Hydrogen Transition Modeling and Analysis HyTrans v. 1.0

David L. Greene
Paul N. Leiby
ORNL

David Bowman
Econotech

Elzbieta Tworek
Strata-G

May 26, 2005

Arlington, Virginia

Project # AN3

We have been working on this challenging task for almost 1 ½ years.

Timeline

- Start: 10/1/2004
- Finish: 10/31/2007
- Status: 40% completed

Barriers

- Transition Scenarios
  - "By 2007, identify and evaluate transition scenarios, consistent with developing infrastructure and hydrogen resources, including an assessment of timing and sequencing issues." p. 4-1

Budget

- FY04 - $540K
- FY05 - $450K

Partners

- ANL – Pipelines & delivery
- NREL & H2A – Production & delivery
- UC Davis - Expert review

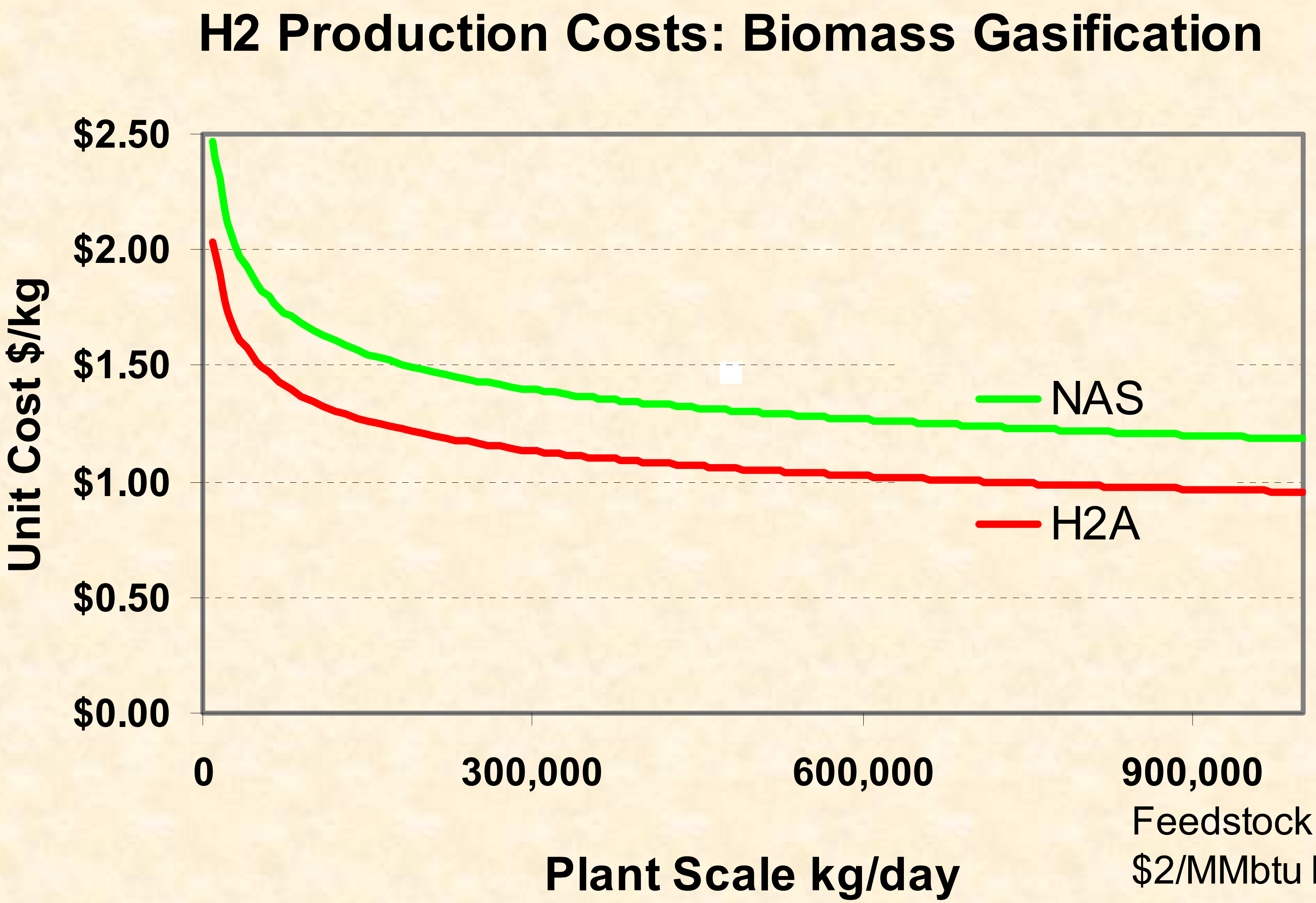
HyTrans' objective is to model the market transition to a H2 vehicle system in a way that is useful for R&D planning, cost-benefit analysis, policy analysis and envisioning.

- 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.

Our method is economic modeling via non-linear optimization.

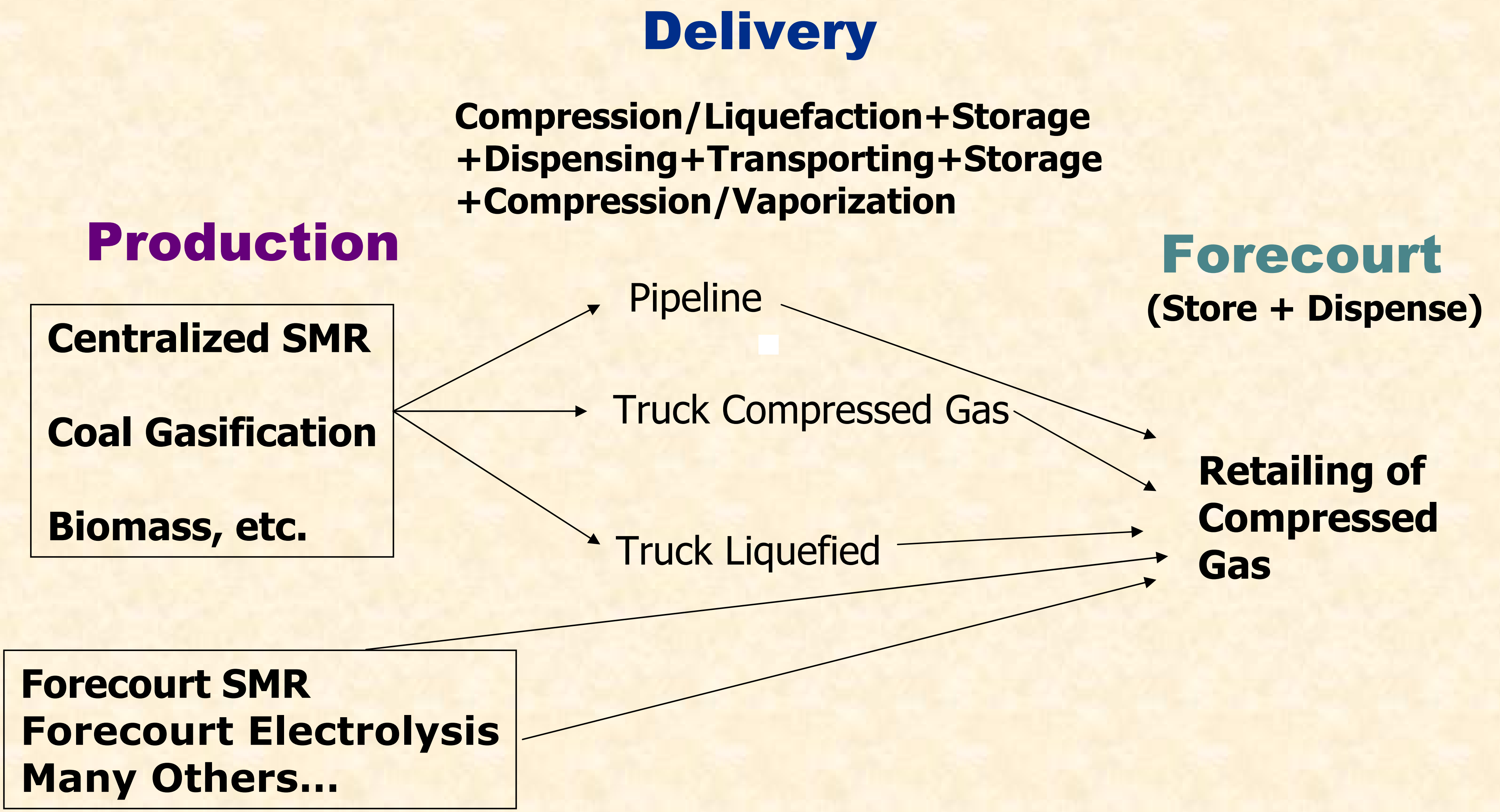
- **Production pathways: cost functions**
- **Vehicle production: cost functions**
- **Consumer demand: NMNL**
- **3 fuel demand density regions**
- **Key dynamic elements:**
  - **Learning-by-doing**
  - **Technological change**
  - **Scale economies**
  - **Fuel availability**
  - **Diversity of vehicle choices**
- G**eneralized** A**lgebraic** M**odeling** S**ystem**

Hydrogen production cost functions derived from H2A and NAS 2004 have been incorporated.



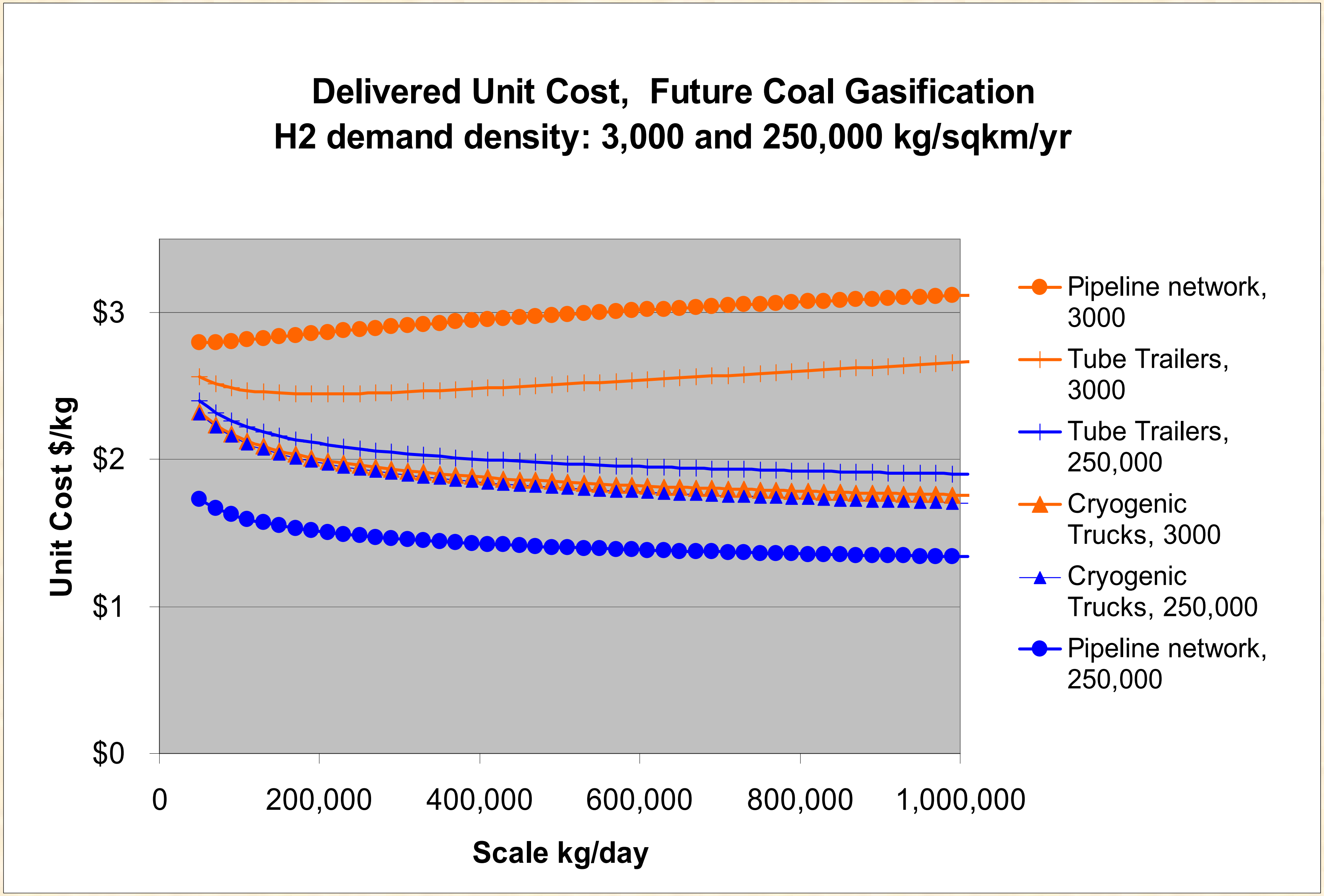
Feedstock price:
$2/MMbtu LHV

A H2 Supply Pathway comprises three parts.



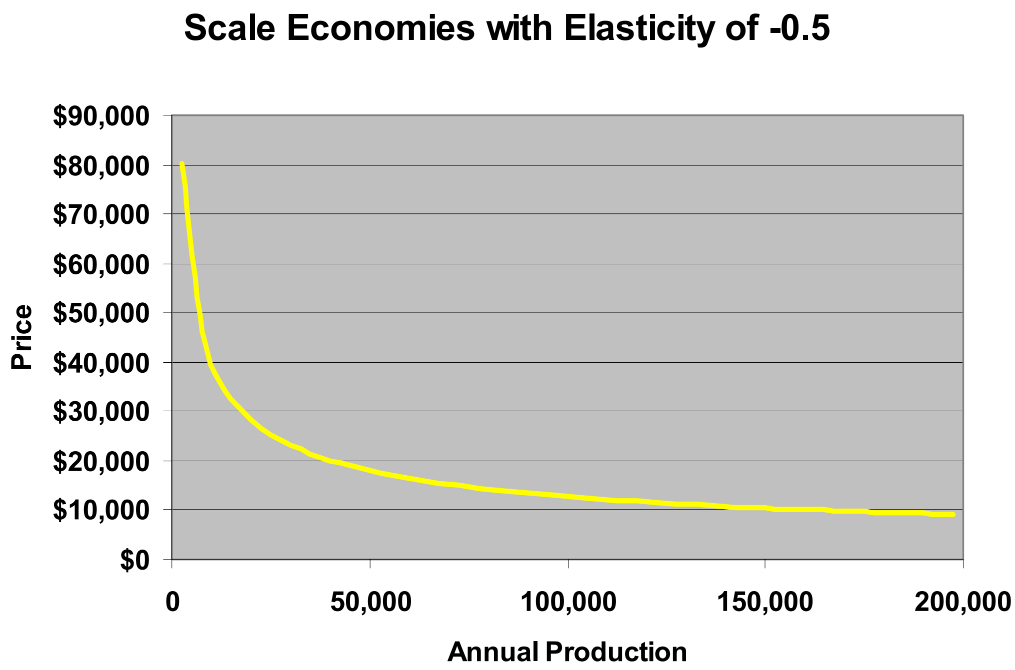
Demand density affects the competitive positions of production/delivery pathways.

(H2 delivered to vehicle excl. taxes)

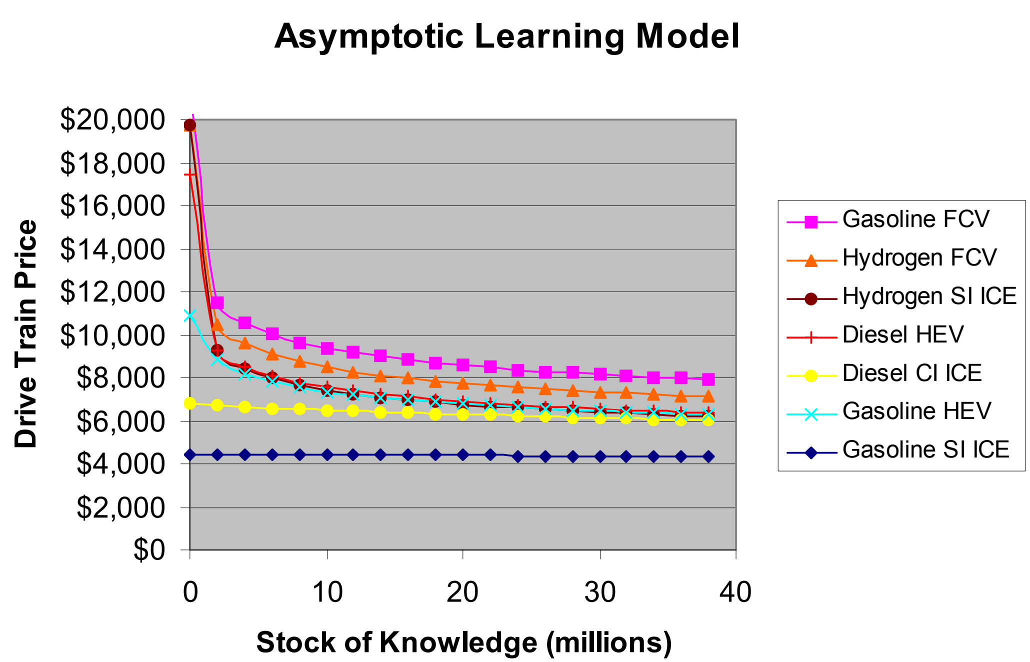


Vehicle technologies improve by 3 mechanisms.

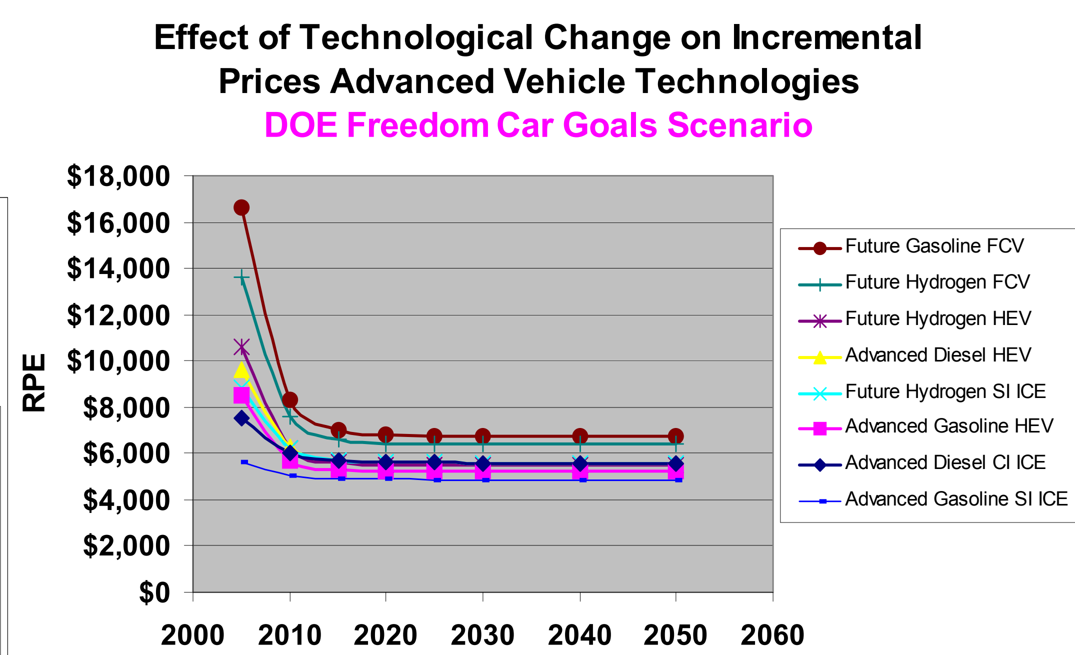
Retail Price =
Scale × Learning × Tech Change × Scenario Price



Scale w/ Annual Production/Plant



Learning & Unlearning w/ Stock on Road



Tech Change w/ Passage of Time (Yr)

UT-BATTELLE

We have completed a preliminary working version of HyTrans.

- Implemented and tested all major components in GAMS
- Translated H2A and NAS hydrogen production models into HyTrans equations
- Developed and implemented a temporary delivery model
- Developed, implemented and calibrated representations of technological change, learning-by-doing and scale economies.
- Produced preliminary, test transition scenario runs

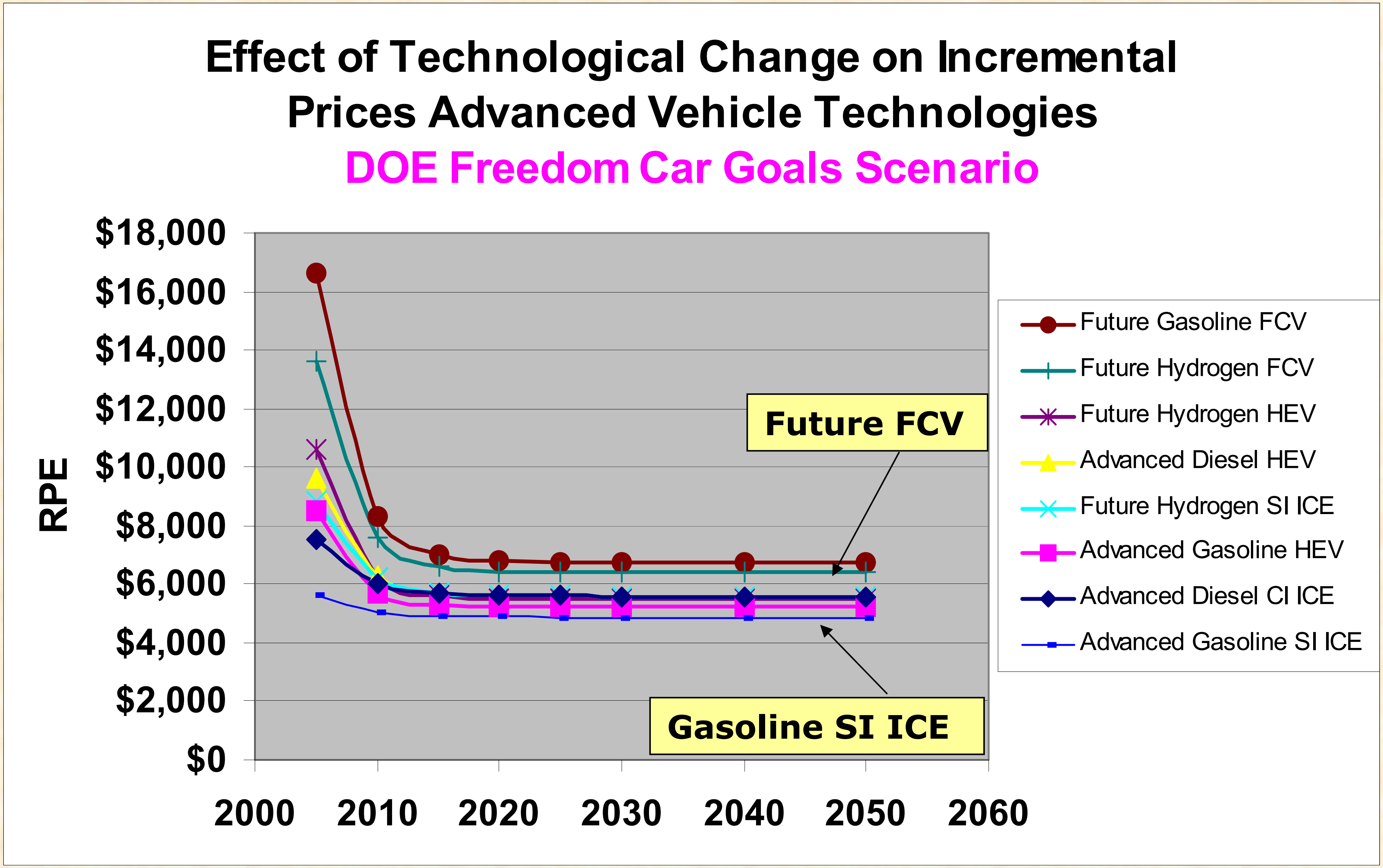
The results I will present today are preliminary not definitive and should not be interpreted as conclusions about the hydrogen transition.

- HyTrans is still under development and review.
- Scenarios to be presented today do not reflect HFCIT program goals via H2A models (will soon).
- NAS production technologies used; results presented below based on restricted sets of production options.
- Geographical regions, several major improvements are needed.
- Results illustrate feasibility of optimization methodology, kinds of analyses that will be possible.

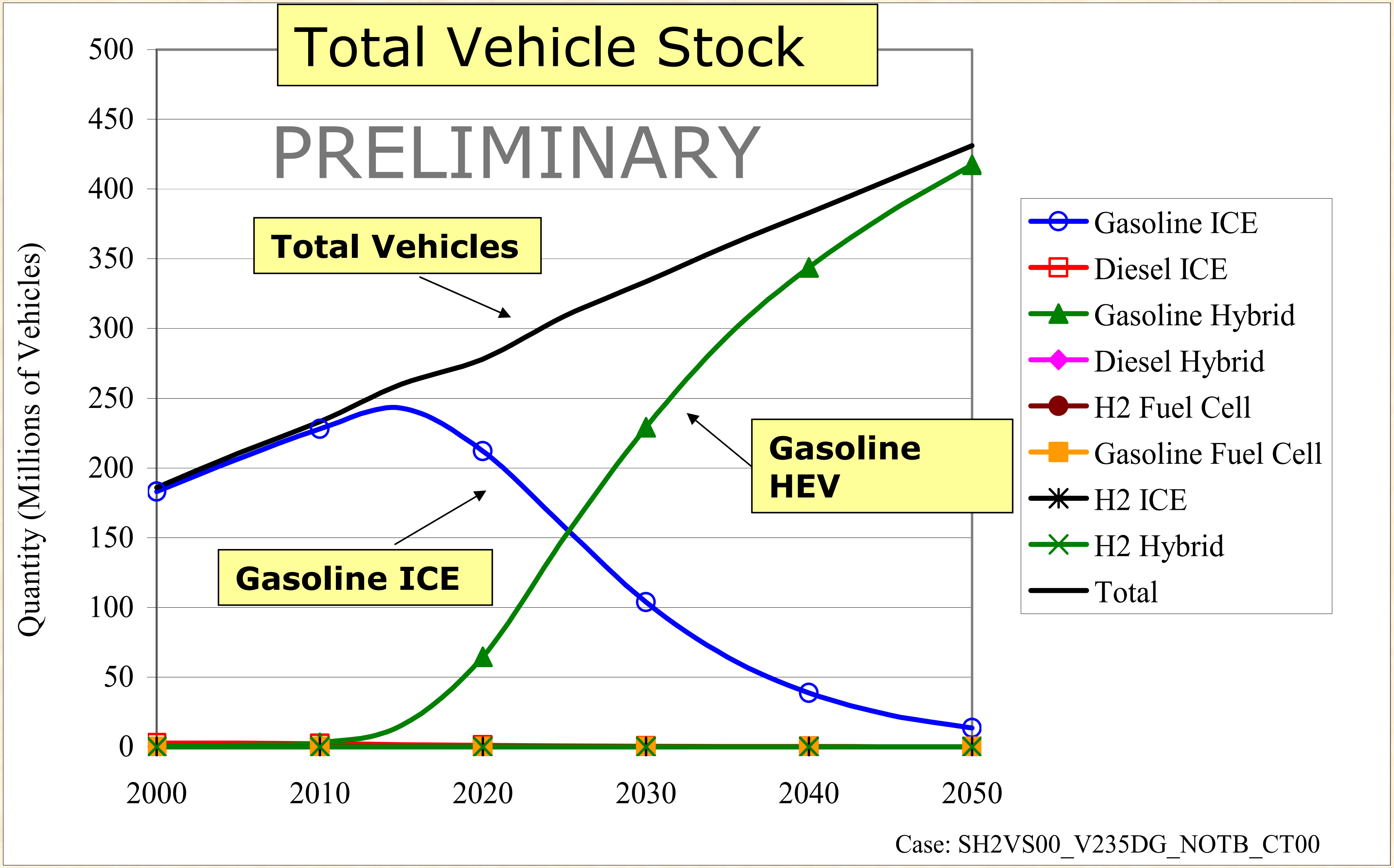
I will show some preliminary results from three scenarios.

- **Based on AEO 2004 Reference Case & extrapolated.**
- **Two policy drivers**
  - **Vehicle subsidies**
  - **Fuel subsidies**
- **1: DOE Freedom Car Goals Met**
- **2: Alternative Vehicle Technology Evolution**
- **3: Carbon Emissions Limitations**
- *ALL scenarios here rely on NAS (2004) H2 production cost estimates – H2A models will be incorporated in the near future.*

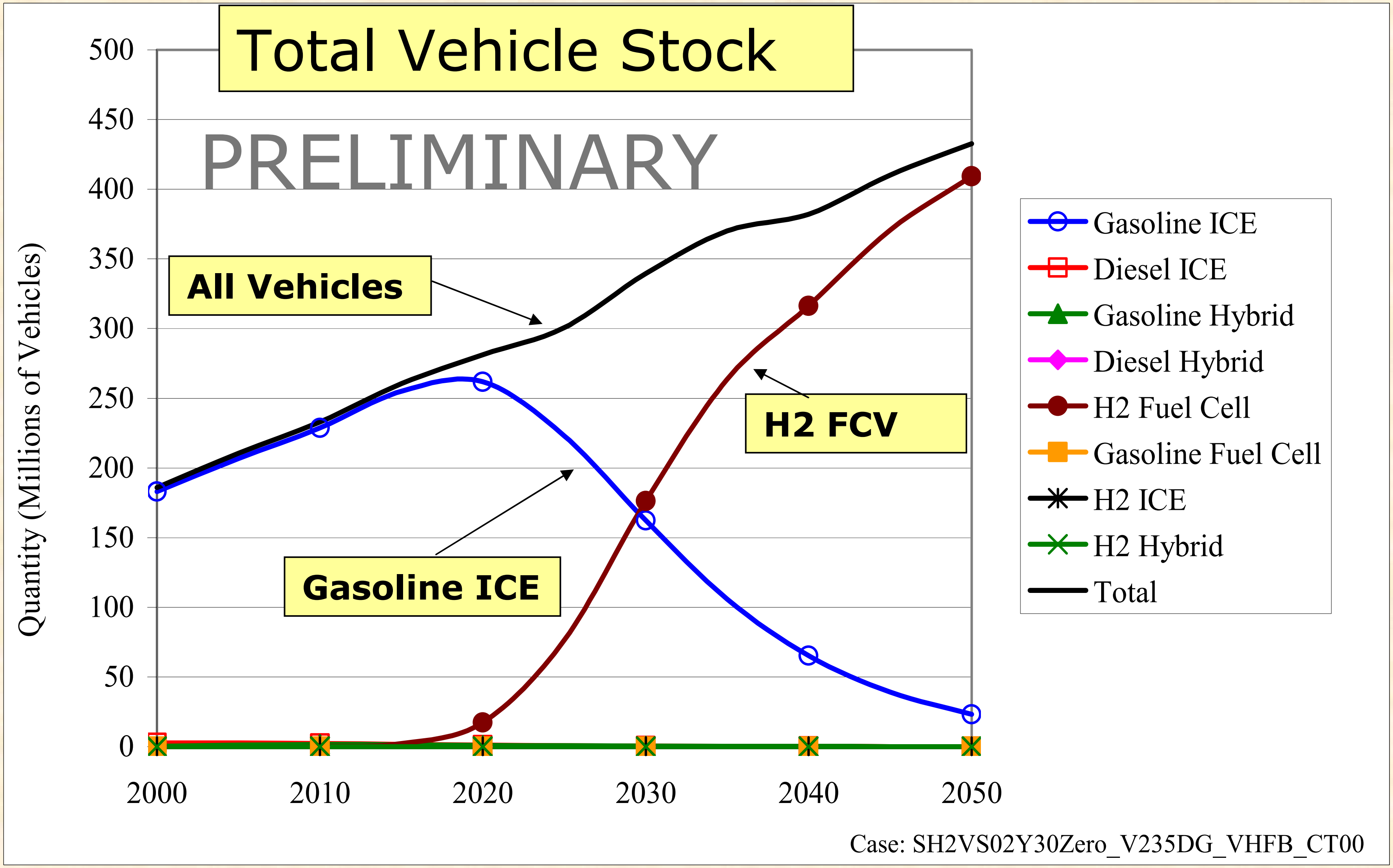
SCENARIO 1
The DOE Vehicle Technology Program Goals scenario anticipates rapid progress for all technologies.



Given no new policies, HyTrans sees a shift to gasoline hybrids in scenario 1.

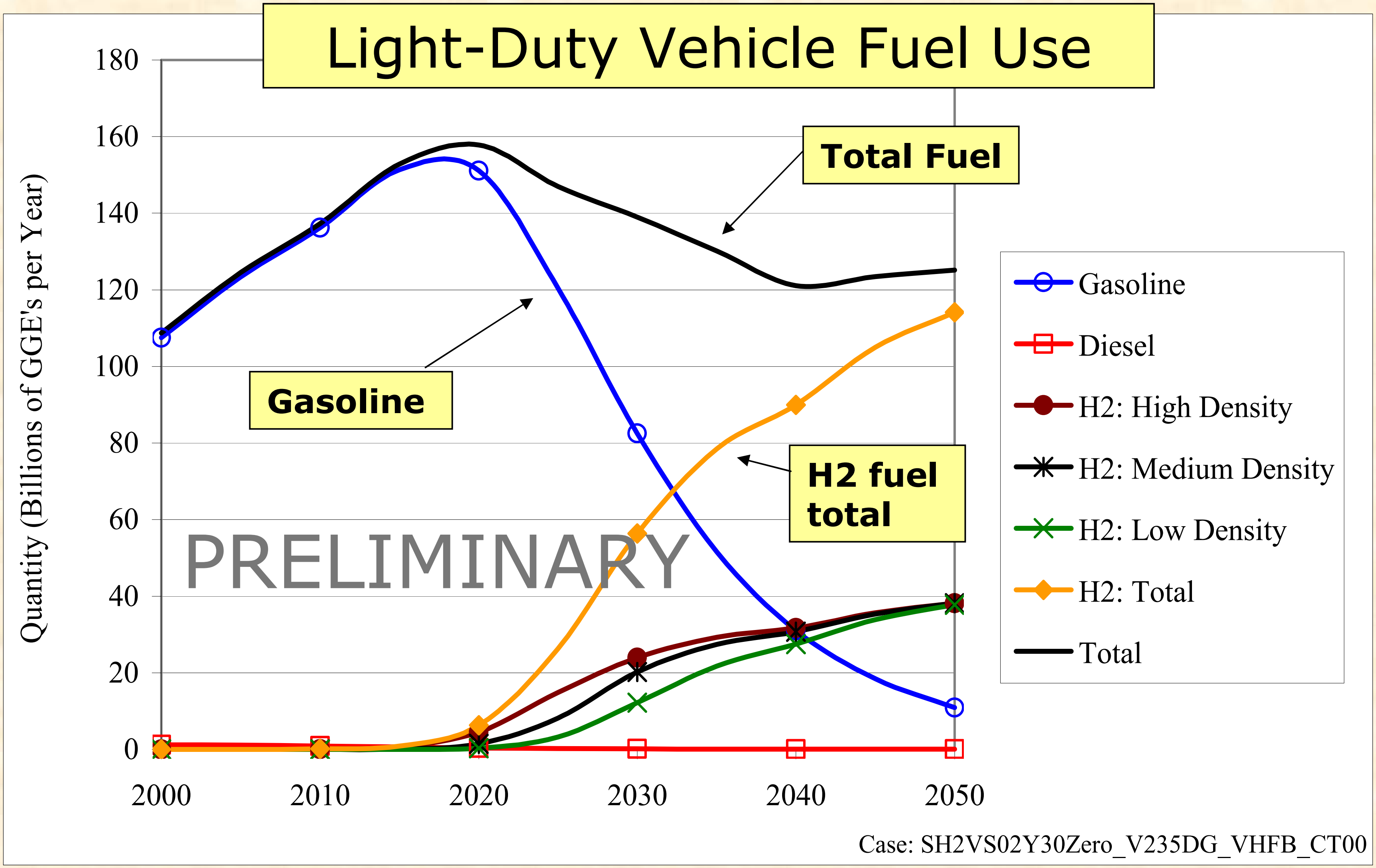


A temporary H2-vehicle subsidy of $2,000 until 2030, and $0 afterwards produces a sustainable transition to hydrogen-powered light-duty vehicles.



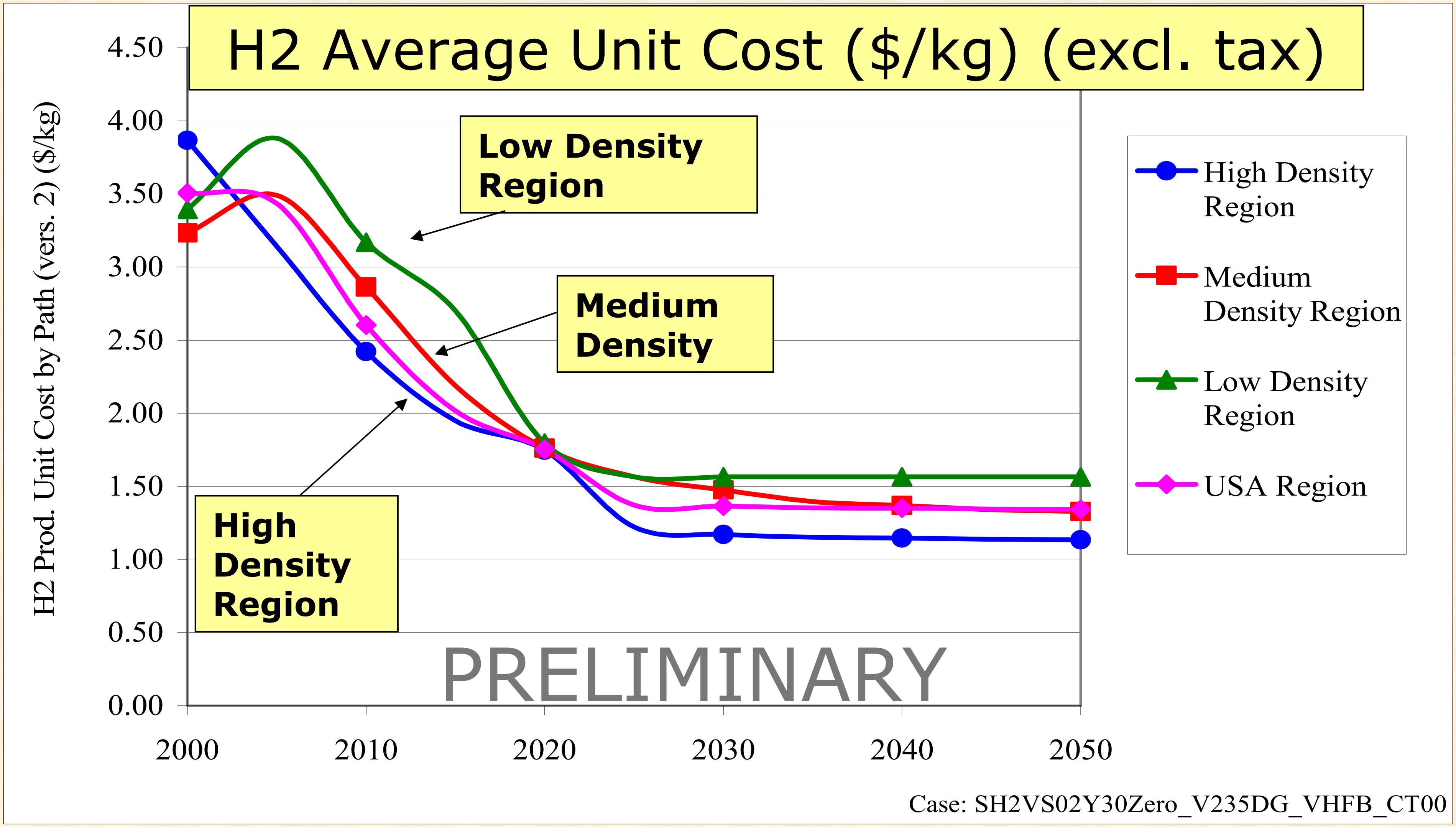
The transition to H_2 reduces vehicle fuel use in the face of steadily growing travel demand.

(Scenario 1: $2,000 H2 Vehicle Subsidy, $0 After 2030)



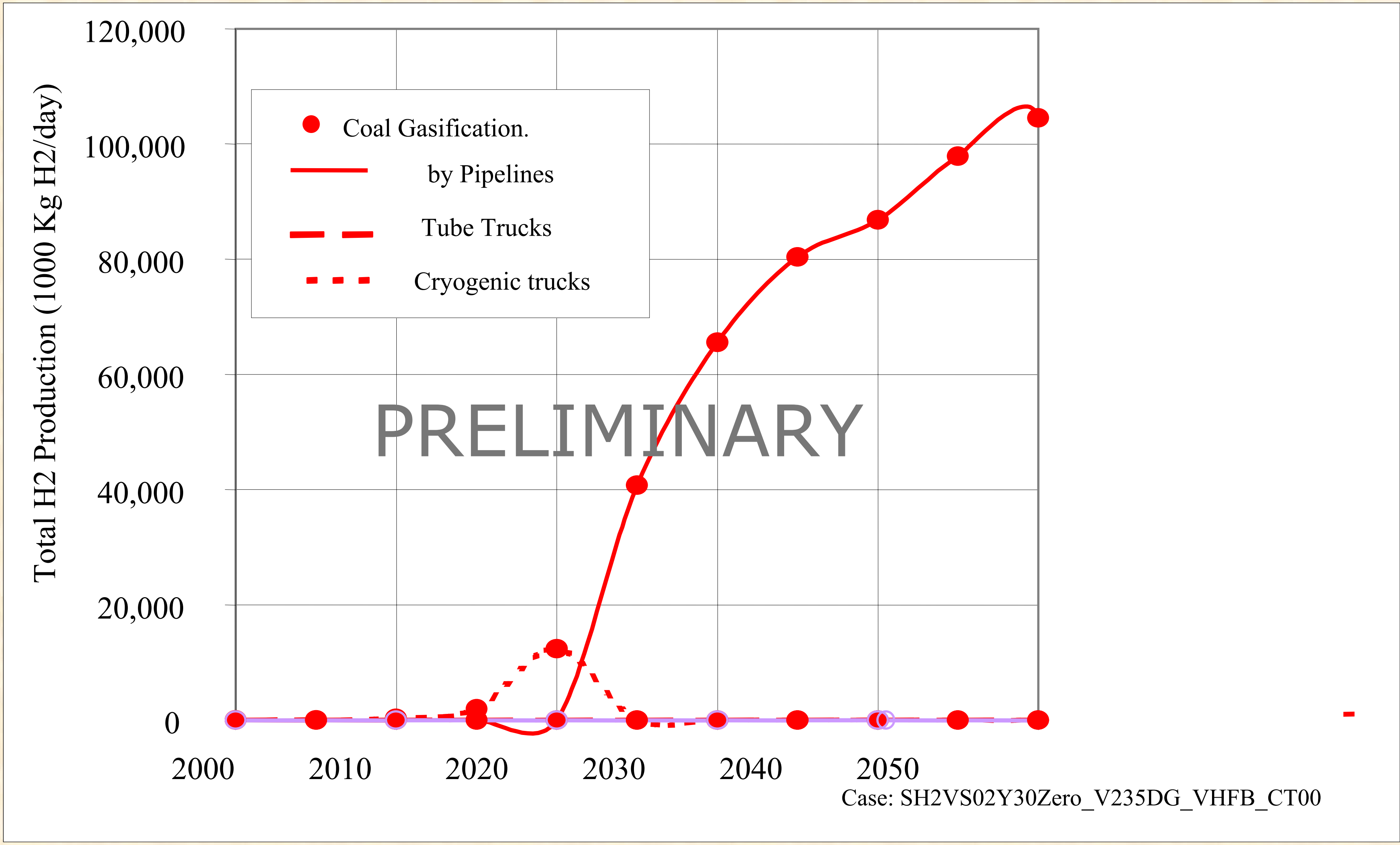
Delivered H_2 costs fall over time with technological progress, scale economies and market share.

(Scenario 1: $2,000/H2-Veh Subsidy, $0 After 2030)



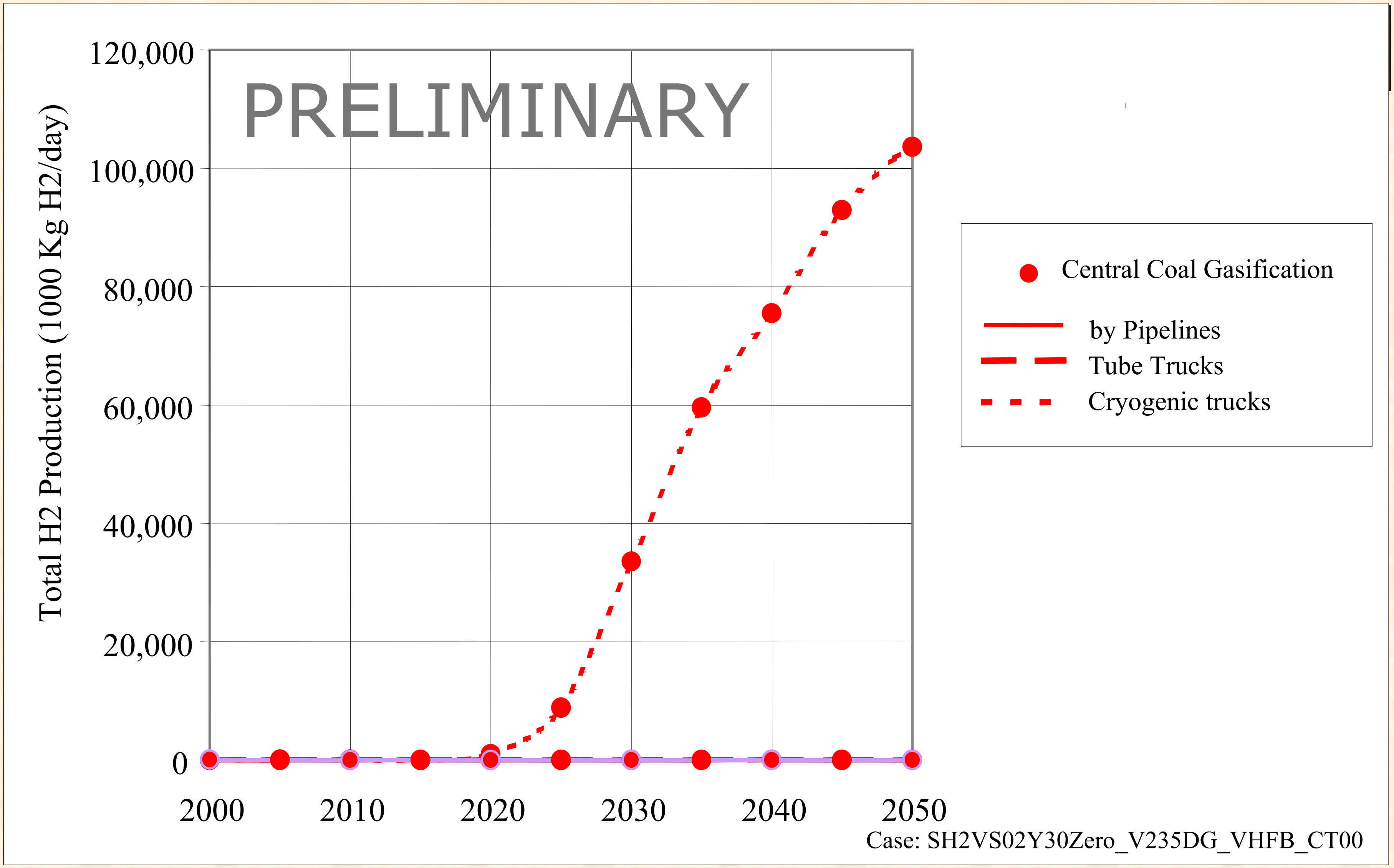
With centralized production, higher density regions start with truck and shift to pipeline as hydrogen's market share grows.

(Scenario 1: $2,000/H2-Veh Subsidy, $0 After 2030)

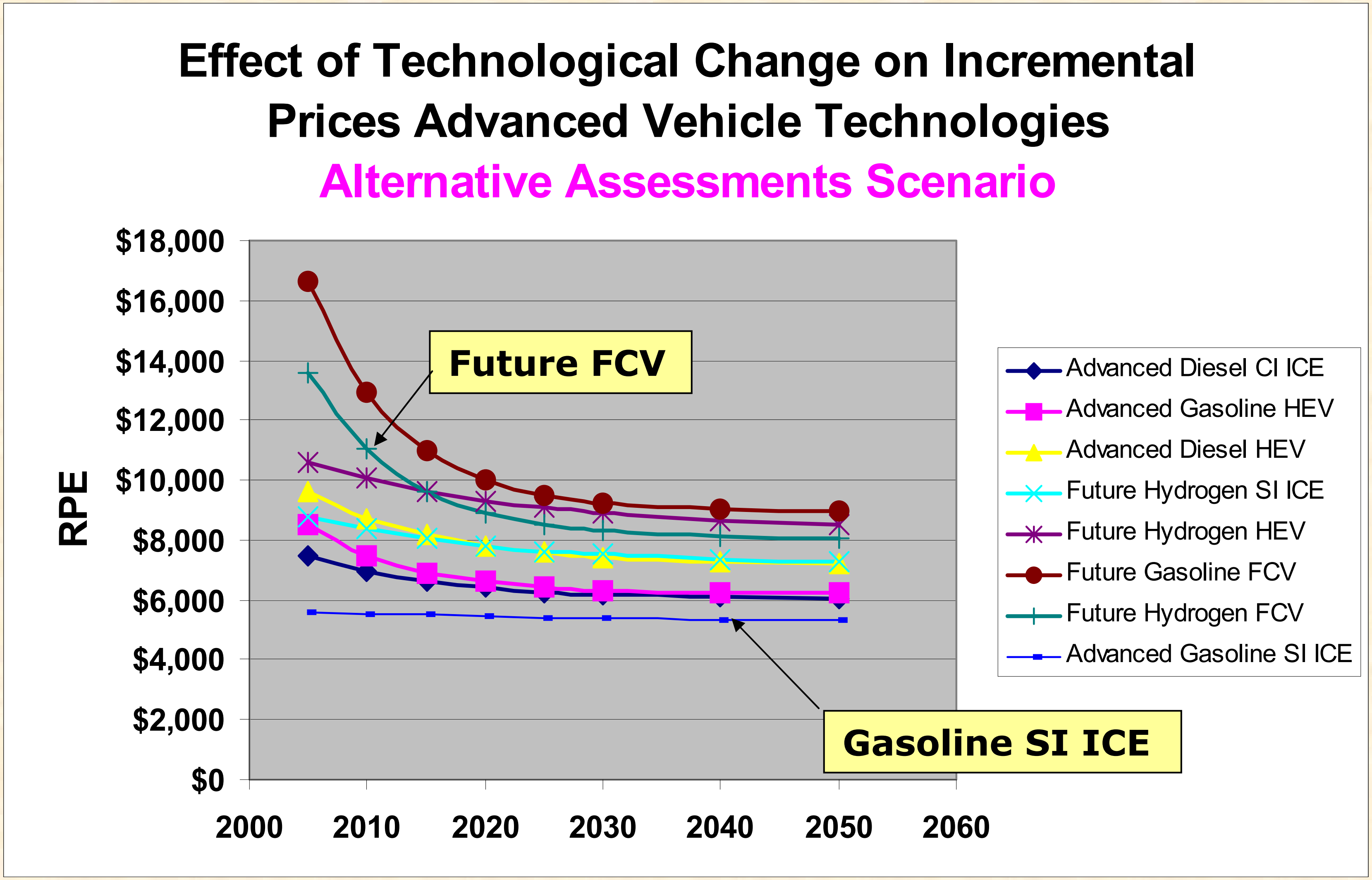


The low density (intercity) region relies on cryogenic-trucking throughout.

(Scenario 1: $2,000/H2-Veh Subsidy, $0 After 2030)

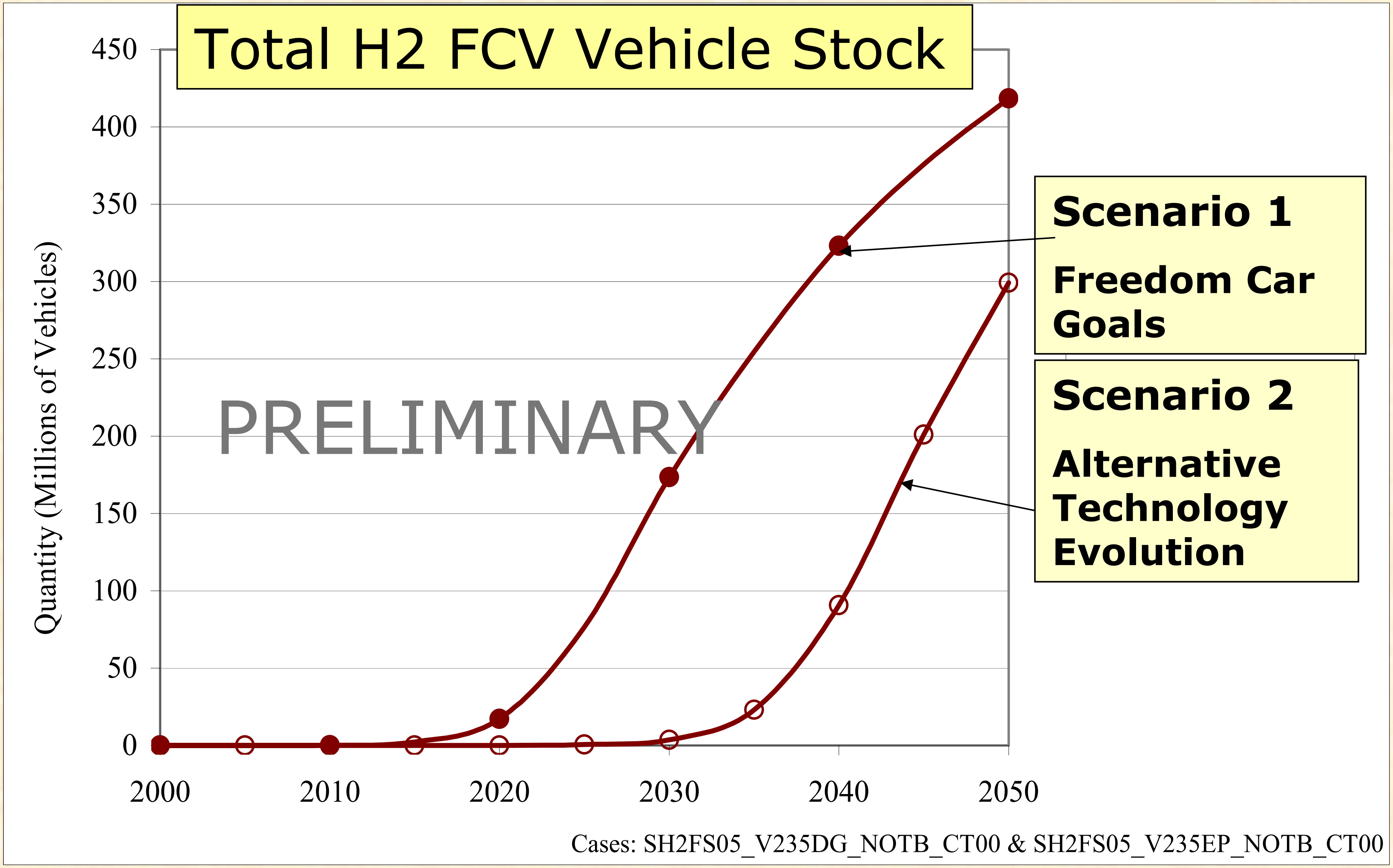


SCENARIO 2
We derived the Alternative Vehicle Technology Case from published studies. It is less favorable for some technologies, certainly for FCVs.



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

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

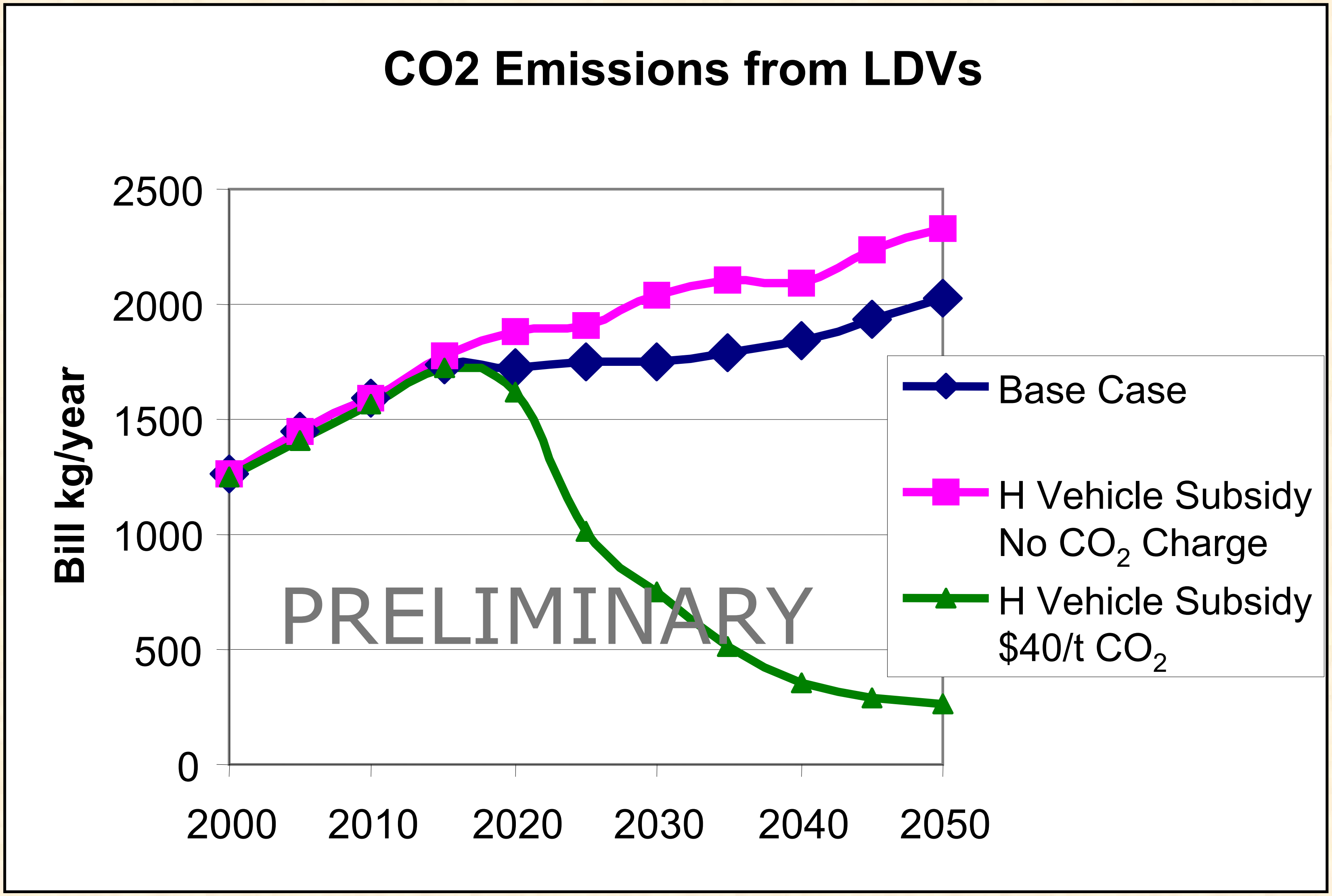


SCENARIO 3: Carbon emission Limits

How do the vehicle technology program goals change the ability to reduce CO_2 emissions from light-duty vehicles?

- GREET 1.6 Supplemented by other sources (GREET update in Spring)
- Represent carbon limits in the form of carbon taxes (cap and trade)
- Add vehicle subsidies, as well
- DOE Vehicle Technology Program Goals

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



HyTrans is making significant progress.

- Plausible answers to:
  - Is a stable transition achievable?
  - When?
  - How long will it take?
- Can begin to test key policies
- Will be able to produce potentially useful cost and benefit measures
- Close to useful visions of the transition
- Beginning to generate insights about R&D goals
  - Good enough?
  - Effects of competing technologies

Several important deficiencies remain to be addressed in FY 2005.

- **Size of the optimization problem, nonconvexities and resulting multiple equilibria are pushing the state of the art of nonlinear optimization software.**
  - Test alternative global solvers (e.g., BARON)
  - Continue development of hybrid scenario/optimization methods
- **Lack of geographic regions makes it difficult for renewable H sources to penetrate the market.**
  - Develop and implement representation of NEMS regions in collaboration with Singh and Wood.
- **Representation of fuel availability needs improvement**
  - Intercity (Melaina methodology)
  - Variable station sizes

Future Work

- Remaining FY 2005
  - Report on sensitivity analysis: 6/30/2005
  - HyTrans documentation: 9/30/2005
  - Report on Plausible Hydrogen Transition Scenarios, Policies, Costs and Benefits: 9/30/2005
- FY 2006
  - Linkages to Macro Model
  - Representation of regional differences affecting choice of production technology

THANK YOU.

Presentations and papers

”Modeling the Demand for Hydrogen by Light-Duty Vehicles: HyTrans Methodolgy”, UC Davis Workshop on Hydrogen Demand Modeling, Institute for Transportation Studies, UC Davis, Davis, CA, June 21, 2004.

“HyTrans: a dynamic equilibrium model of market transitions to hydrogen”, presentation to the National Research Council Committee on Hydrogen, Washington DC, January 24, 2005

“Analyzing Transitions to Hydrogen Powered Vehicles with HyTrans, National Hydrogen Association Conference, Washington, DC, March 30, 2005.

“Modeling the Transition to Hydrogen: Early Experience with the HyTrans Model”, 13Th Annual EIA Midterm Energy Outlook and Modeling Conference, Washington, DC, April 12, 2005.

Draft Reports

` “HyTrans Hydrogen Transition Model: Building Version 1,” Draft report, Center for Transportation Analysis, Oak Ridge National Laboratory, Oak Ridge, Tennessee, March.

“Incorporating H2A Production, Delivery and Forecourt Models into HyTrans”, draft report, National Center for Transportation Research, Oak Ridge National Laboratory, Oak Ridge, Tennessee, December 20, 2005.

“Initial Hydrogen Transition Scenarios Developed Using the HyTrans Model”, Progress Report, National Transportation Research Center, Oak Ridge National Laboratory, Oak Ridge, TN, March 29, 2005.