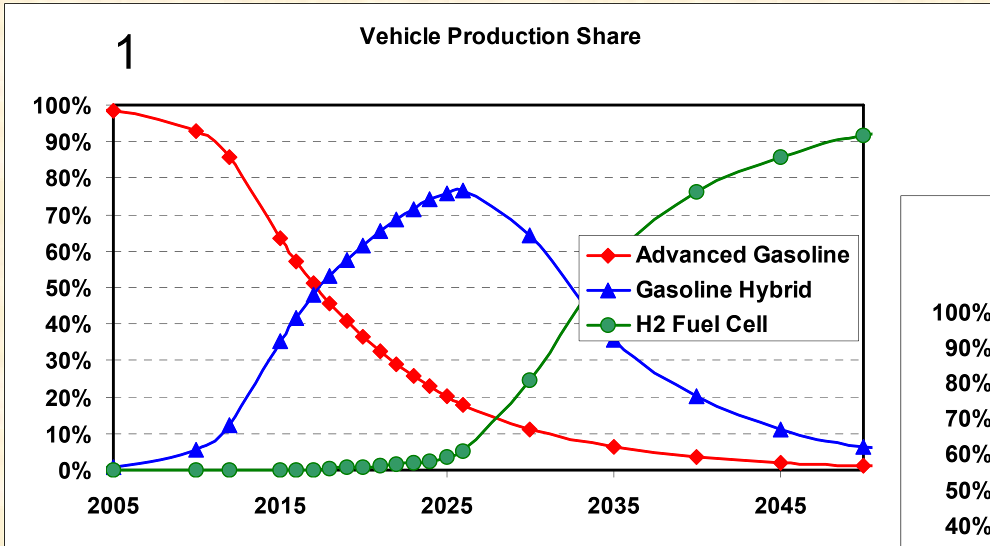
In all scenarios FCV costs decline dramatically, in line with the central tendency of the manufacturers' estimates, as a function of year, scale and cumulative production.

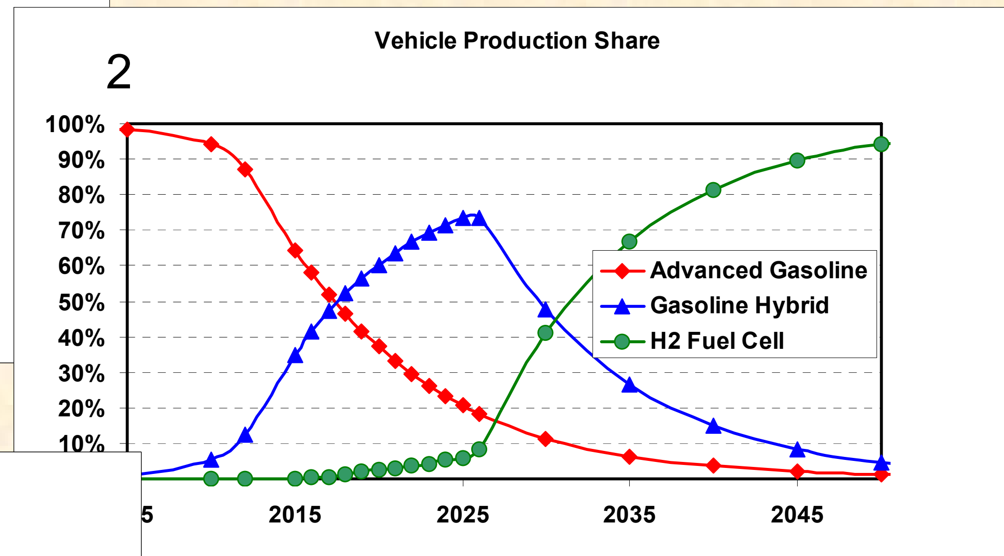


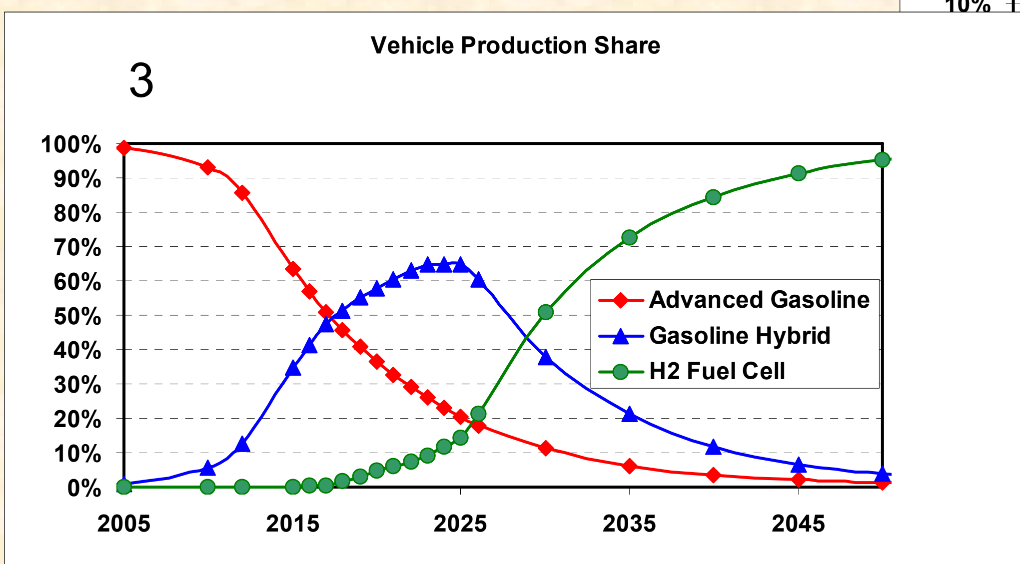
In the absence of "forcing" policies, HyTrans predicts a transition to advanced gasoline hybrid vehicles, which if DOE goals are met, cost 1% less than advanced conventional gasoline ICE vehicles.



All 3 transition scenarios lead to a sustainable transition to hydrogen fuel cell vehicles after 2025.







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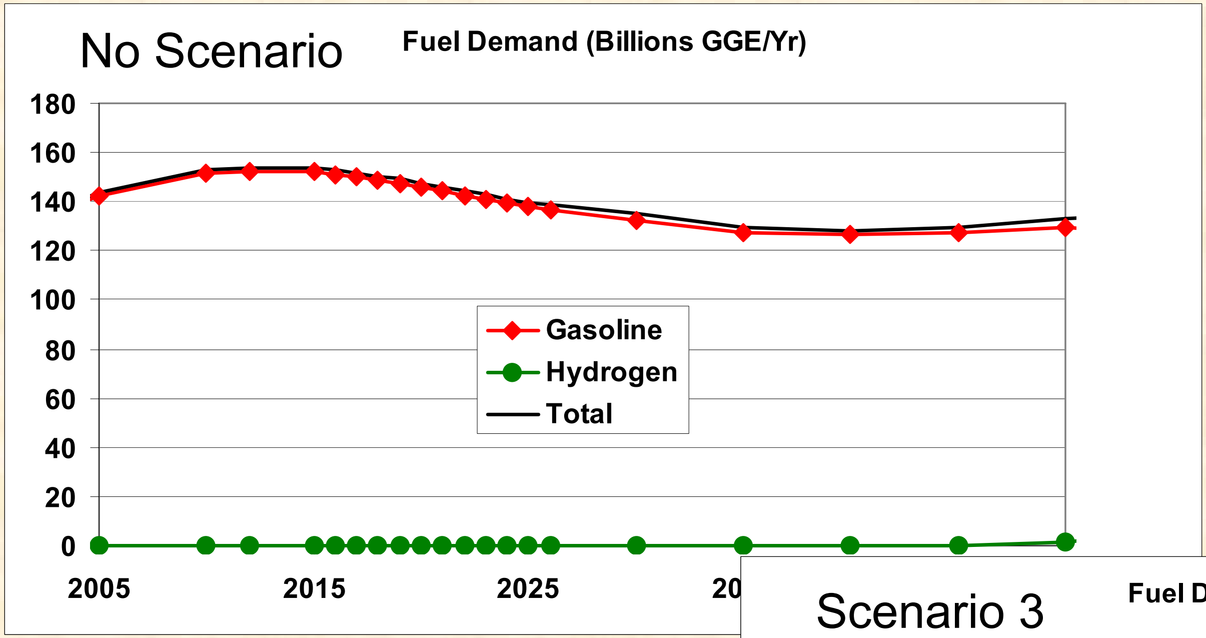
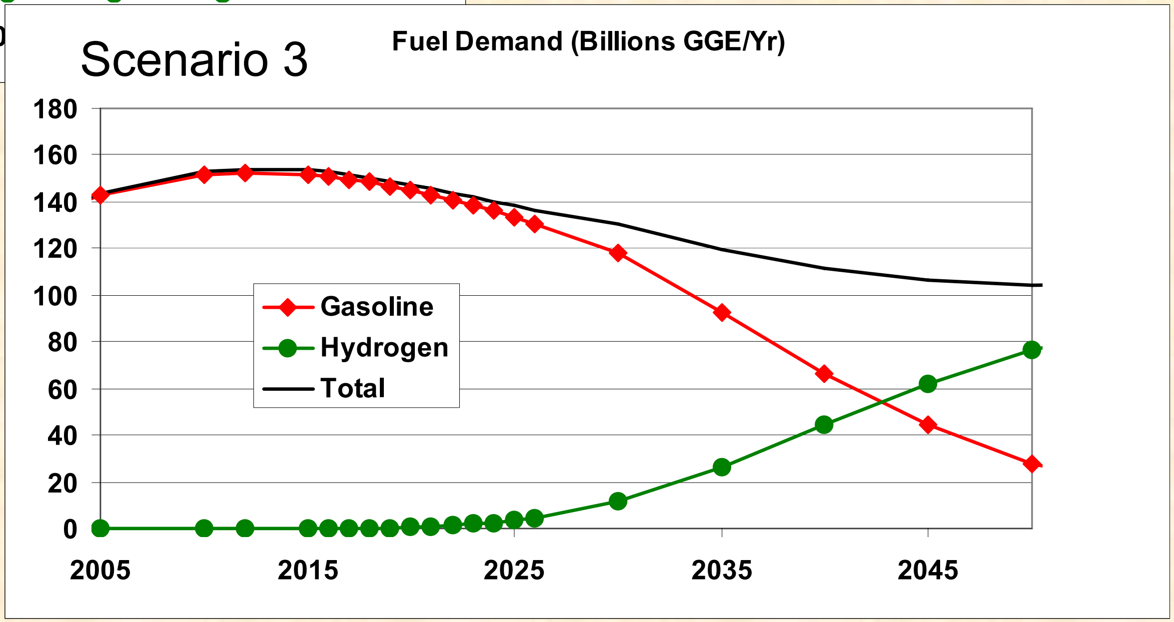
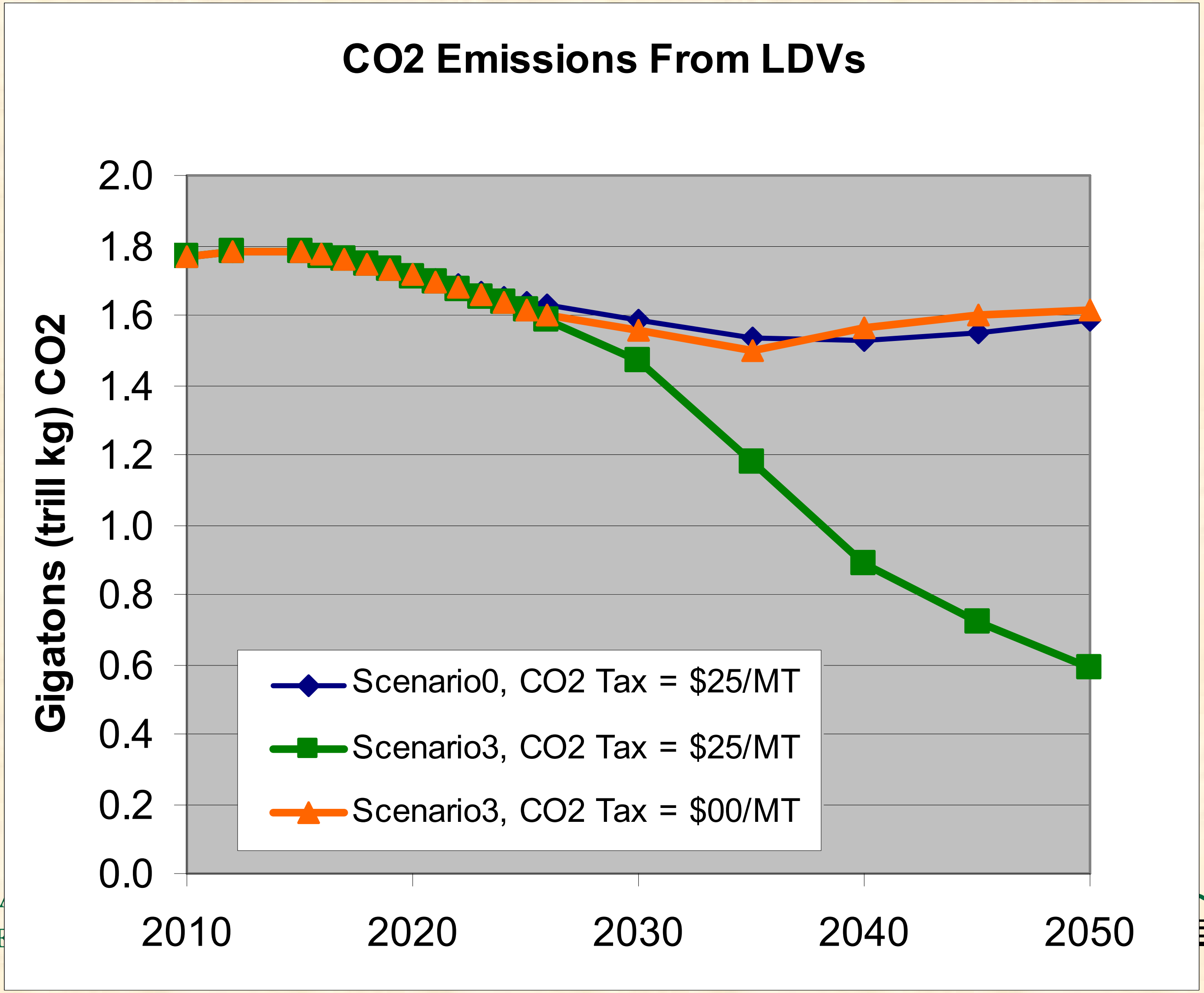
The advanced hybrid's efficiency holds LDV oil use constant but the FCV drives it towards zero.

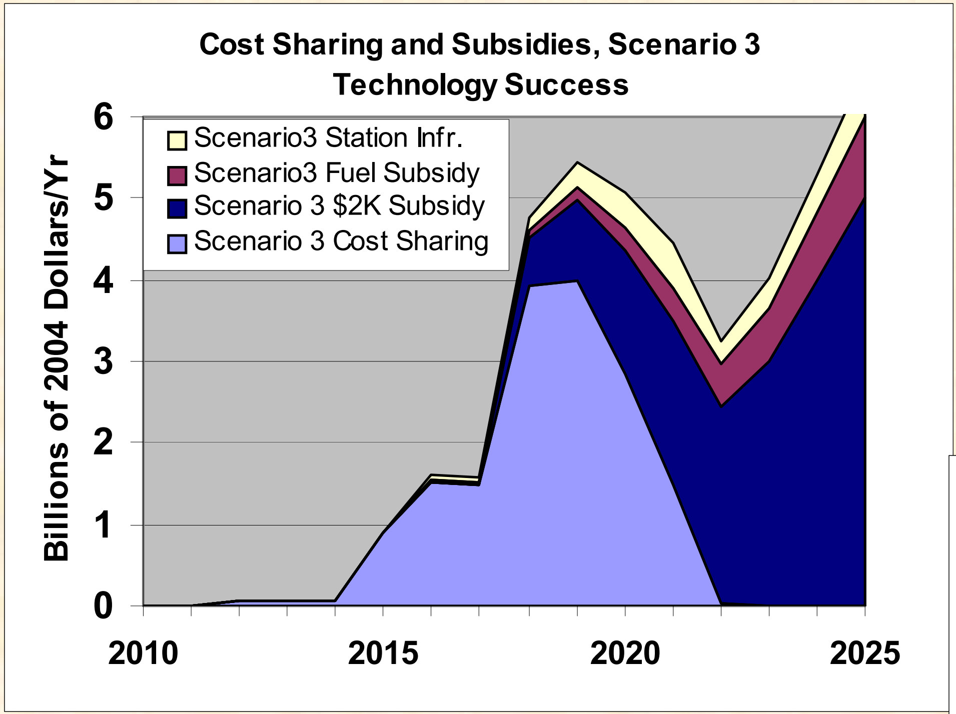


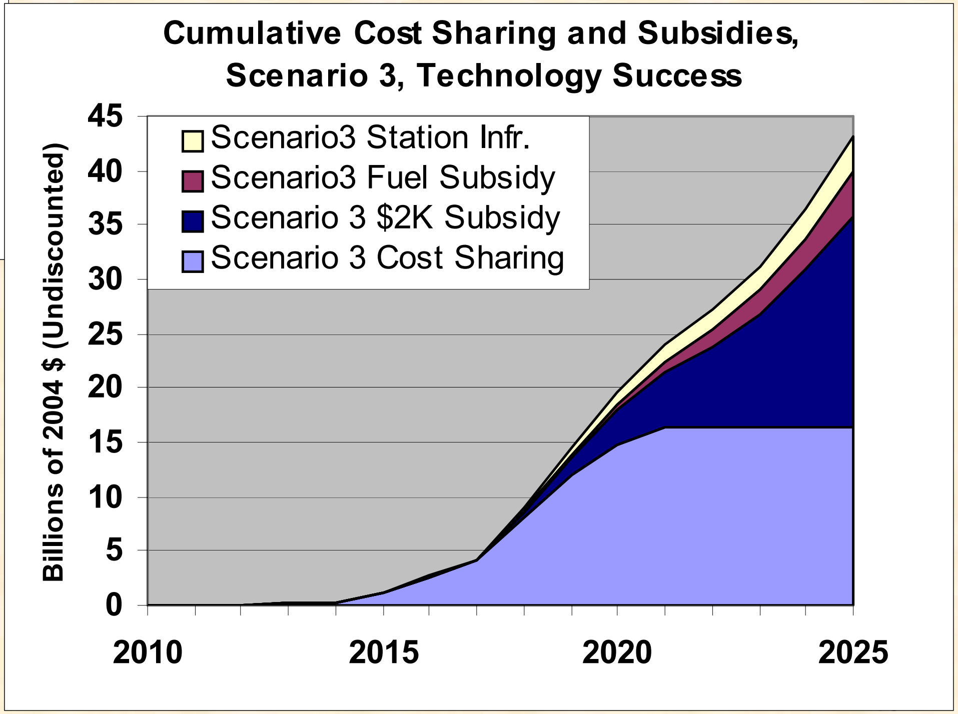


Reducing C emissions requires strong C constraining policy ($10/tCO2 in 2010 to $25/tCO2 in 2025) **AND** the hydrogen transition.

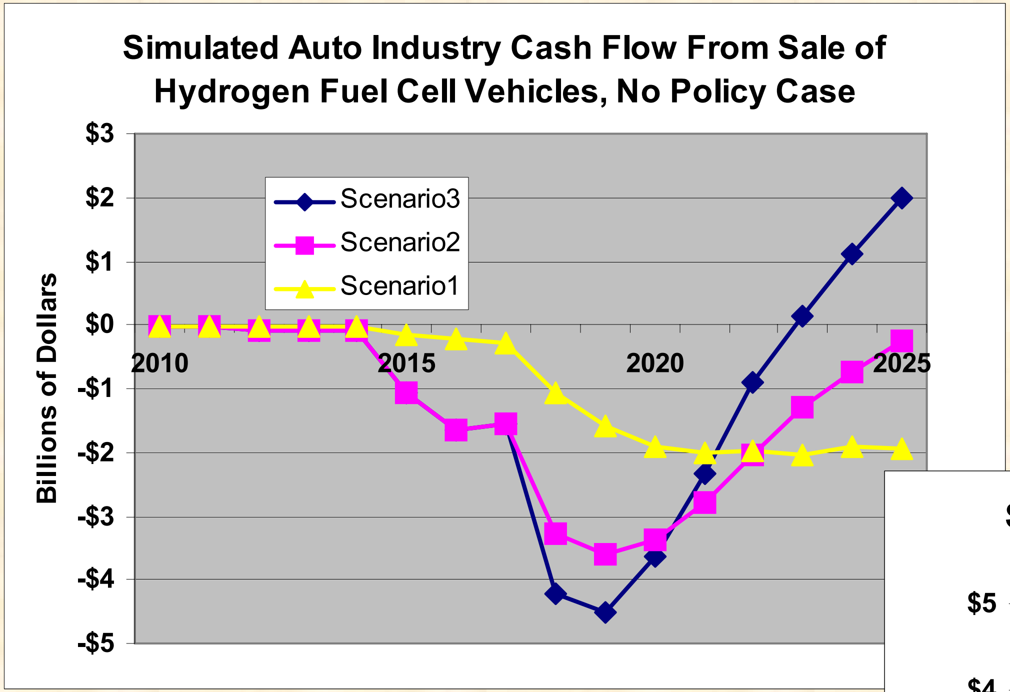


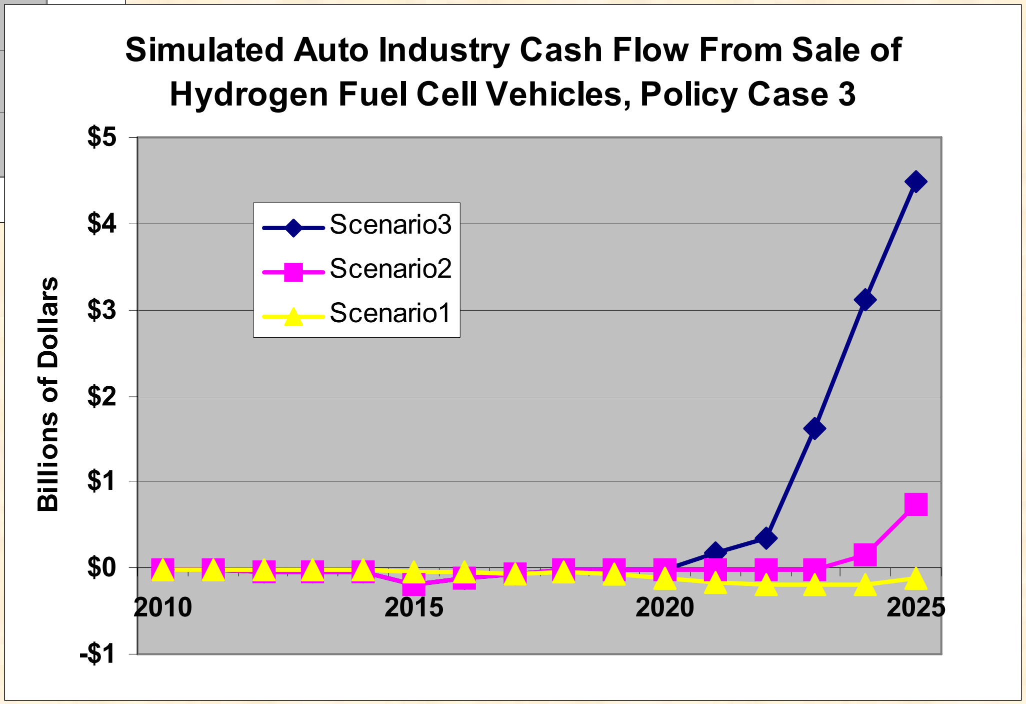
Even in the most expensive policy case, costs to the government are not daunting.





Without government cost-sharing it seems unlikely that industry would attempt transition to hydrogen vehicles. However, perceptions of risk are not yet represented.





Future Work on HyTrans and Transition Analysis.

- Remaining tasks for FY 07
  - Publish report on early transition scenarios.
  - Publish model documentation.
  - Develop and implement rigorous representations of uncertainty on the part of vehicle manufacturers, fuel suppliers and consumers.
- Goals for FY 08
  - Update HyTrans to revised H2A models and AEO 2007 and improve feedstock supply representation.
  - Update and expand vehicle technology characterizations, e.g., including PHEV and plug-in FCV technologies.
  - Develop and implement a connection between U.S. and international hydrogen and FC vehicle market developments.
  - Participate in IPHE international hydrogen transition modeling.
  - Quantify the benefits and costs of the transition to hydrogen vehicles under a variety of scenarios and publish results in a report.

Summary

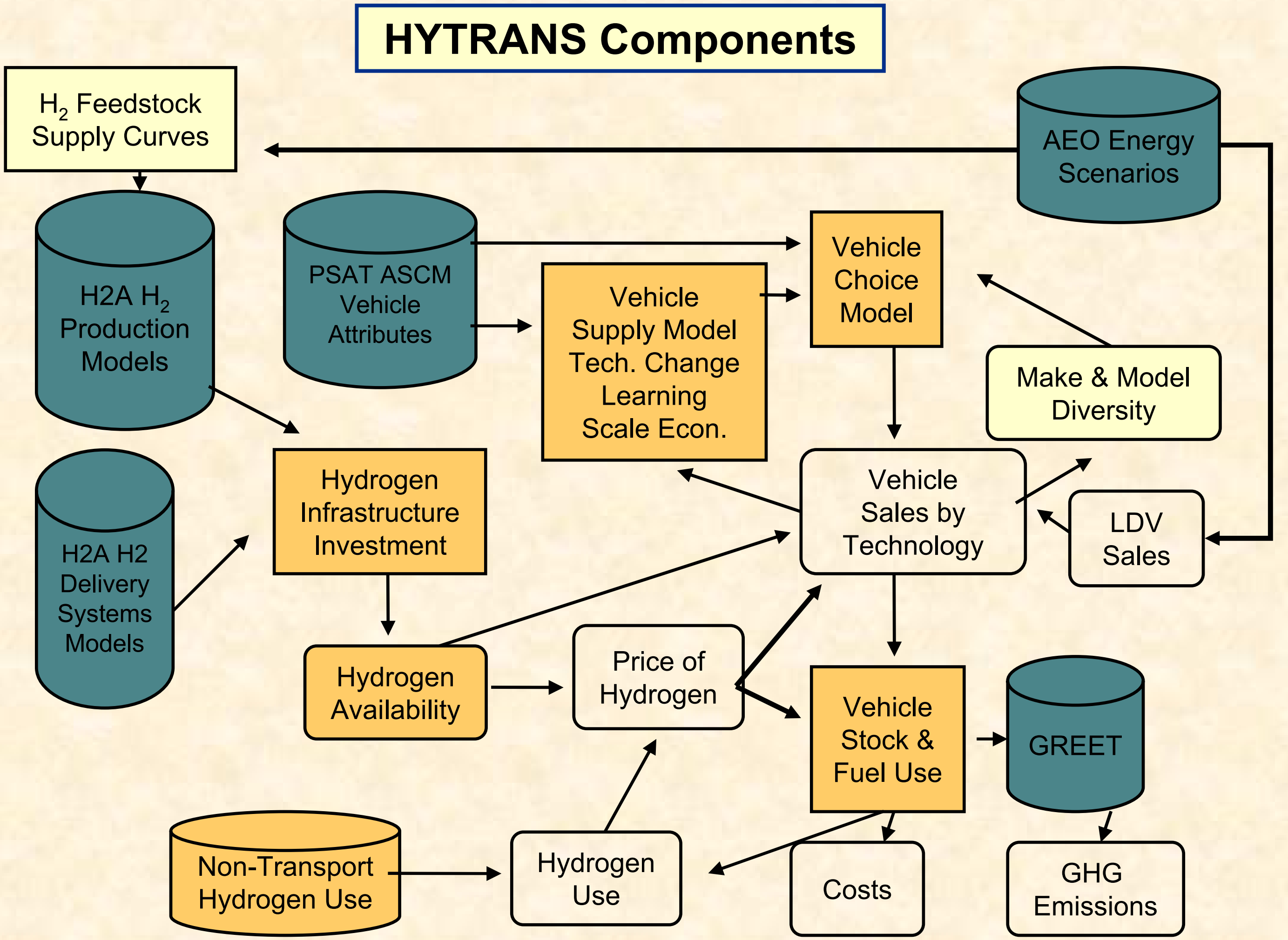
- The first integrated market model of the transition to hydrogen powered transportation in which the supplies and demands for vehicles and fuels and their prices are simultaneously and endogenously determined was completed and applied to the analysis of DOE's early transition scenarios.
- Completion of the transition scenarios analysis satisfies a key Systems Analysis program goal.
- The HyTrans model results indicate that if the DOE technology goals are met, and if a vigorous transition effort is undertaken by government and industry, a sustainable transition to hydrogen powered vehicles is achievable.
- The above conclusions are conditional on the key assumptions of the analysis. Additional development and analysis is needed to address the most important limitations of the HyTrans model.

Additional Slides

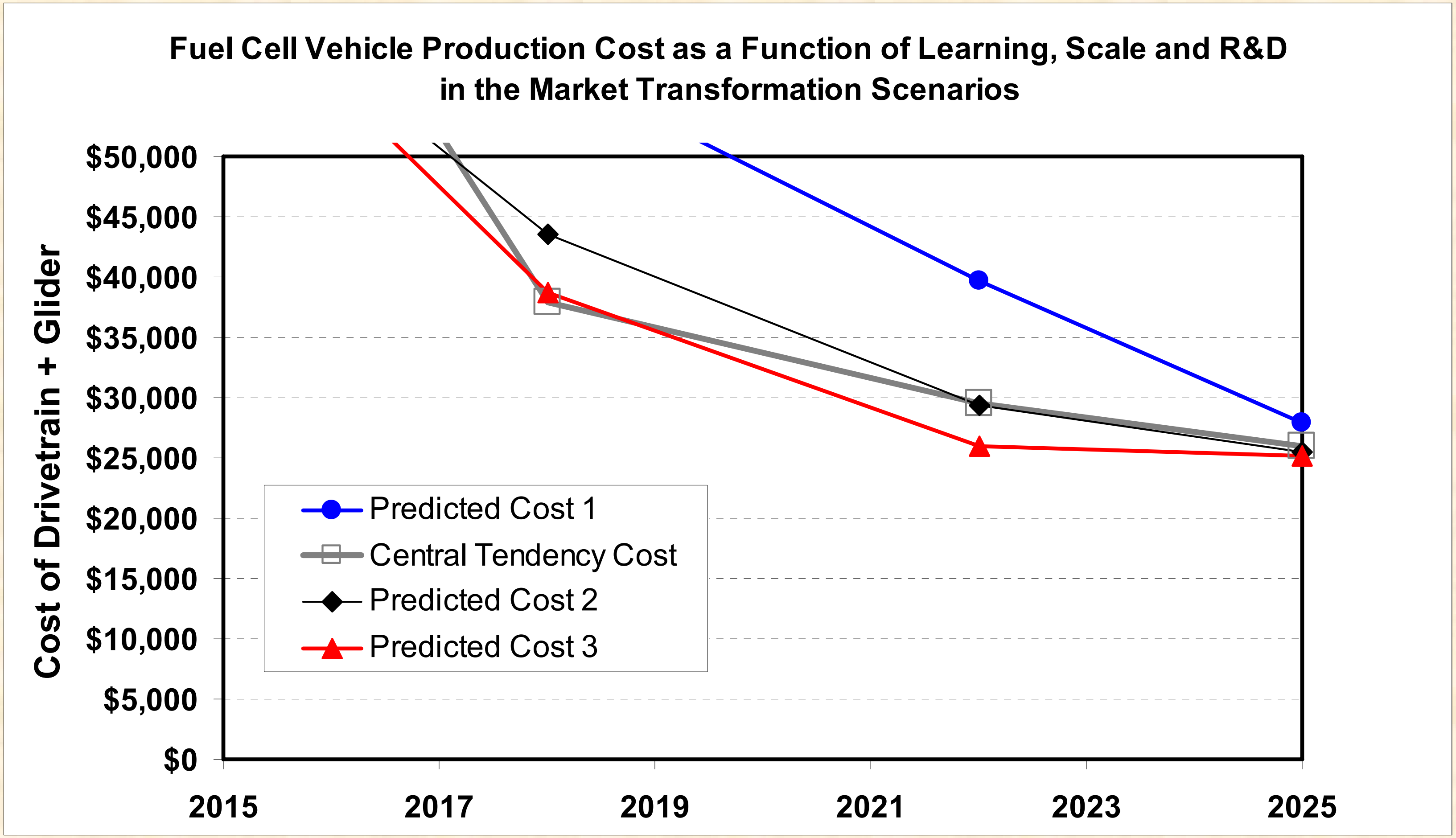
HyTrans' method is economic modeling via non-linear optimization of consumers' and producers' surplus from 2005 to 2050 and beyond.

- Production pathways are cost functions derived from H2A models
- Vehicle production cost functions are based on PSAT/ASCM results and OEM input
- Consumer choice of vehicle technology based on economic choice model with diverse preferences
- 3 geographic, 3 fuel demand density regions
- Key dynamic elements:
  - Learning-by-doing
  - Technological change
  - Scale economies
  - Fuel availability
  - Diversity of vehicle choices
- Positive feedbacks create multiple local optima and necessitate special search methods to find global optimum.

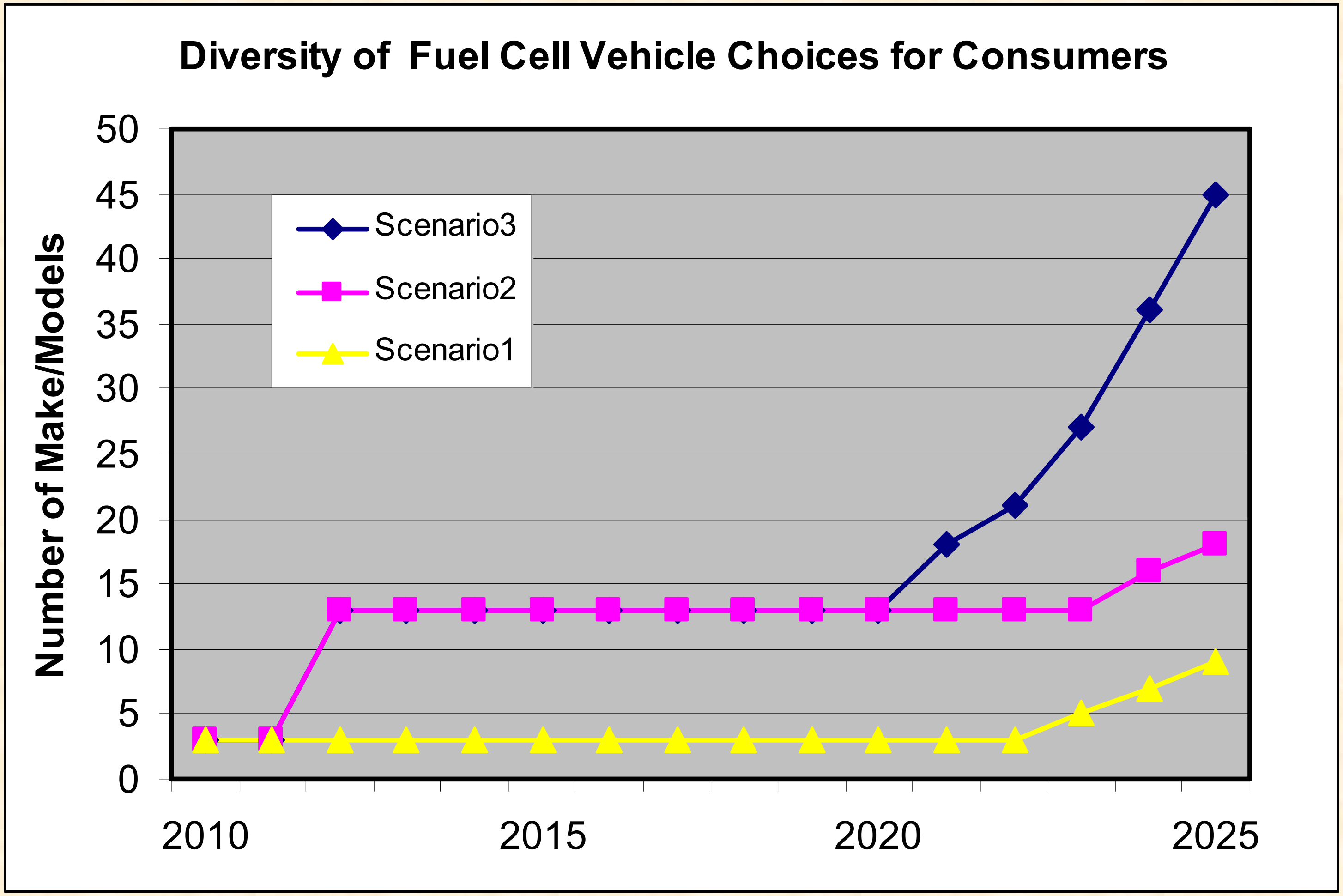
HyTrans simultaneously represents the key agents: 1) fuel supply, 2) vehicle manufacture, 3) consumer choice.



A closer look shows that only scenario 3 meets the long-term price target by 2025. The cost implications are quite important.



The key differences among scenarios are the 1) degree of fuel availability, 2) diversity of make and model choice and, 3) level scale economies achieved by the different production schedules.



Three policy cases with different cost sharing by government were evaluated.

		2012-2017	2018-2021	2022-2025
Vehicle Cost Sharing	Case 1:	50/50 incremental cost share	50/50 incremental cost share	50/50 incremental cost share
	Case 2:	50% total vehicle	None	None
	Case 3:	50% total vehicle cost share	None	None
Vehicle Tax Credits	Case 1:	None	None	None
	Case 2:	None	100% of incremental cost	100% of incremental cost
	Case 3:	None	100% of incremental cost plus $2,000/vehicle	100% of incremental cost plus $2,000/vehicle
Station Cost Sharing	All Cases:	$1.3 Million/Station	$0.7 Million/Station	$0.3 Million/Station
H2 Fuel Subsidy	All Cases:	$0.50/kg	Decreasing starting in 2018 to reach	$0.30/kg in 2025

But if fuel cell technology does not fully meet program goals ($60/kw v. $30/kW FC system cost, or if oil prices are not high, the transition may not be complete or sustainable.