Systems Analysis of the Hydrogen Transition With HyTrans

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Transportation Research Board Annual Meeting

January 25, 2006
Washington, DC

Three Topics

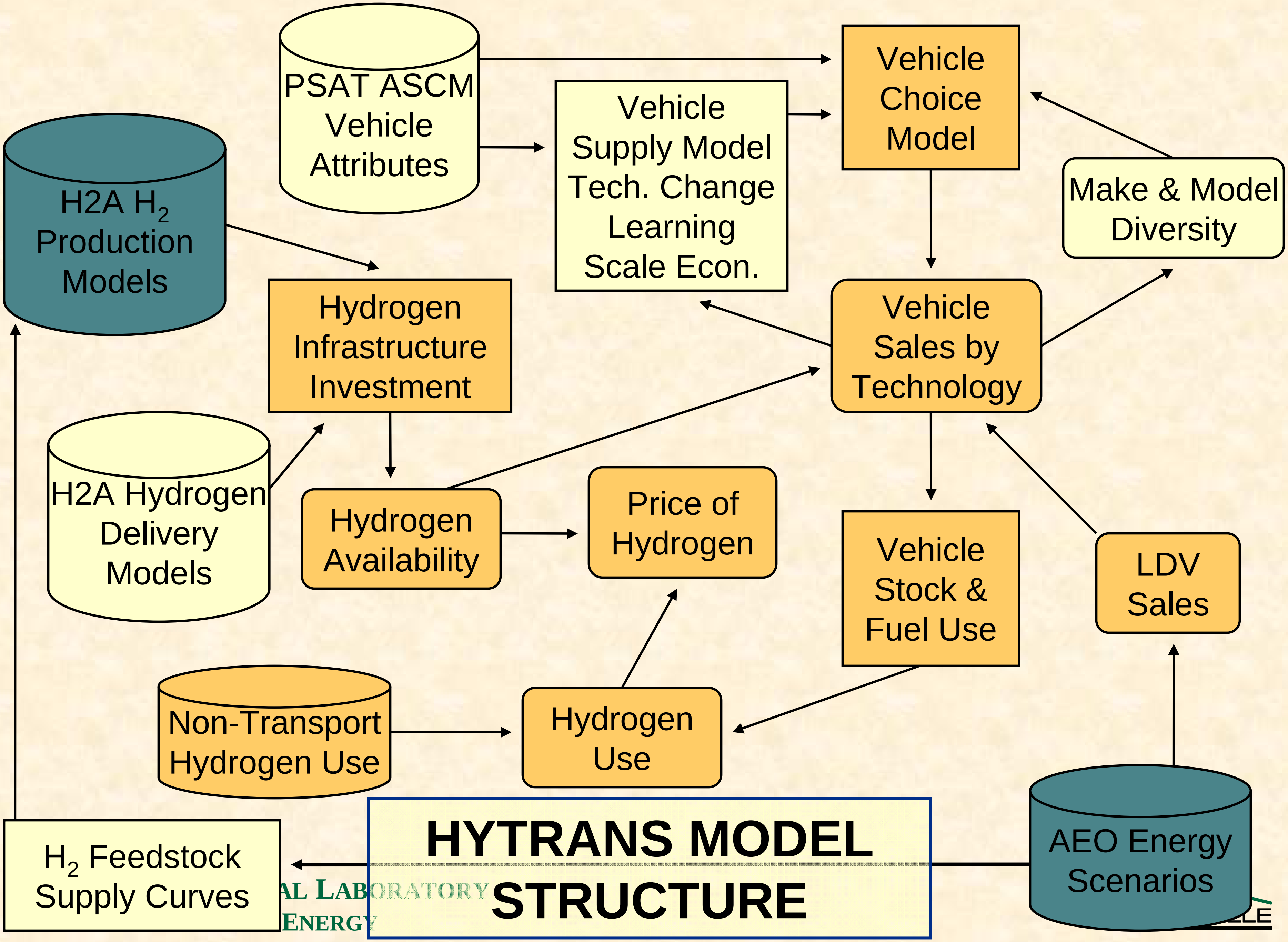
1. **What is HyTrans?**
2. **What can it do (previous analyses)**
3. **Insights, and what improvements are needed for realistic early transition analysis?**

1. What is HyTrans?

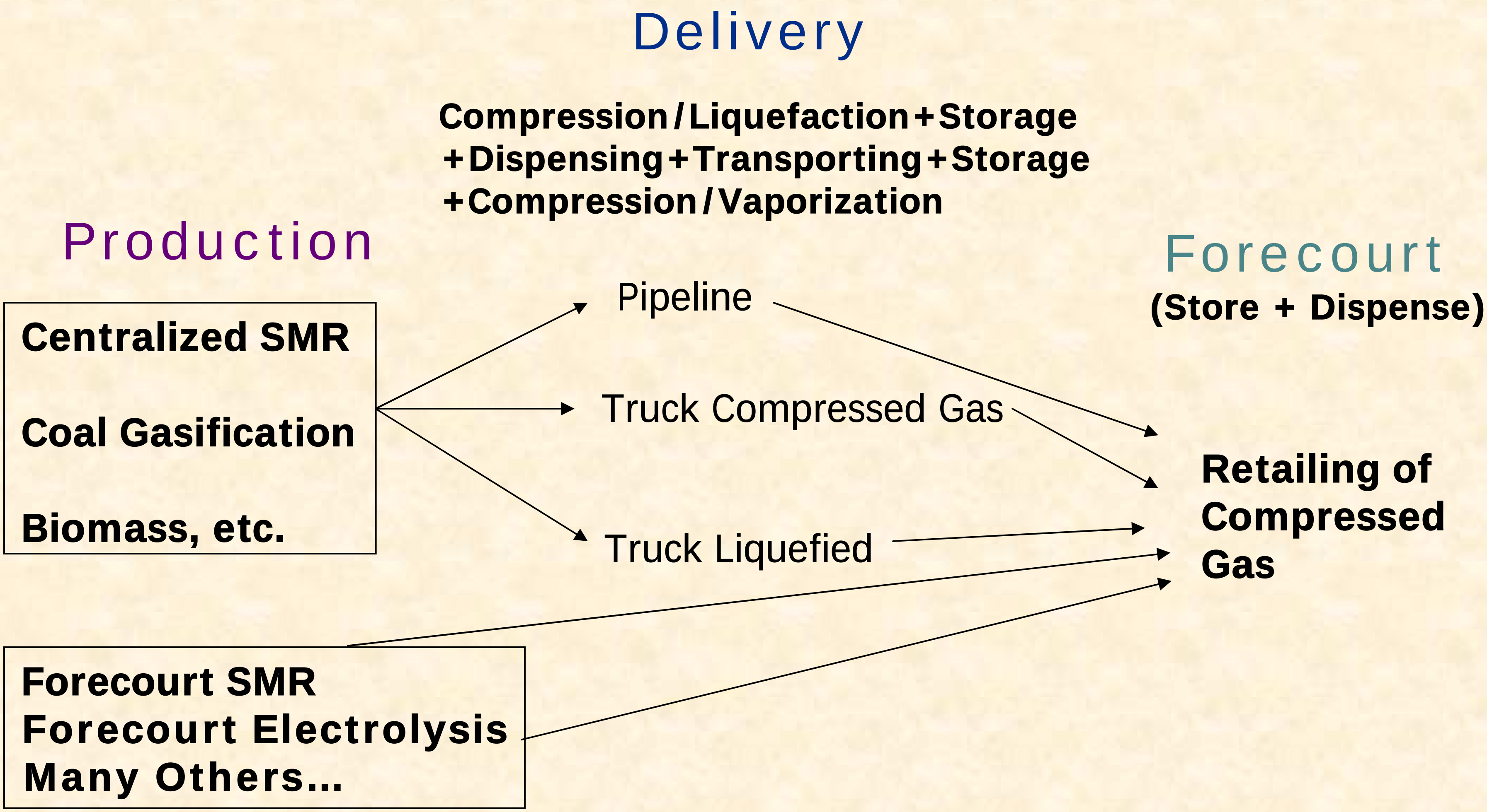
HyTrans is a national (regional) model of the market transition to a H2 vehicle system designed to be useful for R&D planning, cost-benefit analysis, policy analysis and envisioning.

- **Integrates all main H_2 market components**
  - **Hydrogen Production**
  - **Hydrogen Delivery**
  - **Vehicle Production**
  - **Consumer Choice**
  - **Hydrogen Use**
- **Determines a market equilibrium solution**
  - **Maximizes total consumption benefit minus production, distribution, and other costs**
  - **Estimates amounts and timing of costs, benefits, levels of investment and activity, production and consumption, key environmental impacts.**
  - **Sensitive to technological goals and supporting policies.**

HYTRANS MODEL STRUCTURE

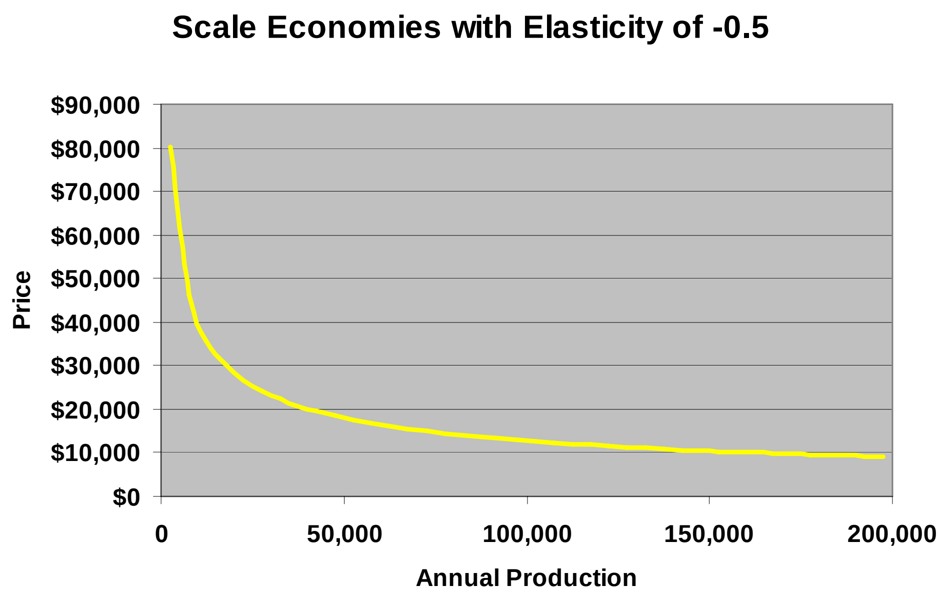


A H2 Supply Pathway comprises three parts.



HyTrans includes a wide range of H production technologies (current and future) based on two major studies (NAS & H2A).

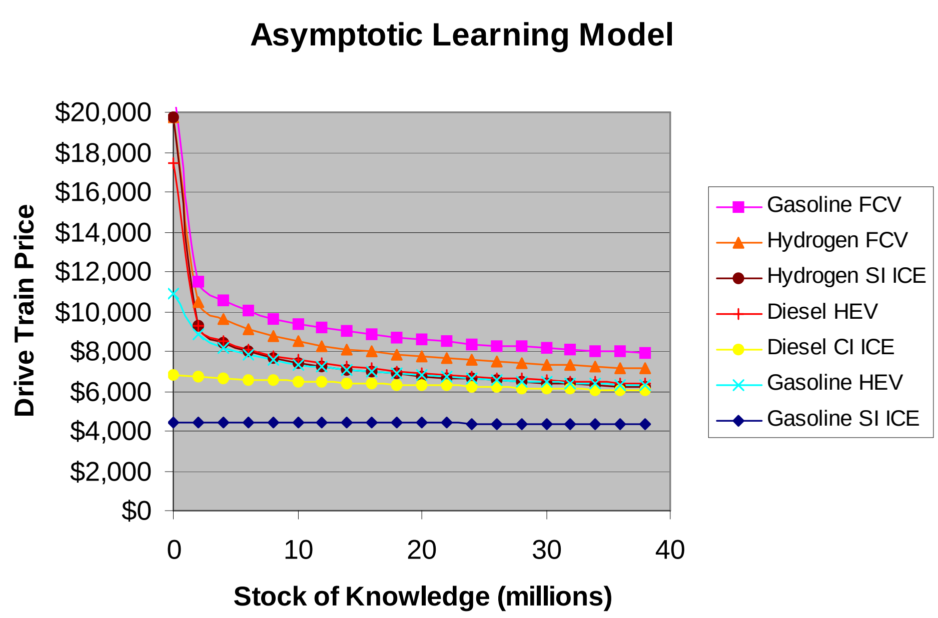
Production Technologies	NAS		H2A		
Central	Current	Future	2005	2015	2030
SMR with CO2 Capture	X	X	X	X	X
SMR without CO2 Capture	X	X	X	X	X
Central Electrolysis	X	X			
Central Wind Electrolysis			X	X	X
Central Wind Electrolysis plus power			X	X	X
Coal Gasification with CO2 Capture	X	X	X	X	X
Coal Gasification without CO2 Capture	X	X	X	X	X
Biomass gasification without CO2 Capture	X	X	X	X	X
Biomass gasification with CO2 Capture	X	X			
Advanced Nuclear Energy – HTGR and High Temperature (Steam) Electrolysis					X
Advanced Nuclear Energy - ALWR/Conventional High Pressure Electrolysis				X	
Advanced Nuclear Energy – HTGR with Sulfur Iodine Thermochemical Process					X
Forecourt					
SMR	X	X	X	X	X
Electrolysis	X	X	X	X	X
Ethanol Reforming			X	X	X
Wind Electrolysis	X	X			
Solar Electrolysis	X	X			
Hybrid Wind Electrolysis	X	X			
Grid Electrolysis	X	X			
Hybrid PV, and Grid Electrolysis	X	X			
SMR SOX future		X			

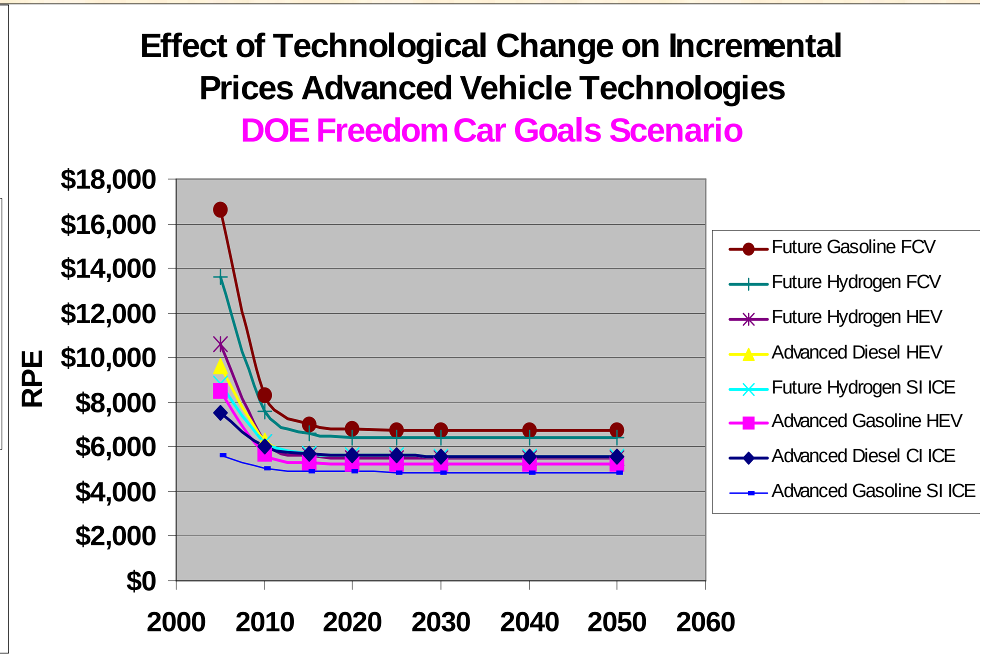


Vehicle technologies improve by 3 mechanisms.

Retail Price =
Scale × Learning × Tech Change
× Scenario Price

Scale w/ Annual Production/Plant

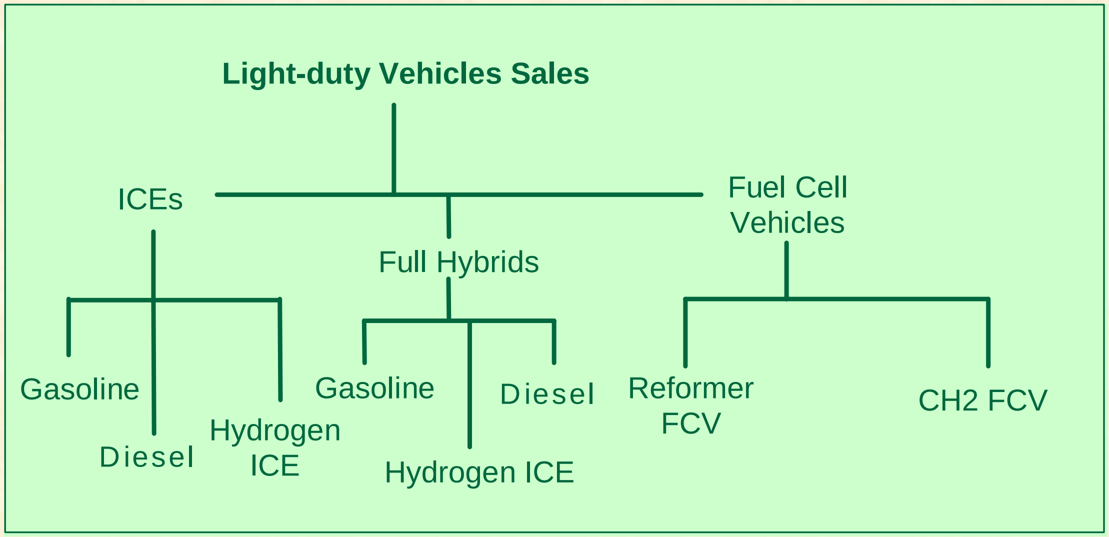




Learning & Unlearning w/ Stock on Road

Tech Change w/ Passage of Time (Yr)

Consumers' choices of vehicle technology are represented by a Nested MNL vehicle choice model that predicts the market shares of alternative technologies (grouped into "nests" of closer substitutes) based on their attributes.



	NAS 2004	HyTrans
Retail Price	X	X
Operating (fuel) cost	X	X
Maintenance cost	X	X
Range	X	X
Passenger/cargo space	X	Cargo
Performance (accel. +)	X	Accel
Quality	X	No
Safety	X	No
Battery cost	No	X
Value of electricity generation	No	X
Extra value of fuel cell vehicle	No	X

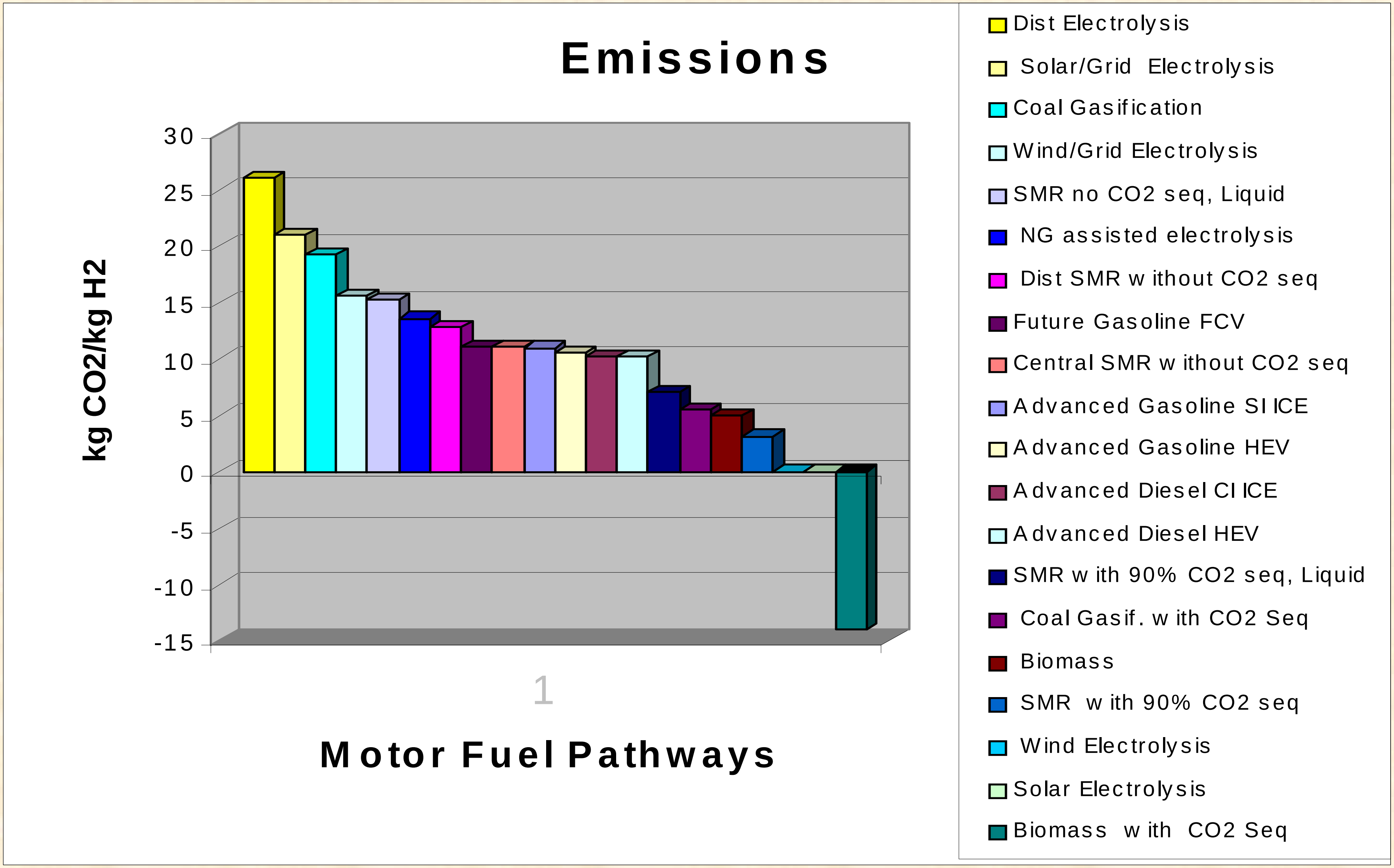
HyTrans' vehicle choice model includes most variables the NAS (2004) report listed as important.

The US (& region 9) is divided into 3 fuel demand density regions. The delivered cost of hydogen depends on density.

According to EPA data, 2/3 of LDV fuel is used in <10% of the land area.

The two high fuel demand density areas in Region 9 are LA and the Bay Area (>240,000 $kg/km^2/year$).

HyTrans includes GHG emissions estimates obtained from the ANL GREET Model.



2. What can it do?

Previous analyses.

What kinds of questions can HyTrans answer?

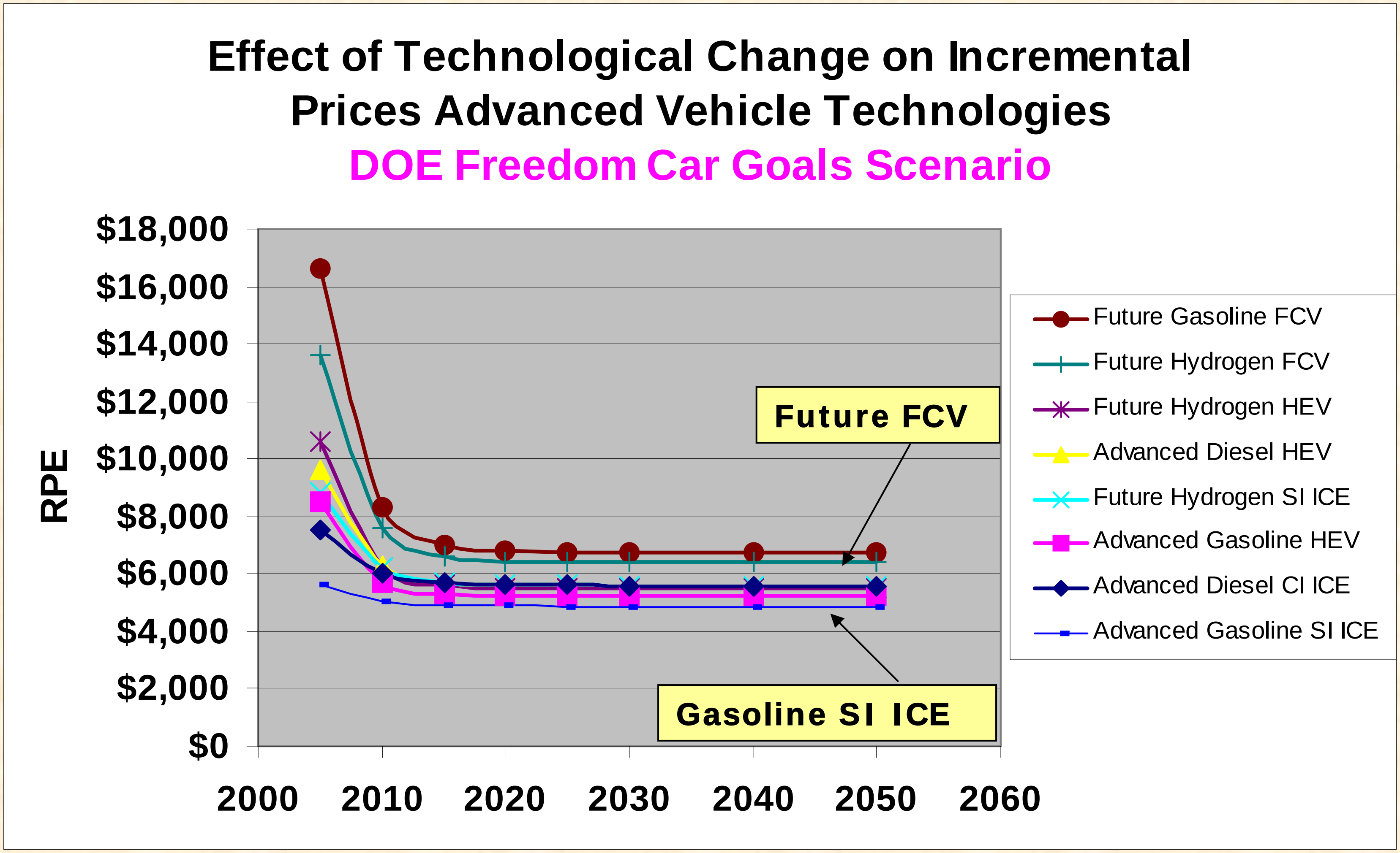
- **Produces plausible answers to key issues:**
  - **Is a stable transition achievable?**
  - **When?**
  - **How long will it take?**
- **Can test effectiveness of alternative policies**
  - **Vehicle or fuel subsidies or tax policies**
  - **Mandates or regulatory policies**
  - **Demonstration fleets, etc.**
- **Produces cost and benefit measures**
- **Close to creating useful visions of the transition**
- **Beginning to generate insights about R&D goals**
  - **Good enough for a stable transition?**
  - **Effects of competing technologies?**

We have used HyTrans' to produce several provisional transition scenarios and tested its sensitivity to key assumptions and parameters.

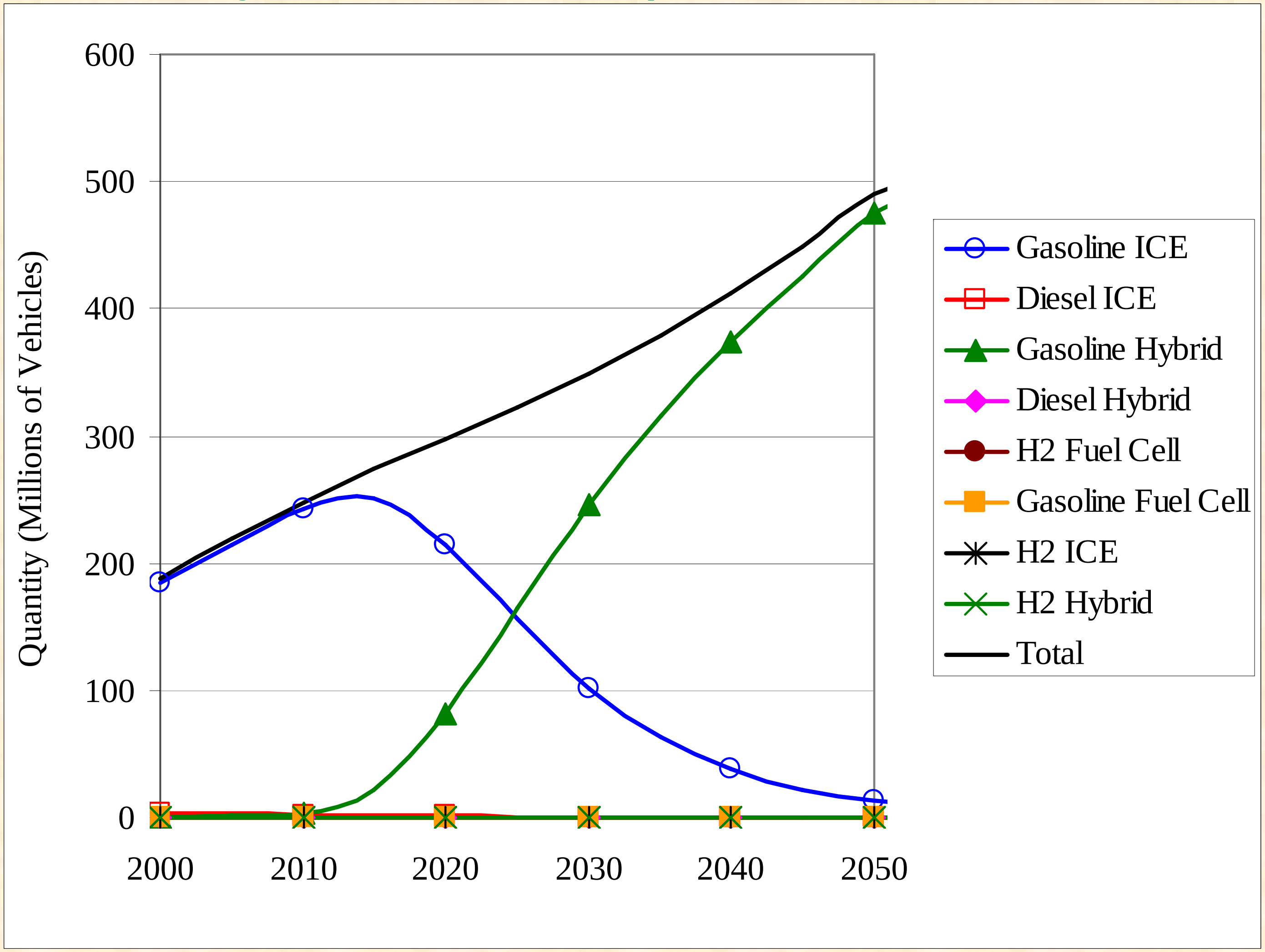
Base Case (NAS, FreedomCAR technologies)

- **Vehicle technology evolution**
- **H2 pathway costs (H2A v. NAS)**
- **Energy Prices**
- **Feedstock Supply Curves**
- **Discount Rate**
- **Scale Economies in Vehicle Production**
- **Consumer Choice**
  - **Elasticities of vehicle choice to price**
  - **Cost of low fuel availability**
- **GREET CO_2 coefficients & Low C constraints**

SCENARIO 1
The DOE Vehicle Technology Program Goals scenario anticipates rapid progress **for all technologies.**

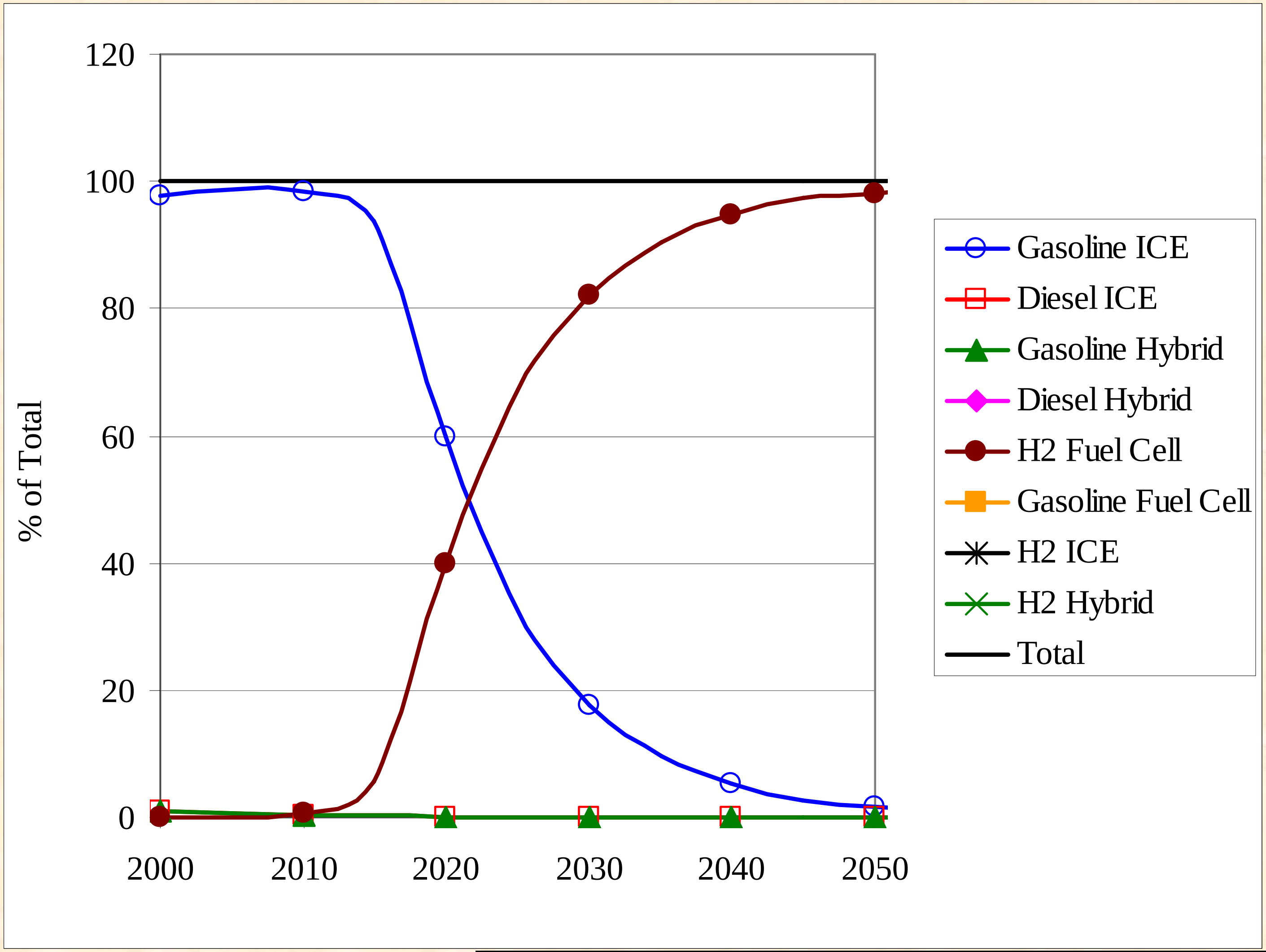


In the Base Case with no new policies gasoline hybrids conquer the market.



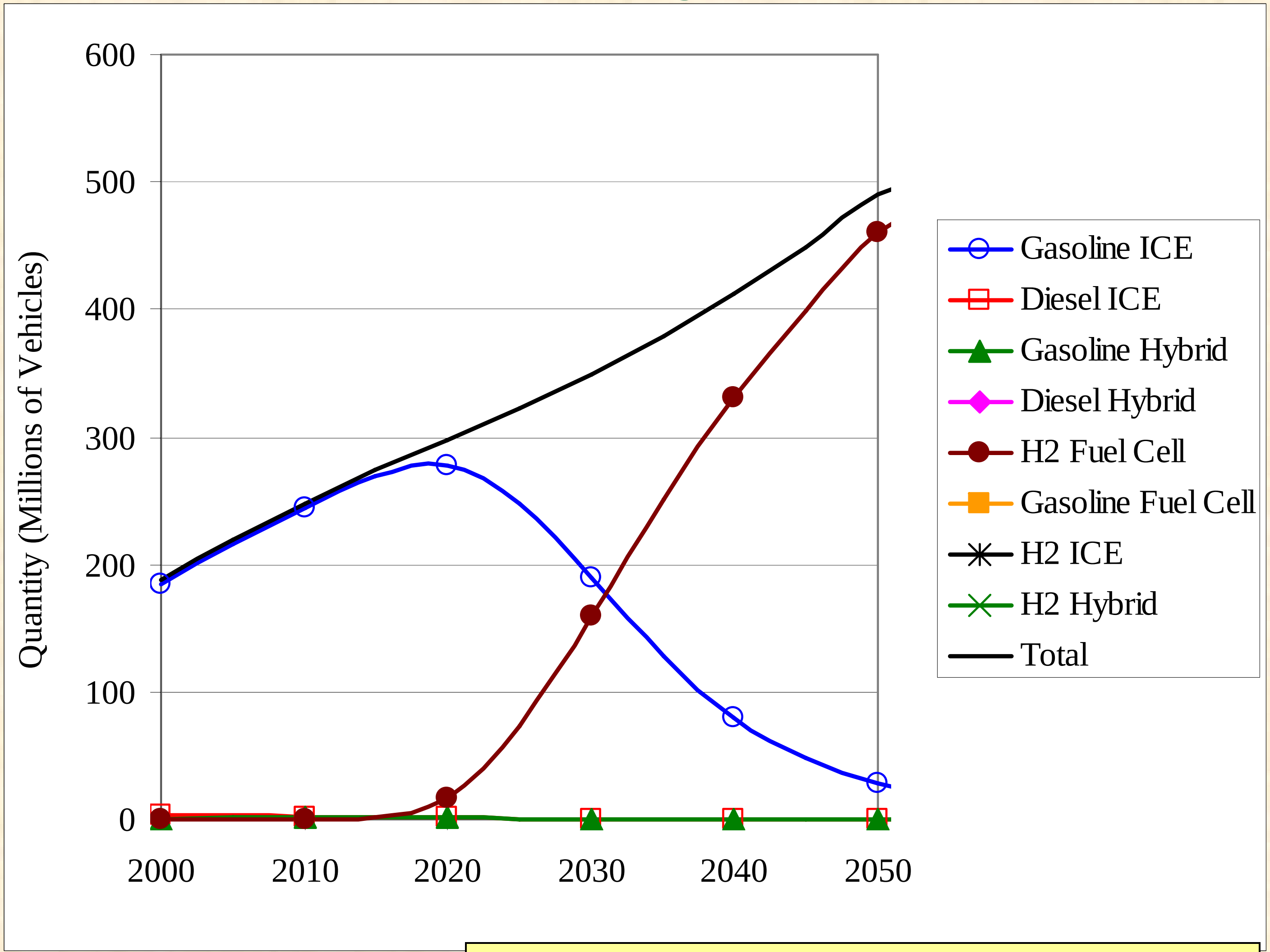
Case: No fuel or vehicle subsidy

A $1,500/vehicle subsidy (discontinued in 2030) brings on FCVs instead of hybrids, 5 years later.



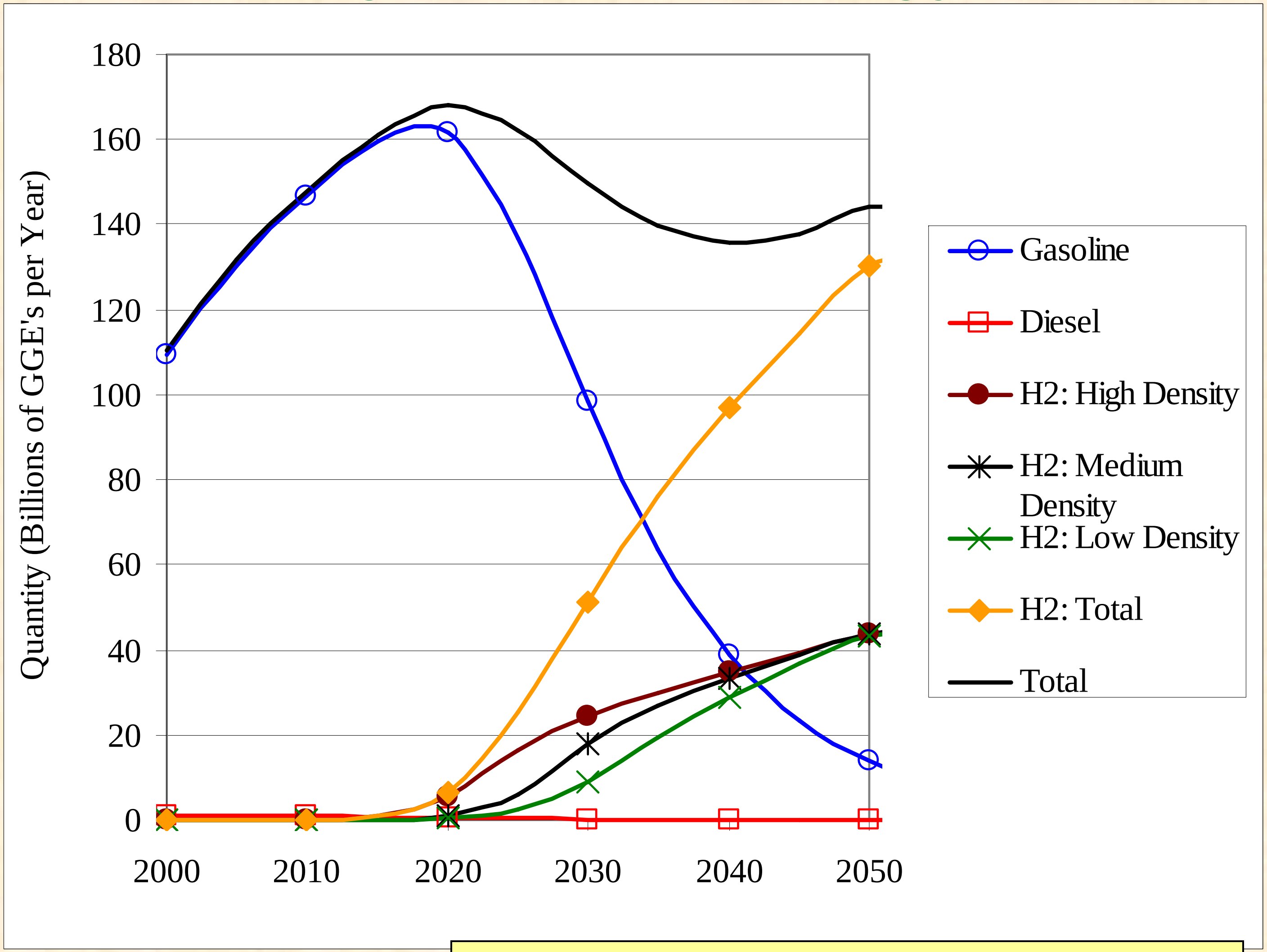
Case: $1500/veh temp subsidy

It takes 30 years for hydrogen FCVs to replace conventional gasoline vehicles.



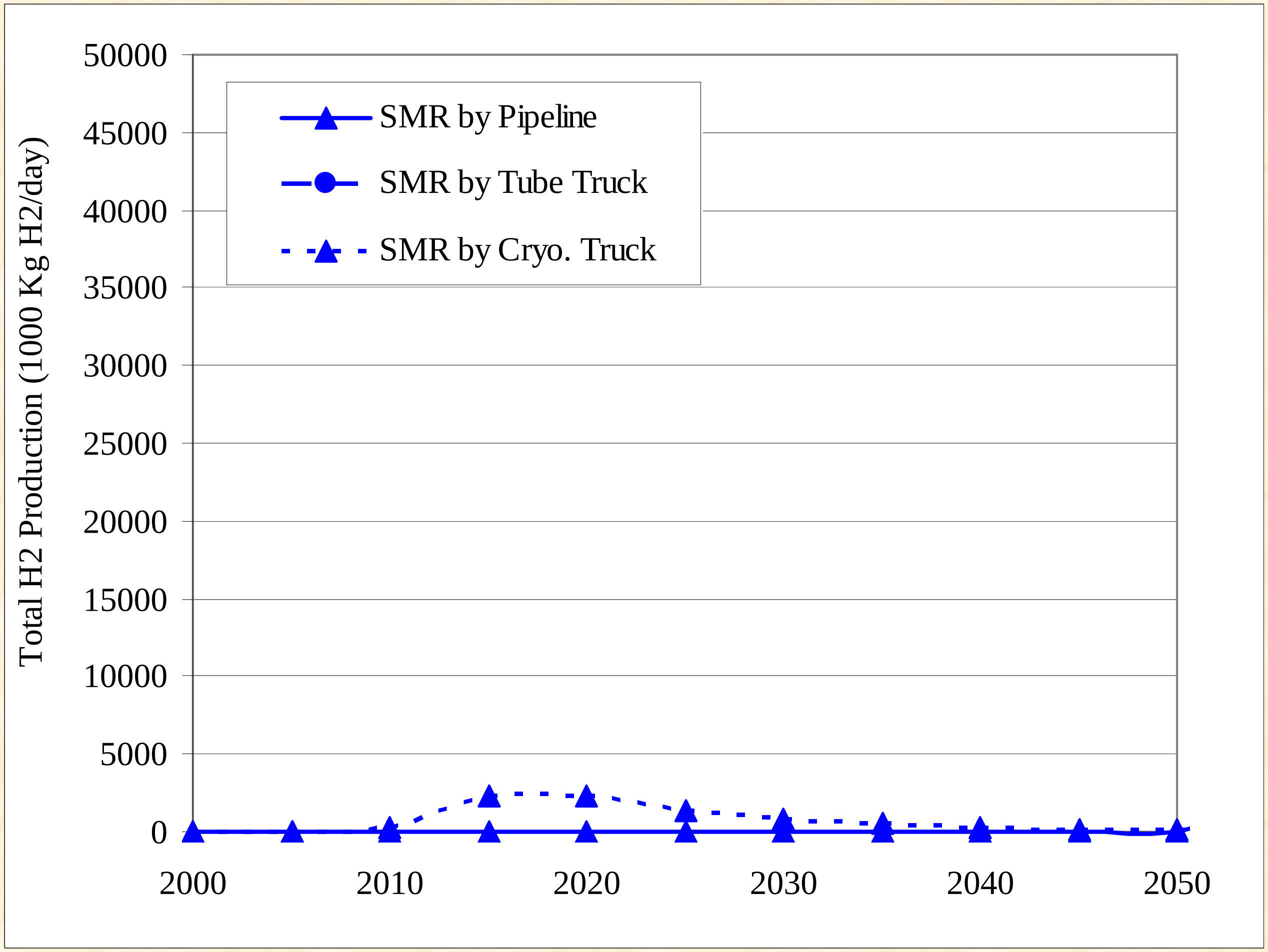
Case: $1500/veh temp subsidy

The greater efficiency of FCVs actually reverses the growth of energy demand.



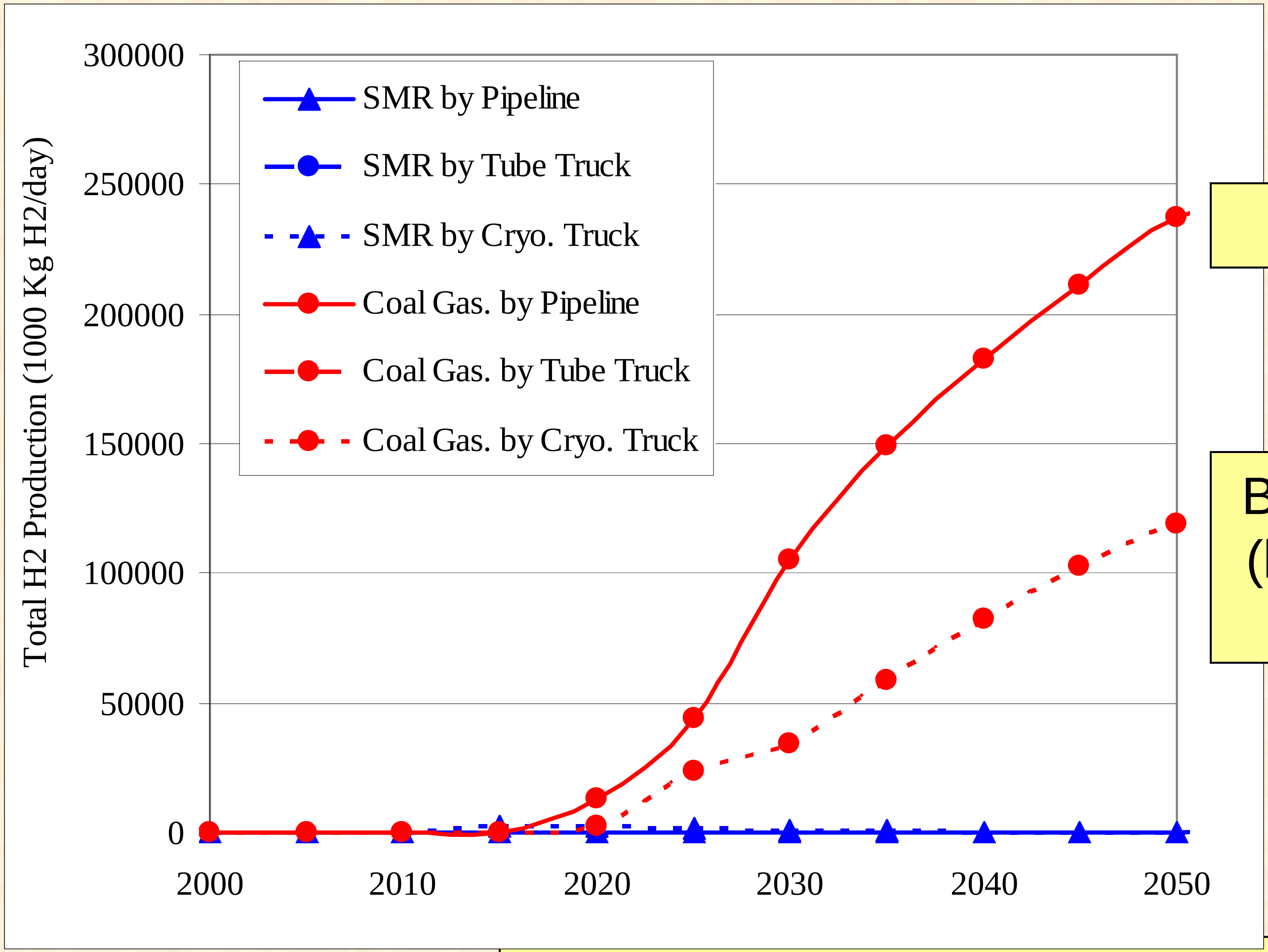
Case: $1500/veh temp subsidy

Zooming in: Initially, H2 from (high cost) Distributed SMR, Followed by Central SMR



Case: $1500/veh temp subsidy

Later, in this case: Shift to Production from Central Coal Gasification Plants



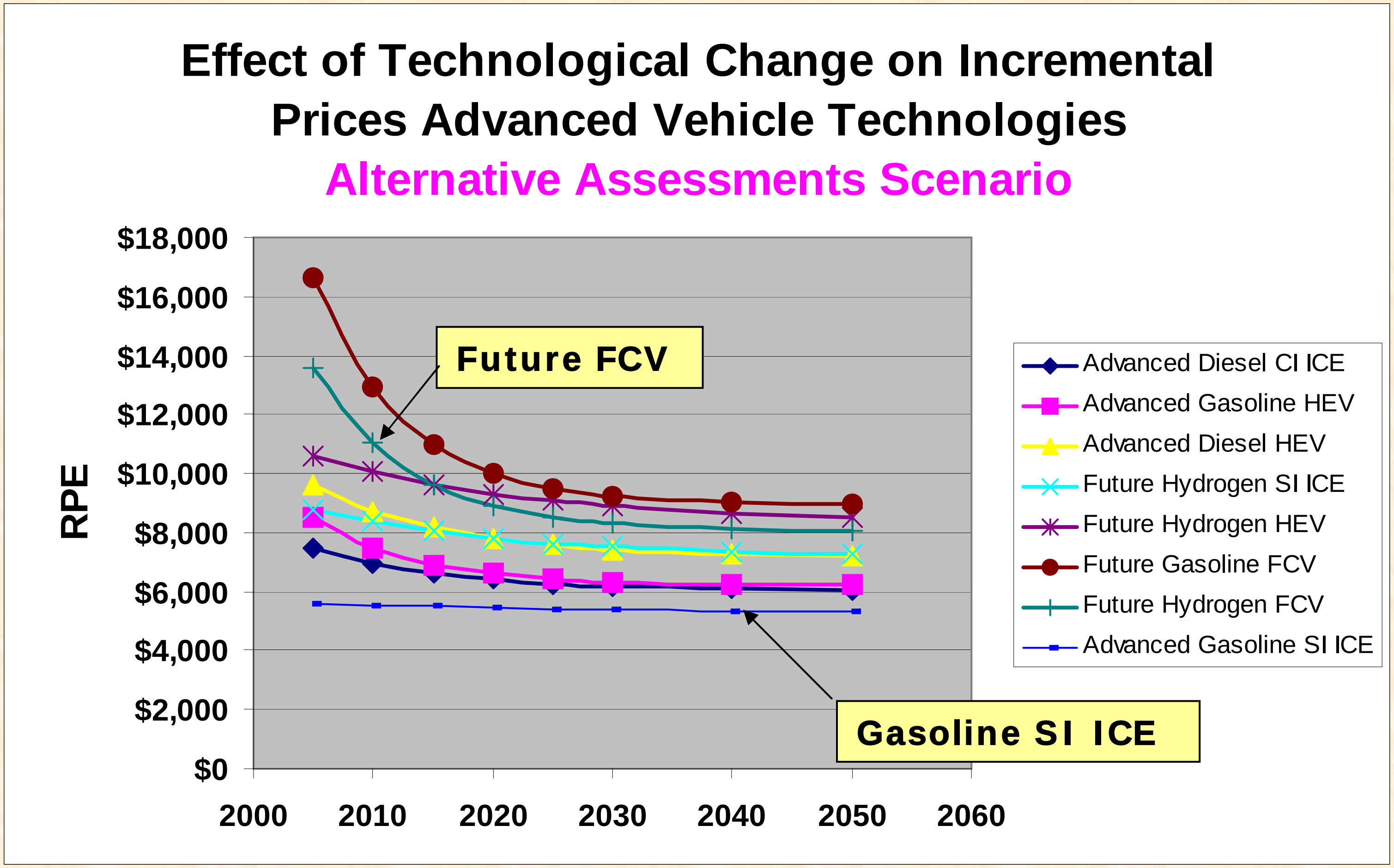
By Pipeline

By Cryo Truck (lower density regions)

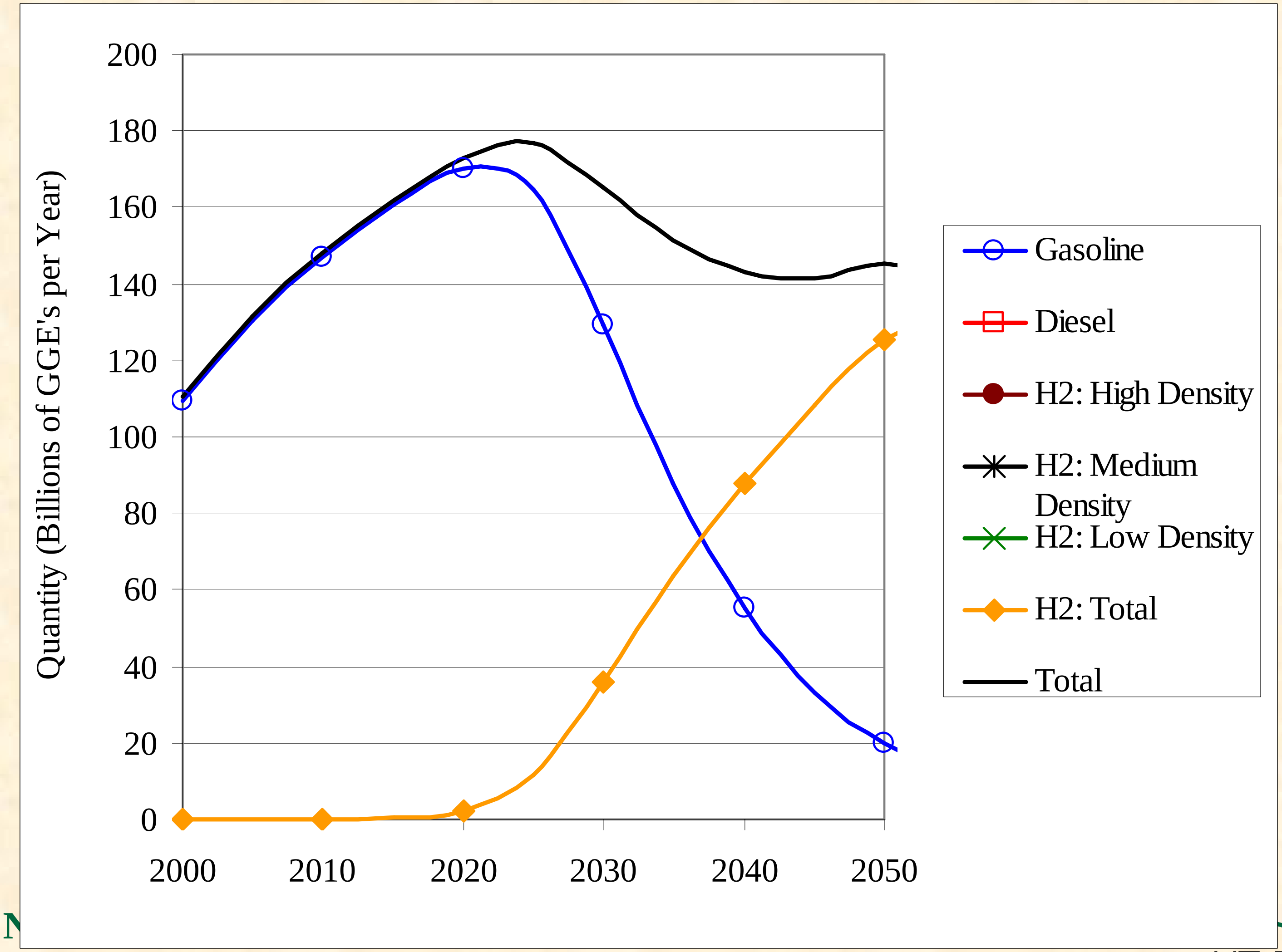
Case: $1500/veh temp subsidy (NAS Production costs, no carbon constraints or sequestration)

SCENARIO 2

We derived the Alternative Vehicle Technology Case from published studies. It is less favorable for some technologies, certainly for FCVs.



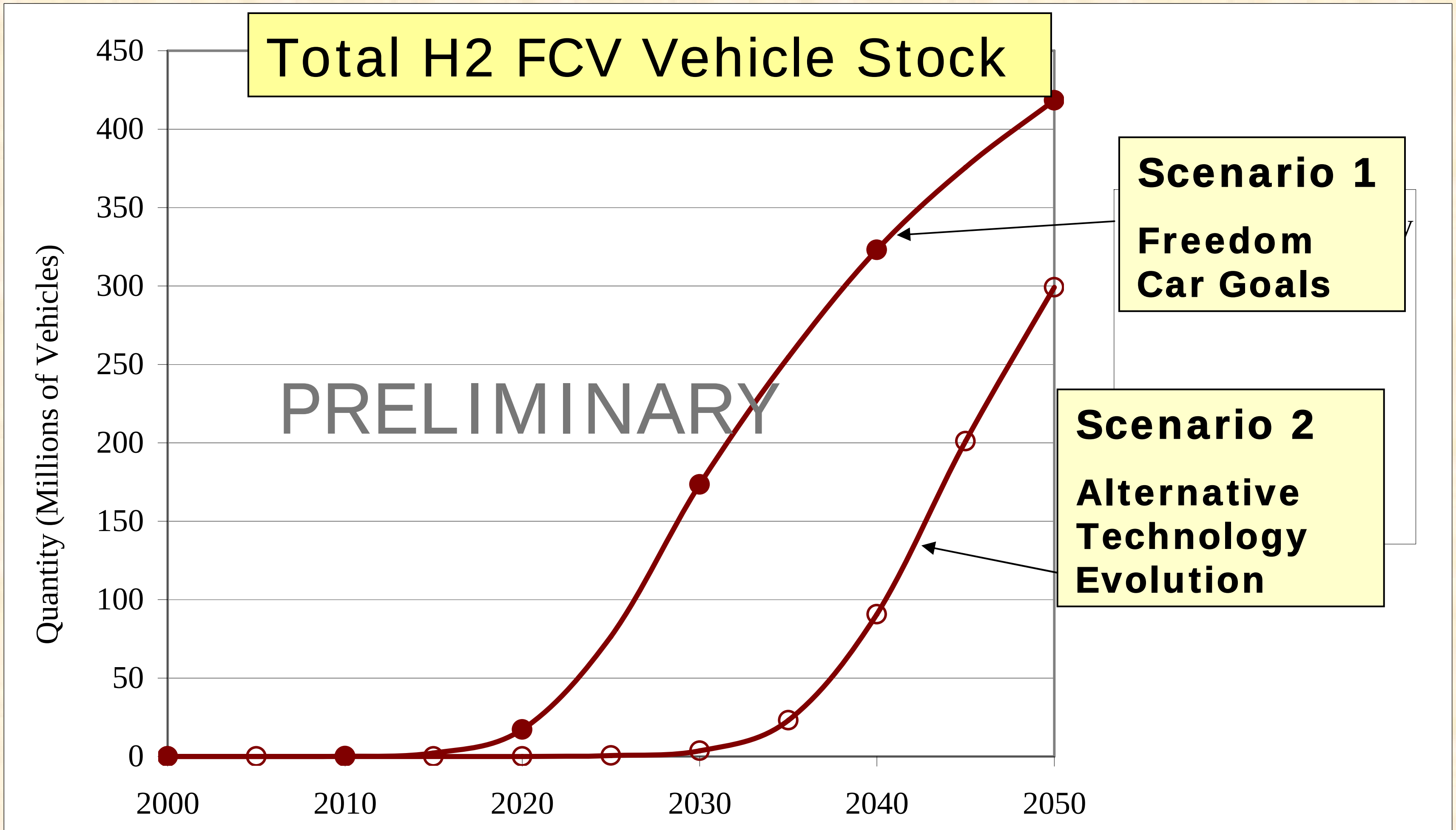
In the alternative technology case it took a $3,000 subsidy (discontinued in 2030) to cause a transition to FCVs.



Case: $3000/veh temp subsidy

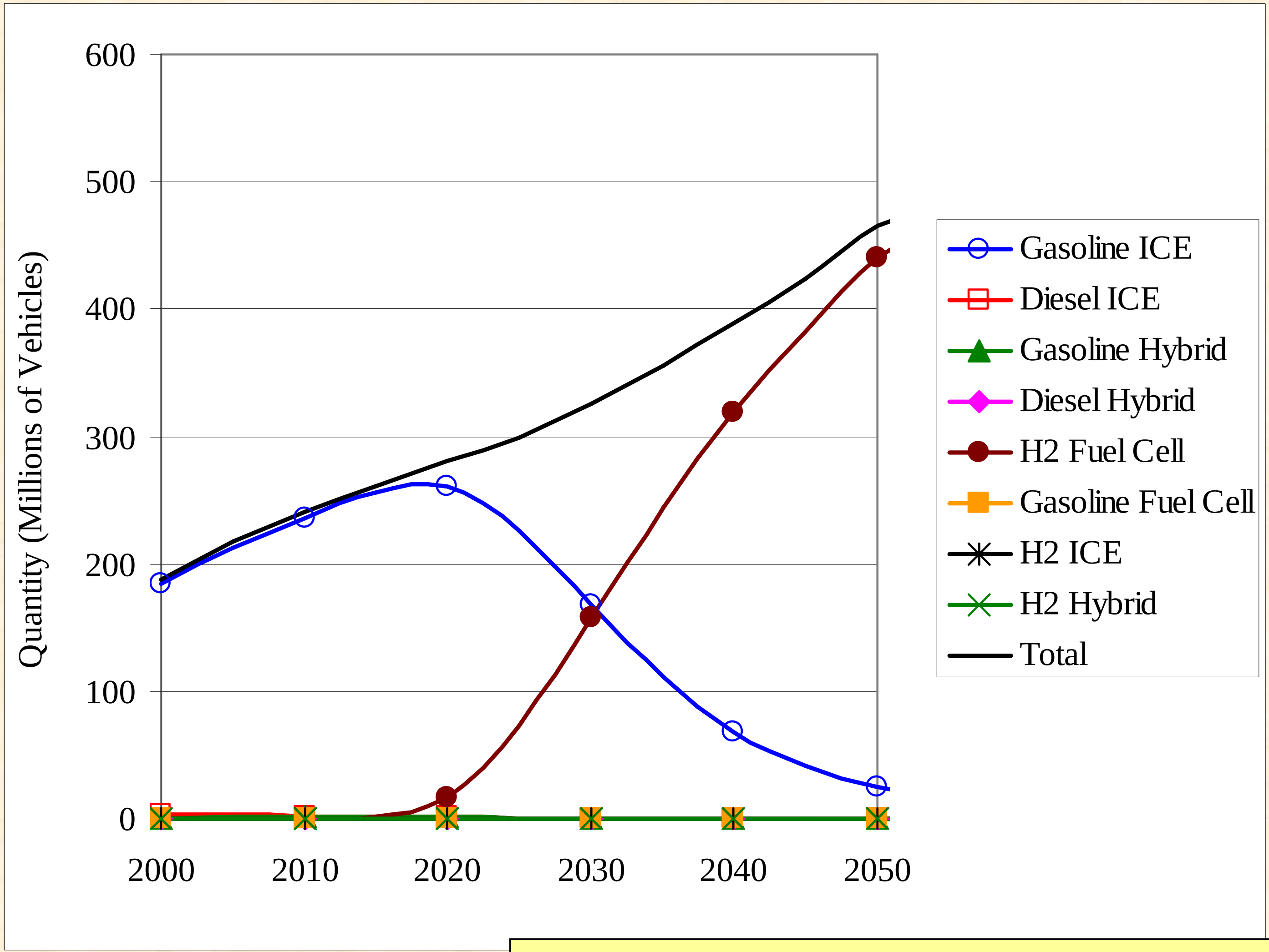
Given the same fuel subsidy policy, the H2 transition occurs later in scenario 2.

(Scenarios 1 & 2: $0.90/GGE H2 Fuel Subsidy)



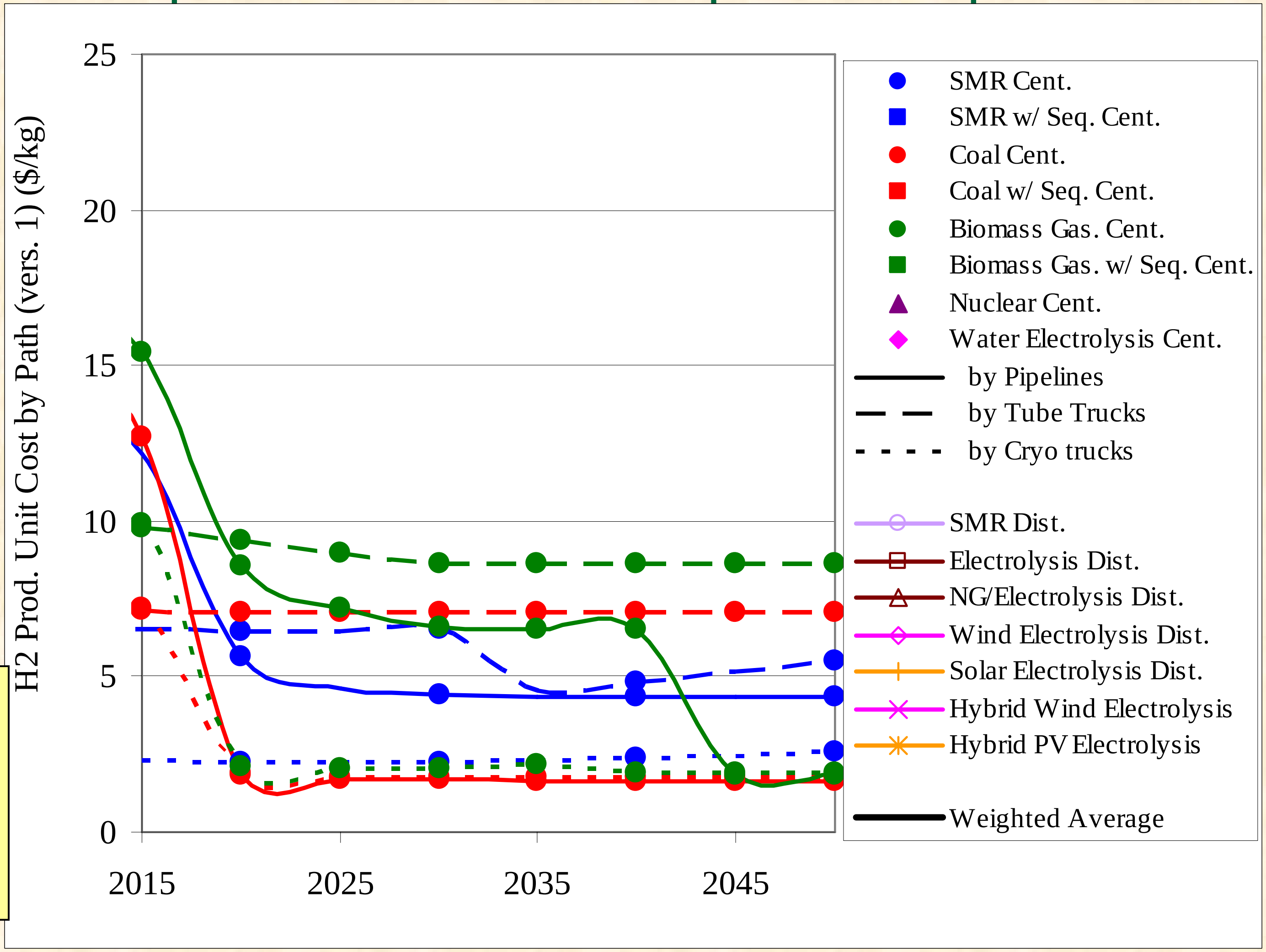
Cases: $0.90/kg H2 Fuel Subsidy

With higher oil prices ($48 v. 30$/bbl in 2030) a $1,000 is sufficient to cause the transition to H_2.



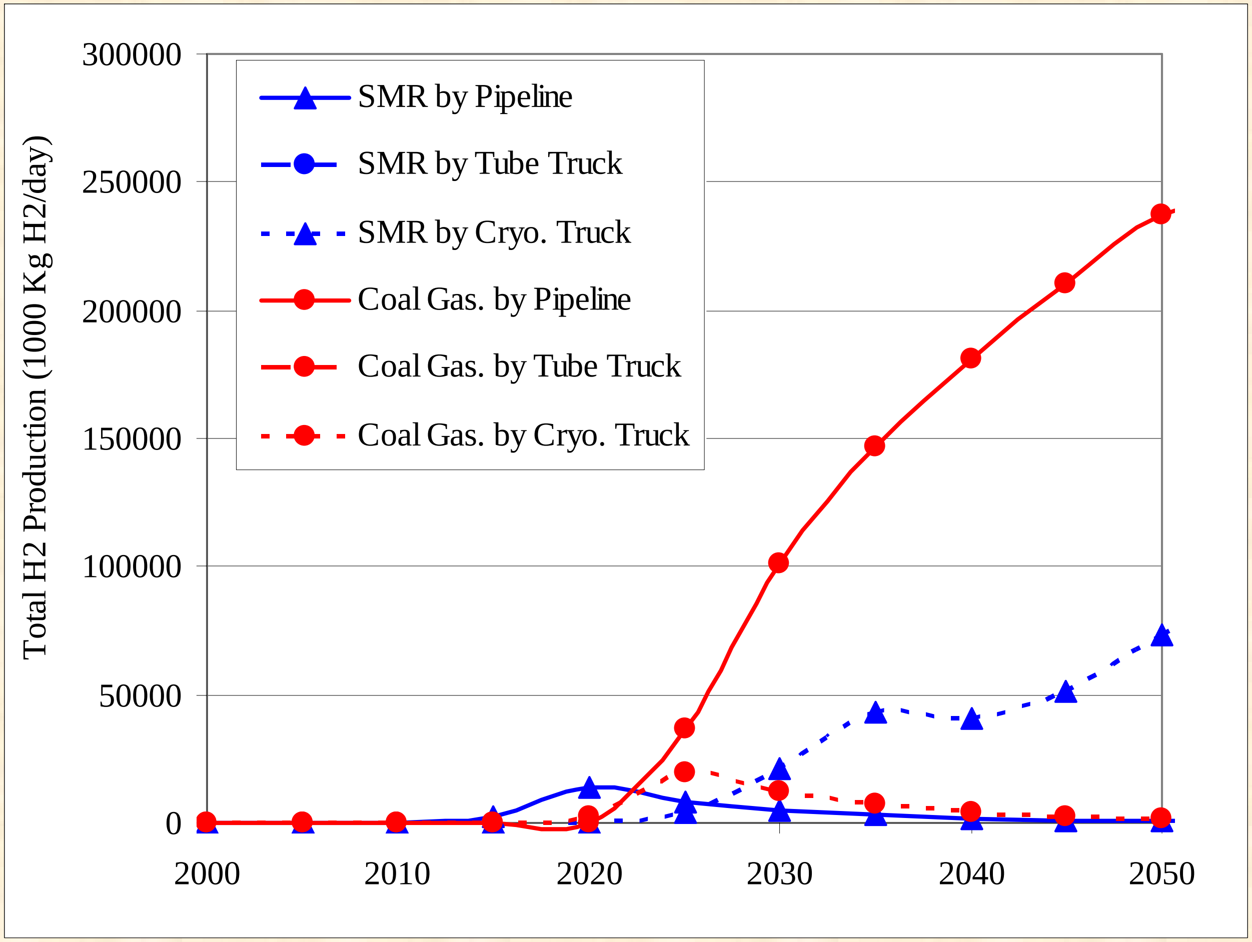
Case: $1000/veh temp subsidy

Alternative H2 Pathway Costs: According to H2A, Coal, SMR and biomass can be produced at comparable prices.

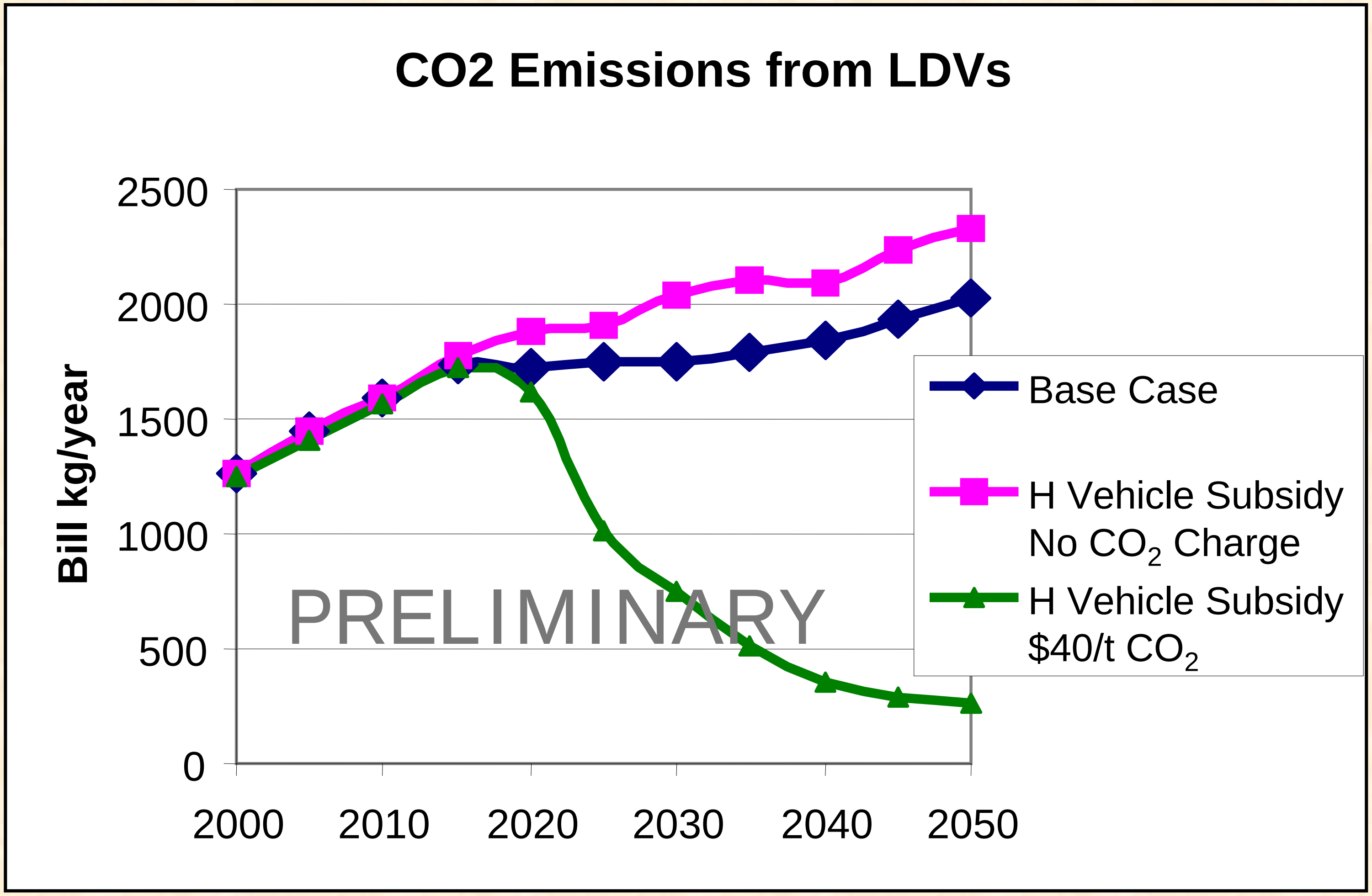


Delivered Costs fall to ~$1.75/gge by 2020

Introducing feedstock supply curves raises the cost of hydrogen and the required subsidy for a transition, but also diversifies the hydrogen supply system.



Transition to H_2 creates an opportunity for massive reductions in C emissions.



Early (Preliminary) Results Indicate Key Features for Investigation

- **Strong preference for single drivetrain suggests valuation and cost of diversity of choice is a key issue**
- **Cost and performance of drivetrain technologies are key for timing and sustainability of transition**
- **Projected close-competitiveness of some H2 pathways means least-cost, aggregate national approach inadequate**
- **Sensitivity to oil prices, feedstock supplies**

Our goal for FY2006: Realistic transition scenarios. Requires HyTrans enhancements.

- **Added representation of region 9 and rest of U.S.**
- **Added representation of supply from existing H2 production facilities.**
- **More regions & metropolitan areas**
- **Improve representation of existing H2 supply extended to all U.S.**
- **Improve representation of manufacturers' decision making, introduction of makes & models**
- **Improve representation of fuel availability**
- **Integrate HyTrans spatially aggregated scenarios with NREL's geographically detailed analyses**

Other improvements to HyTrans will be made in 2006.

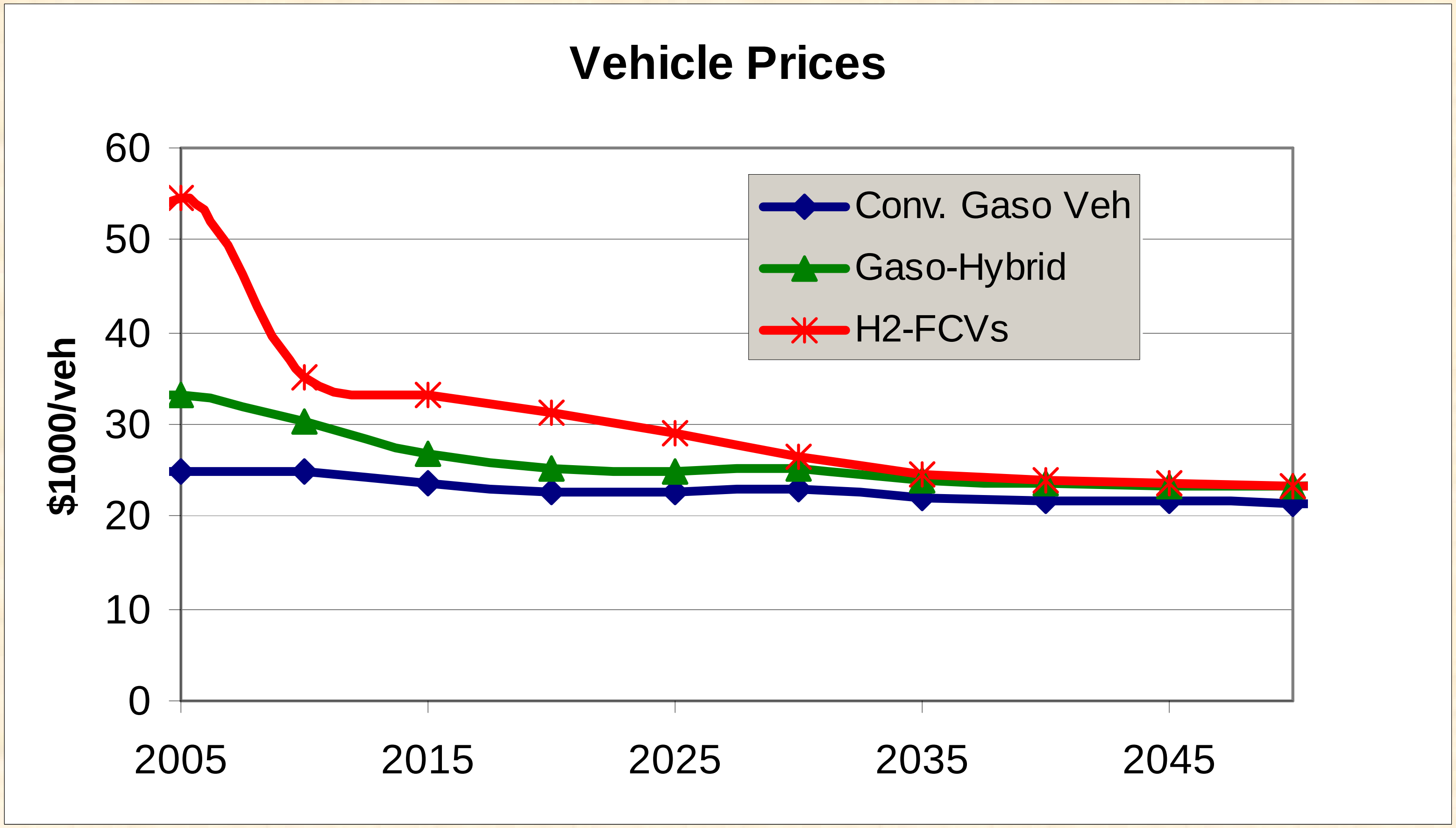
- **Regional feedstock supply and transportation demand**
- **Complete and update DOE hydrogen delivery and H2A production models**
- **Enhanced representation of consumer choice**
- **Improved scenarios of technological progress**
- **Incorporating alternatives to complete information ("perfect foresight")**
- **Update calibration to AEO 2006**

Thank You.

Diversity of choice among makes and models is a key issue.

- **In NMNL model it is a substantial source of value for consumers.**
- **Diversity value represented by log of ratio of number of makes and models to reference number for conventional technology**
- **Initially, a strong trade-off with scale economies.**
- **Fuel cell vehicle drive train diversity and scale economies may be very different.**

H2 vehicle prices decline quickly due to technological progress, scale economies and learning-by-doing, eventually reaching near parity.



Case of H2-FCV Introduction Program 3, Followed by $1.5K Subsidy for FCVs

Significant cost reductions via by learning-by-doing are achieved in all the scenarios.