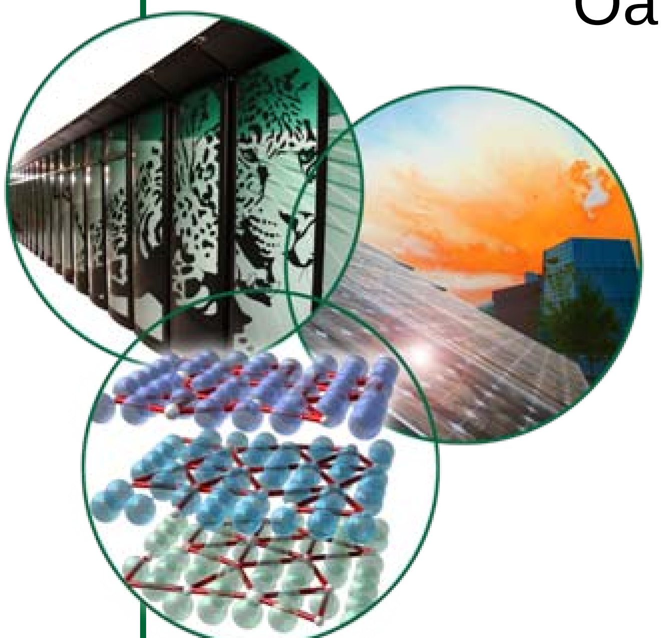
Hydrogen Policy and Analyzing the Transition

Paul N. Leiby, David L. Greene, Zhenhong Lin, David Bowman, Sujit Das

Oak Ridge National Laboratory

November 16, 2009



Presented at the Workshop, “Delivering Renewable Hydrogen,”

NREL/CaFCP,

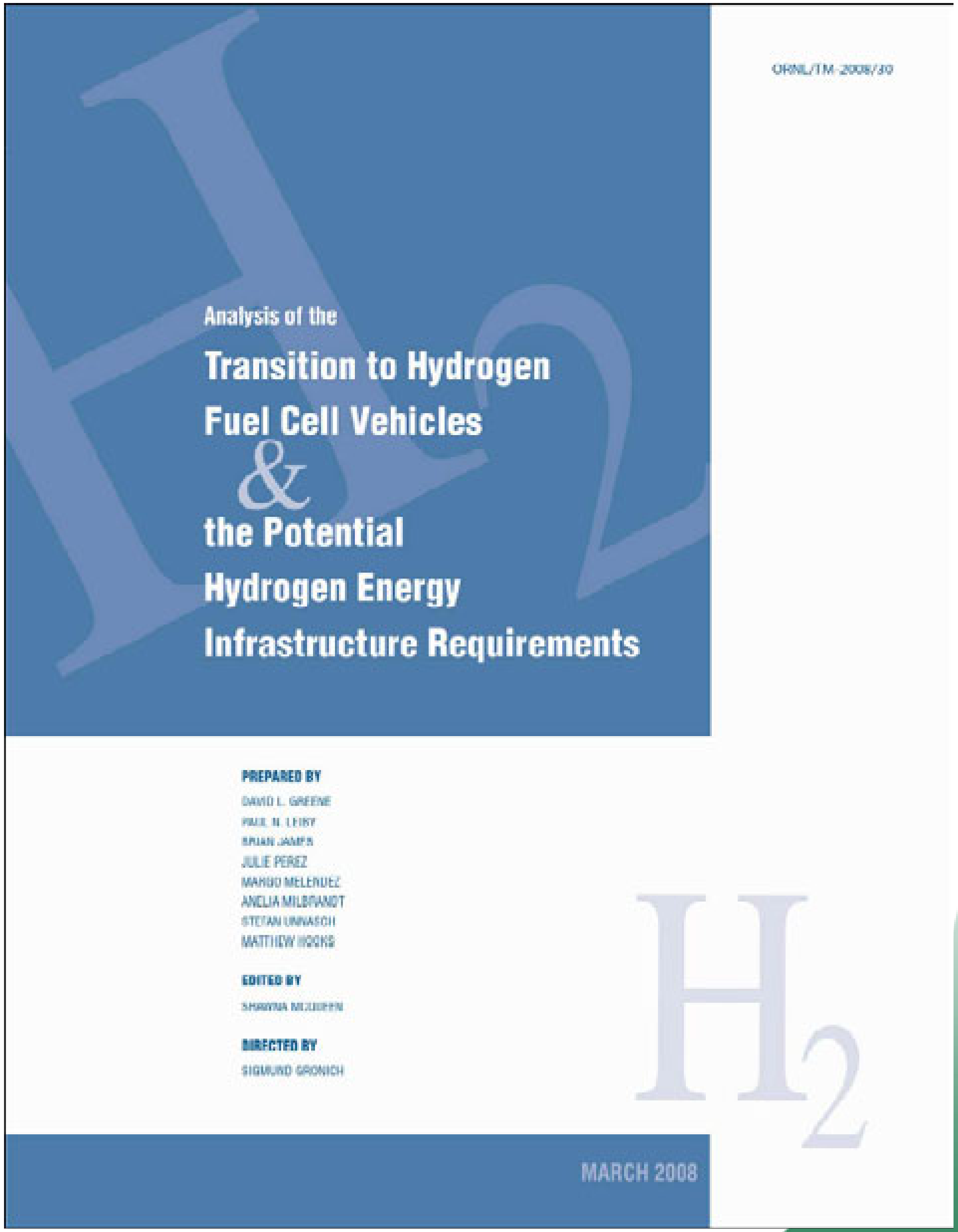
Palm Springs, CA

Overview: Hydrogen Policy and Analyzing the Transition

- **Some lessons learned from analyzing fuel transitions**
  - Find barriers to transitions significant, but progress being made
  - Review work by DOE-sponsored team, highlighting key factors
    - Note some similar findings by NRC
- **Find valuable role for policy**
  - in advancing R&D
  - In promoting & shaping infrastructure development and tech choice
- **Policy can help, indeed is necessary**
  - Effectively drive down economy-wide costs of new tech development, achieve scale, and widespread fuel and vehicle availability more quickly
  - Need vehicle and station support to avoid "valley of death" firms face in early years
- **Discuss results for lower carbon/renewable hydrogen**
  - Policy can prevent early H2 technology and infrastructure choices from concentrating only on lowest cost, sometimes less beneficial pathways

Describe report, published 2008, documenting first integrated national hydrogen transition analysis.

Responded to the NAS' call to better understand what a transition to H2 powered vehicles would require



cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2008_30.pdf

Stakeholder workshops led to Lighthouse strategy. Three Early Vehicle Scenarios intended to span a range that would encompass an efficient transition.

Scenario 1:

100s per year by 2012,

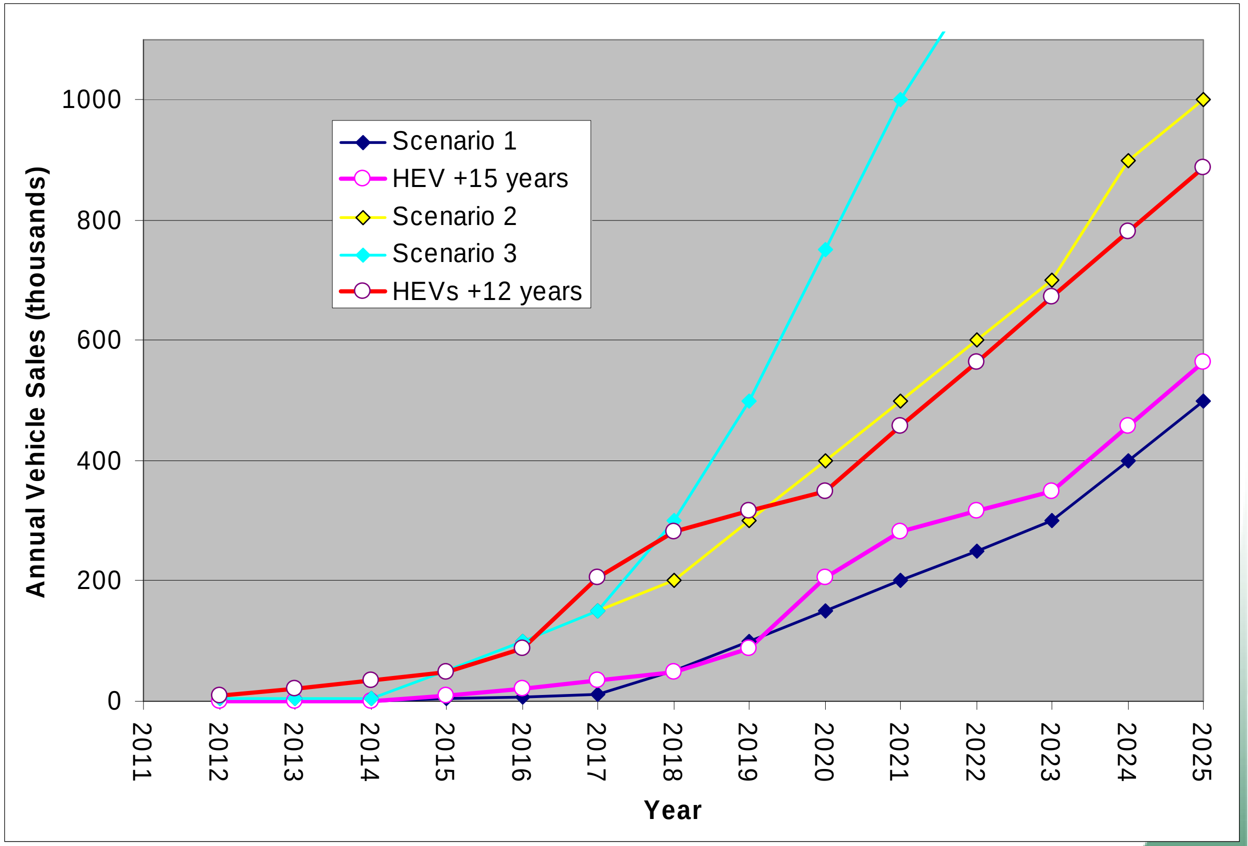
tens of thousands of vehicles per year by 2018. On-road fleet of 2.0 million FCVs by 2025.

Scenario 2:

1,000s of FCVs by 2012, *tens of thousands* by 2015 and *hundreds of thousands* by 2018. On-road fleet of 5.0 million FCVs by 2025.

Scenario 3 (NRC scenario):

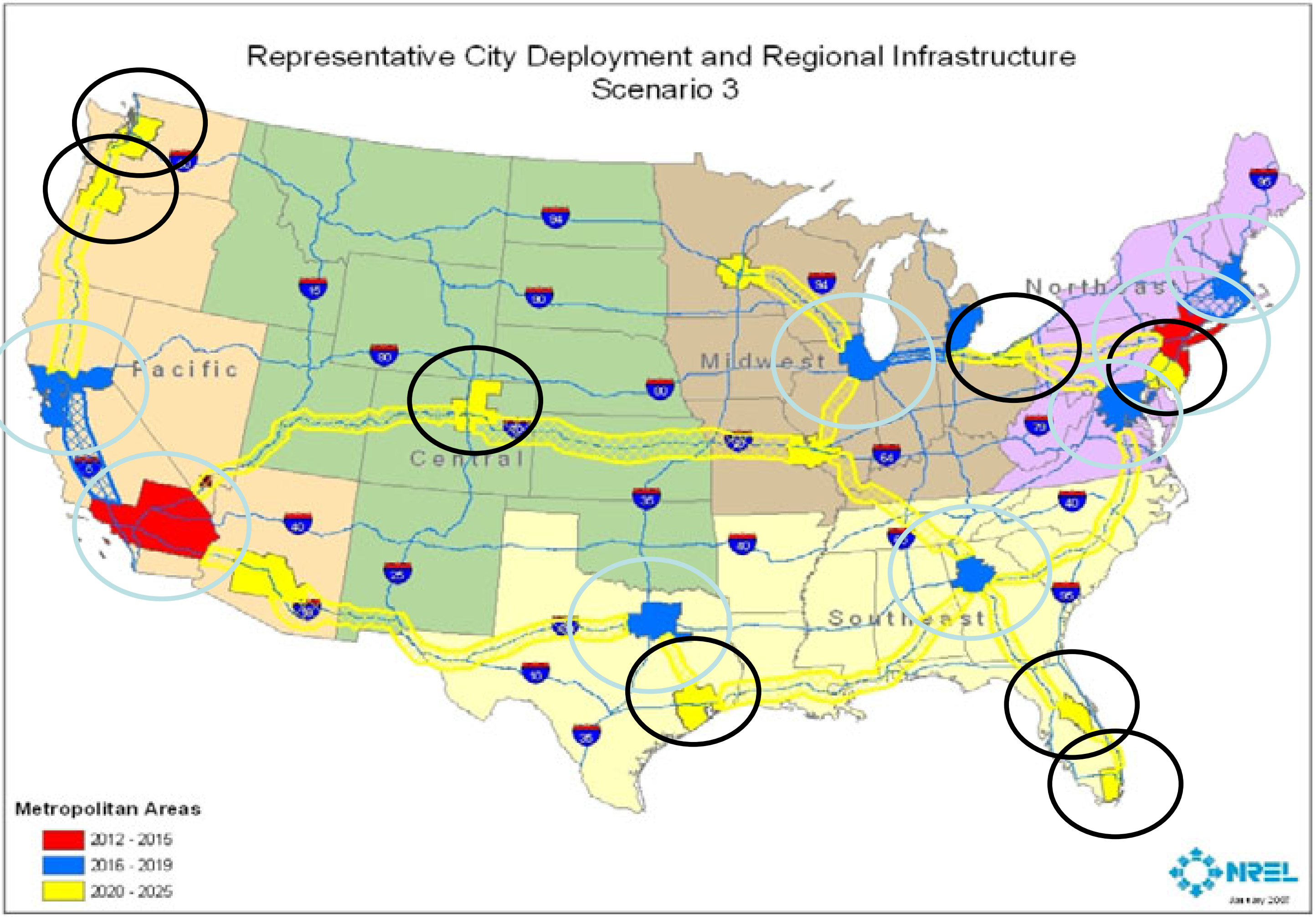
1,000s of FCVs by 2012, and *millions* by 2021, 10 million on the road by 2025.



Scenarios 1 and 2 are consistent with current and projected HEV penetration rates

These scenarios *do not represent a policy recommendation*.

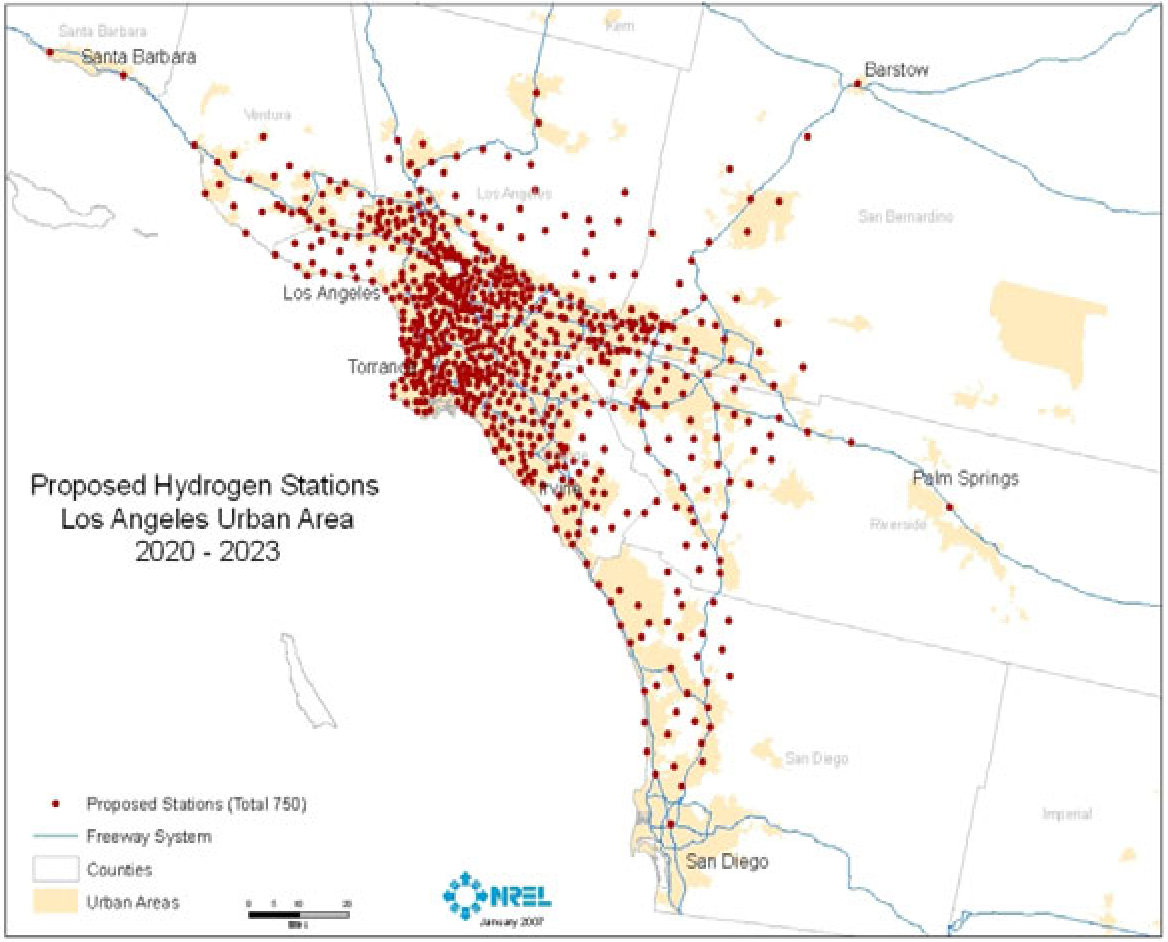
The *Lighthouse* concept of infrastructure build-out reflects a trade-off between the need to concentrate infrastructure and the need to maximize hydrogen availability.



NREL Analyzed Optimal Strategies for Refueling Network Evolution

- **Phase 1(2012-2015): Stations located generally on major arteries**
- **Phase 2 (2016-2019): Additional stations provided beyond city centers to provide greater driving range**
- **Phase 3 (2020-2025): High station deployment located outside city limits**

2020-2025: Regional Expansion LA



Accessibility	Population
3 Miles	83%
5 Miles	89%
10 Miles	95%

Scenarios: Premises matter.

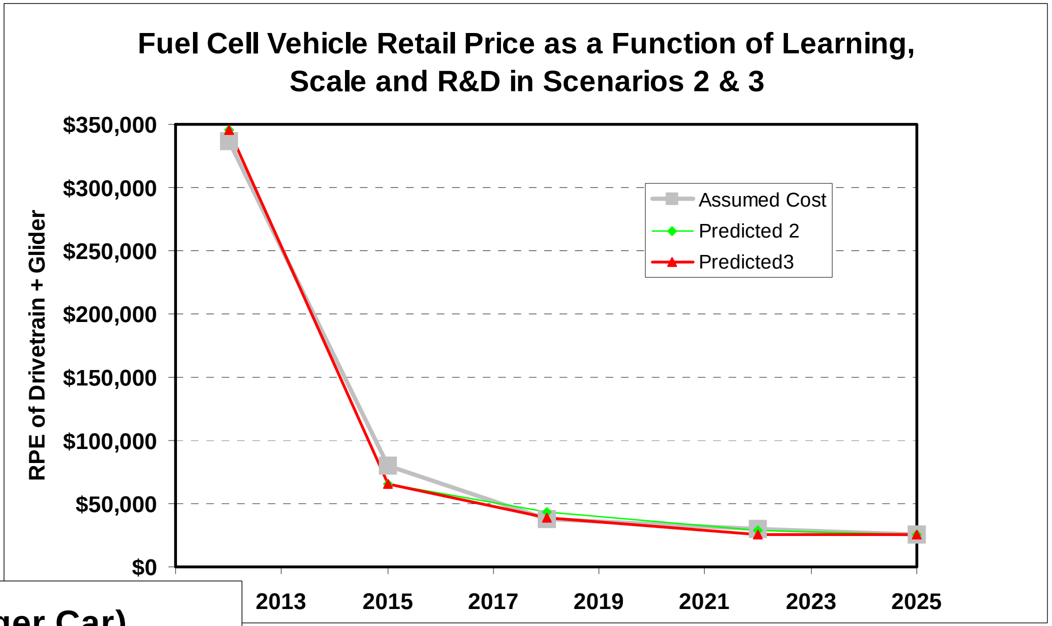
- All DOE FreedomCar program goals met on schedule.
  - Vehicle cost and performance estimates based on PSAT/ASCM analysis (Rousseau et al., 2000).
  - Estimates in “DOE Goals” scenario based on meeting program goals in 2010 and 2015, with 5-year lag to the first production vehicles.
- H2A production and delivery models used for H_2 supply costs.
- CO_2 price impact was investigated in sensitivity cases
- 2006 AEO oil price scenarios
  - High Oil Price Case used as base case…$72/bbl in 2015
  - Also Reference Case….$43/bbl in 2015
- HyTrans constrained to follow scenarios to 2025, then simulate for endogenous market solution.

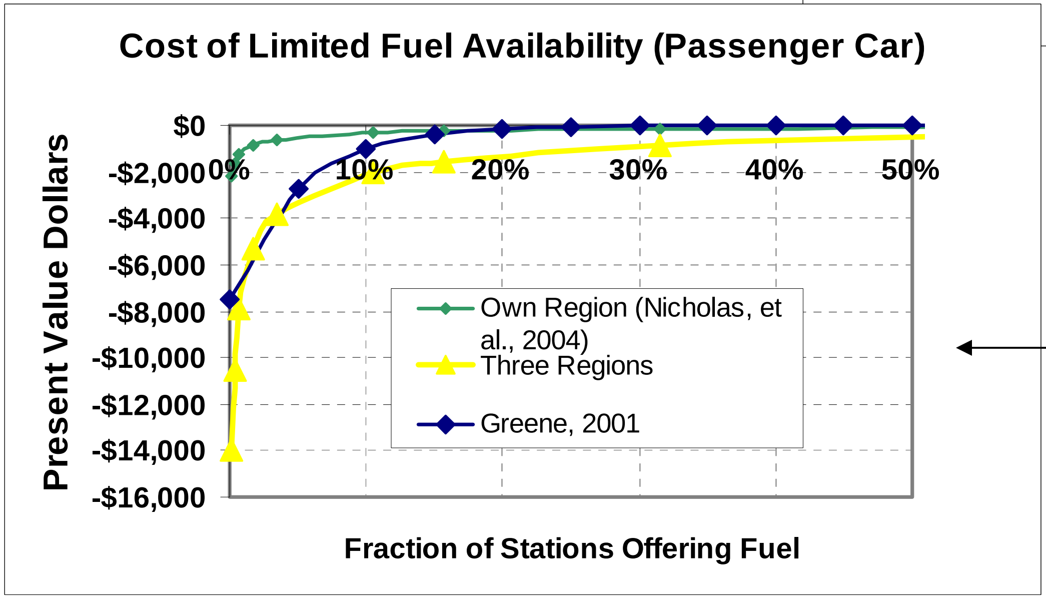
Finding: Excess “transition costs” are incurred in overcoming the natural market barriers to a new transportation fuel.

- **Fuel infrastructure (density/distance/cost)**
- **Limited fuel availability**
- **Limited make and model availability**
- **Scale (dis)economies**
- **Learning-by-doing**
- **All are represented in HyTrans**

Early production experience and infrastructure development can drive down costs significantly

Importance of Learning through experience and building Scale: FCV costs decline dramatically

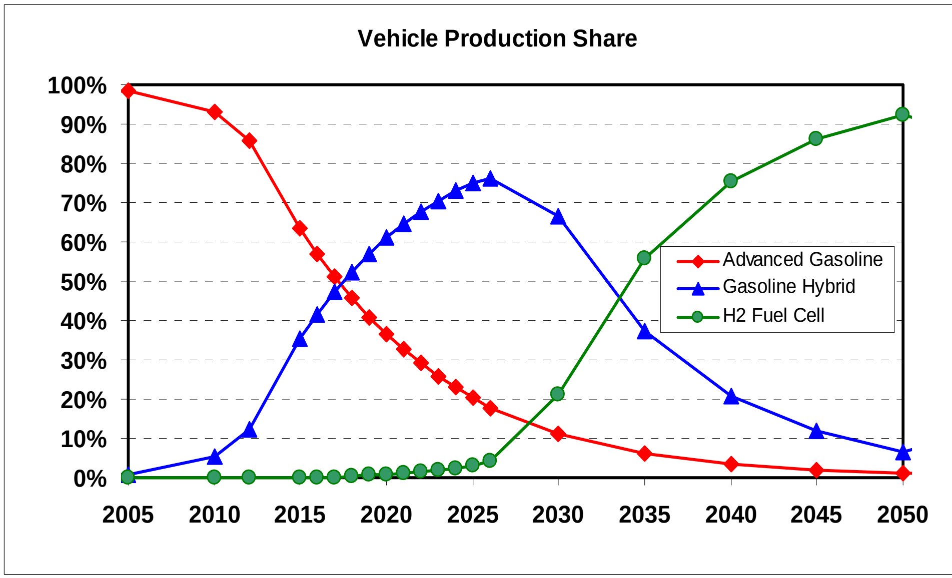




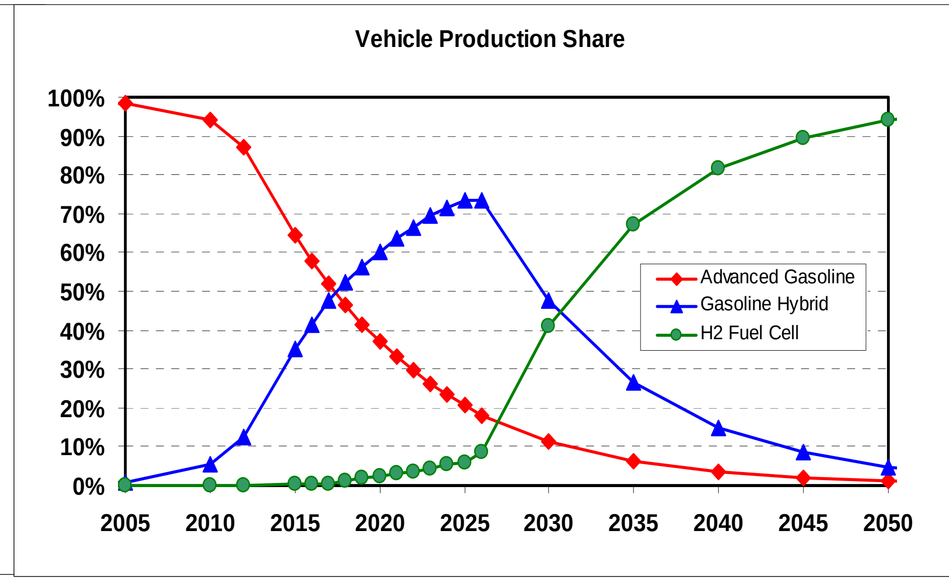
Limited retail fuel availability imposes costs on consumers, alters their choices

All three scenarios produced a sustainable transition to hydrogen powered light-duty vehicles without any additional policy measures after 2025.

Scenario 1

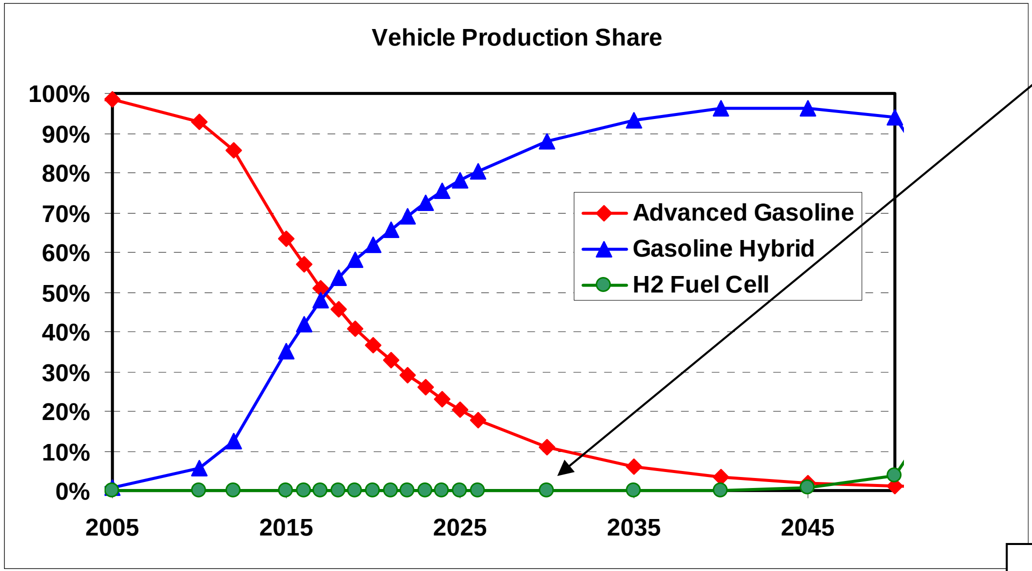


Scenario 3



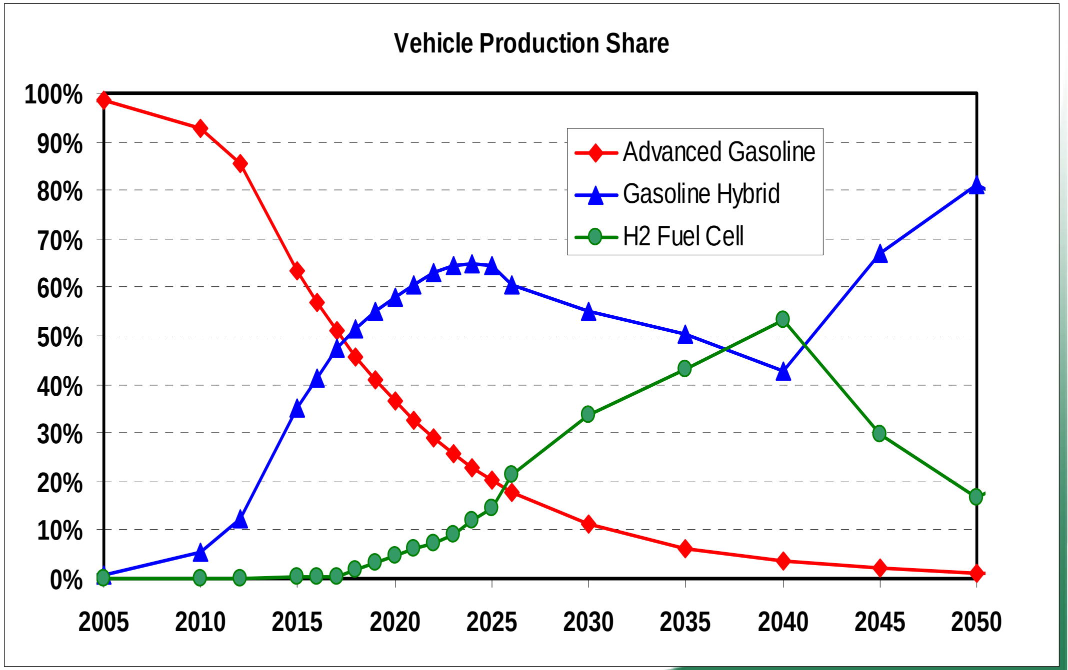
- **Policies will almost certainly be required for early transition period (2012-2025).**
- **Assumes Hi Oil case and the Hydrogen and FreedomCar Programs achieve full success.**
- **Does not consider impact of uncertainty on willingness to invest.**

No Policy Scenario



With no early transition scenario, FCVs do not begin to penetrate the market until after 2045 (still assumes high tech progress, all FC targets met).

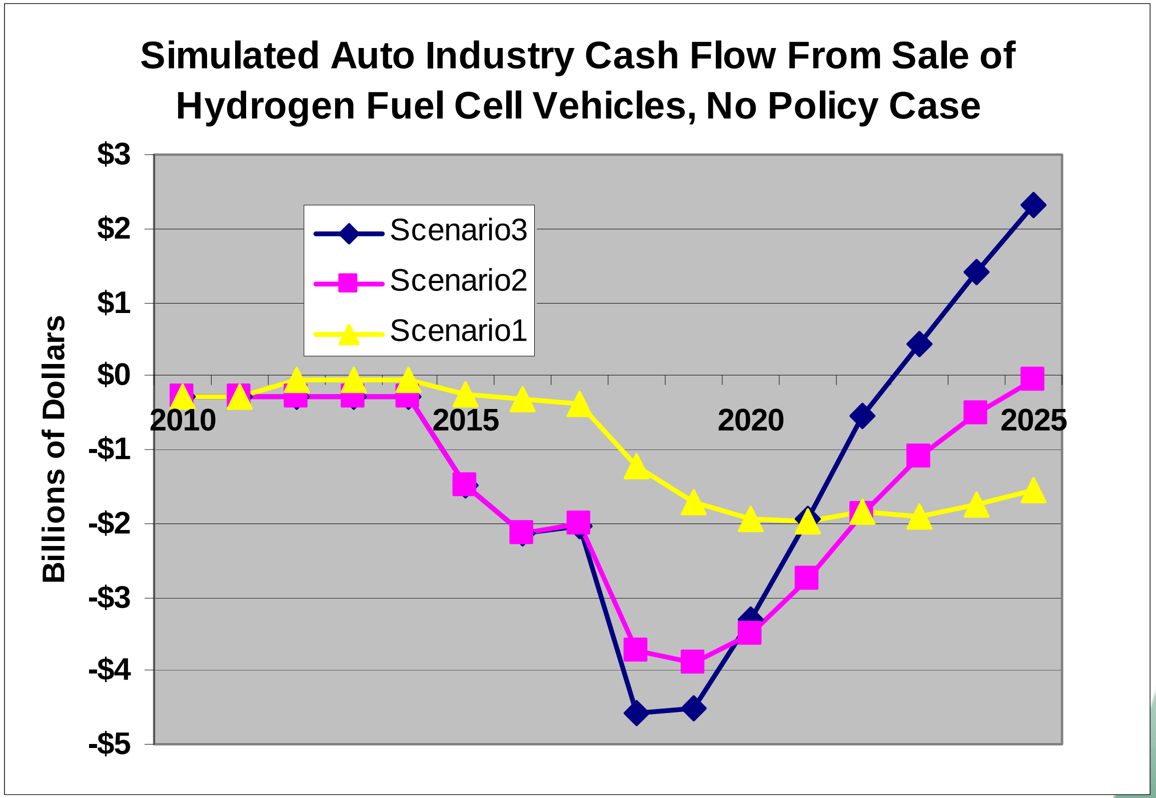
$60/kW Fuel Cell Cost



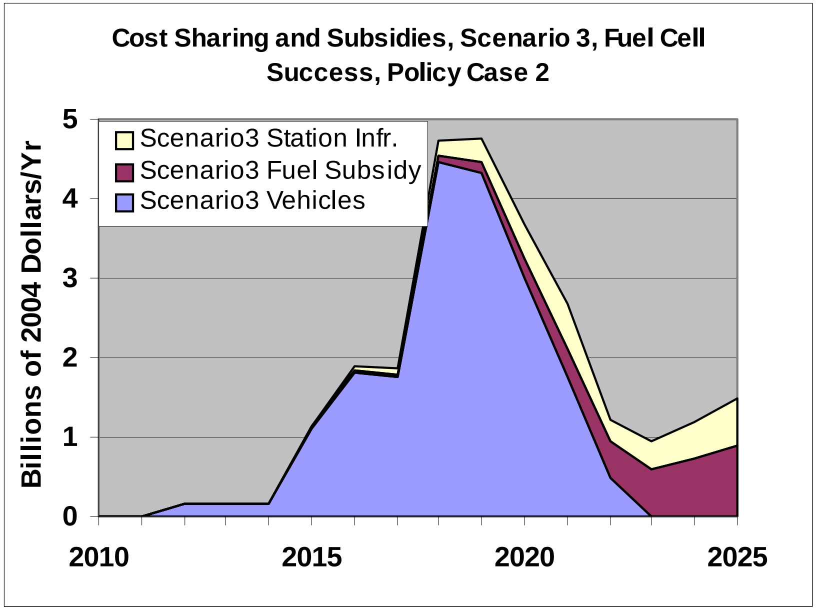
If fuel cell and storage technologies fall short of program goals, reaching a sustained market becomes more uncertain.

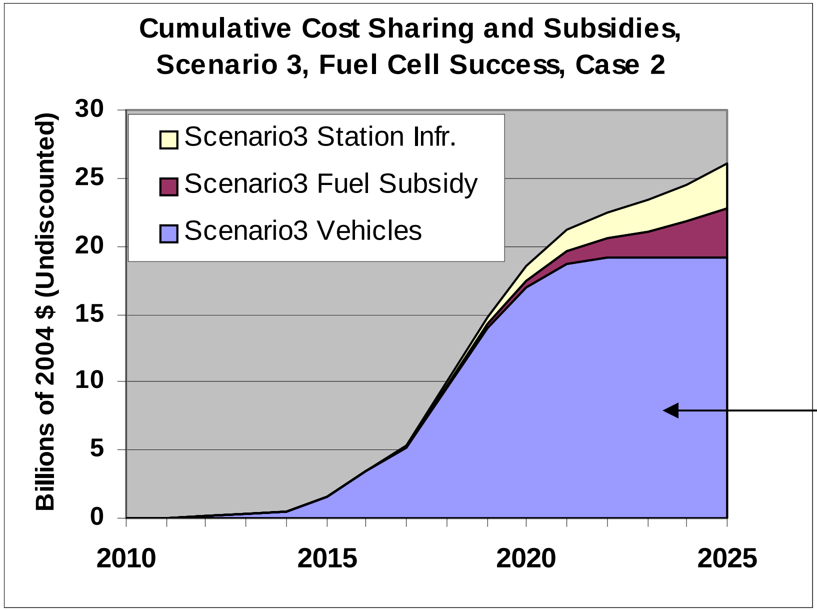
The need for transition policies is indicated by the excess costs of the transition scenarios.

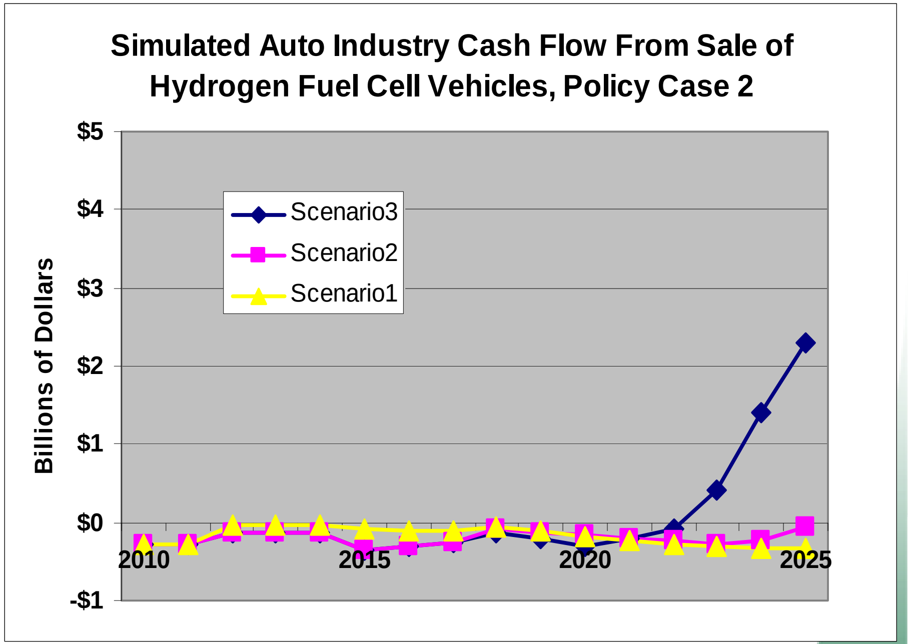
- Without government policies, the entire transition burden would have to be borne by industry.
- Automotive and energy industries faced with years of billion dollar+ losses without government policy.
- Investment unlikely until outer years (2045+)



In Policy Case 2, scenario 3 annual costs peak near $5B. Cumulative government costs rise to $26B by 2025.

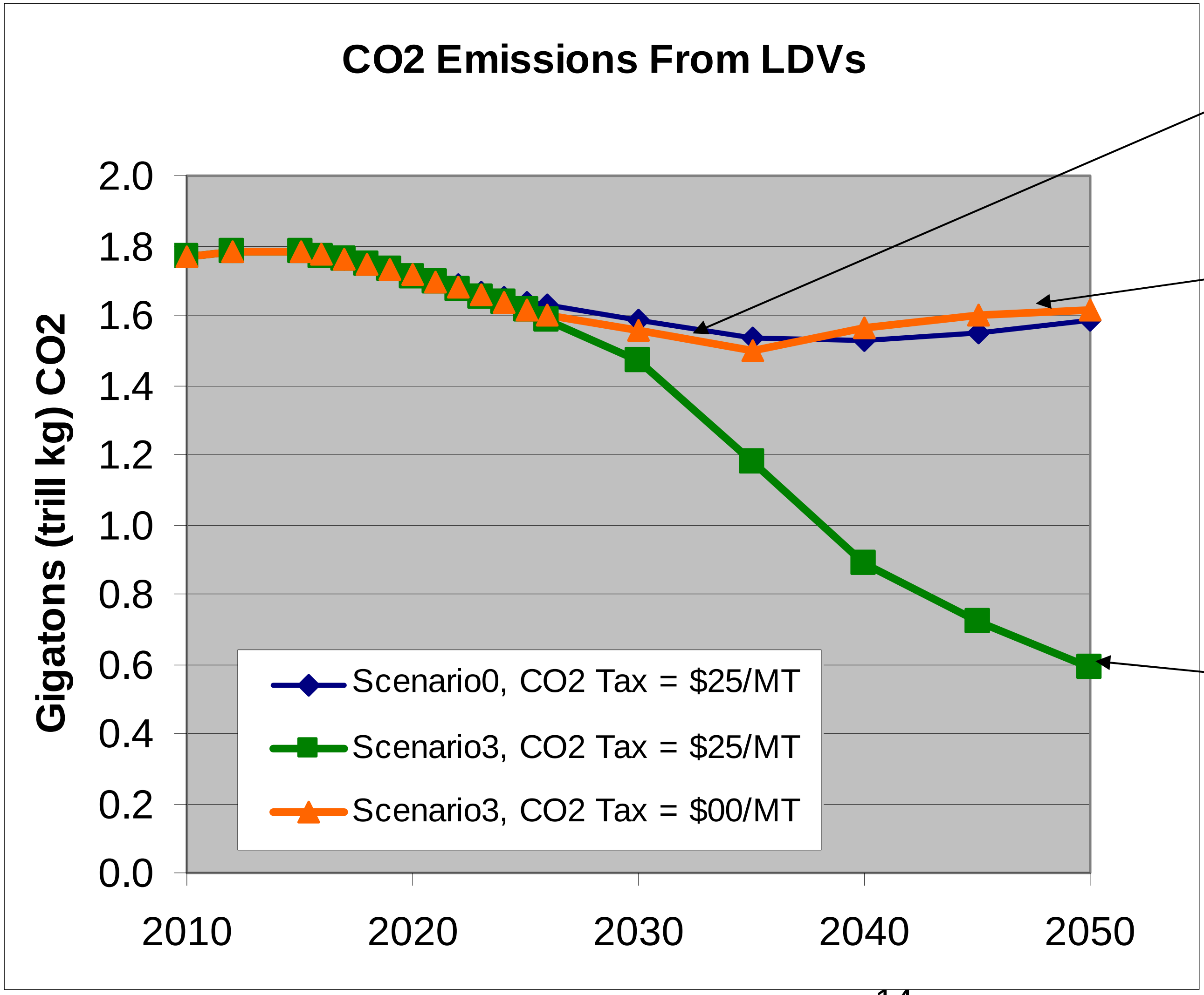






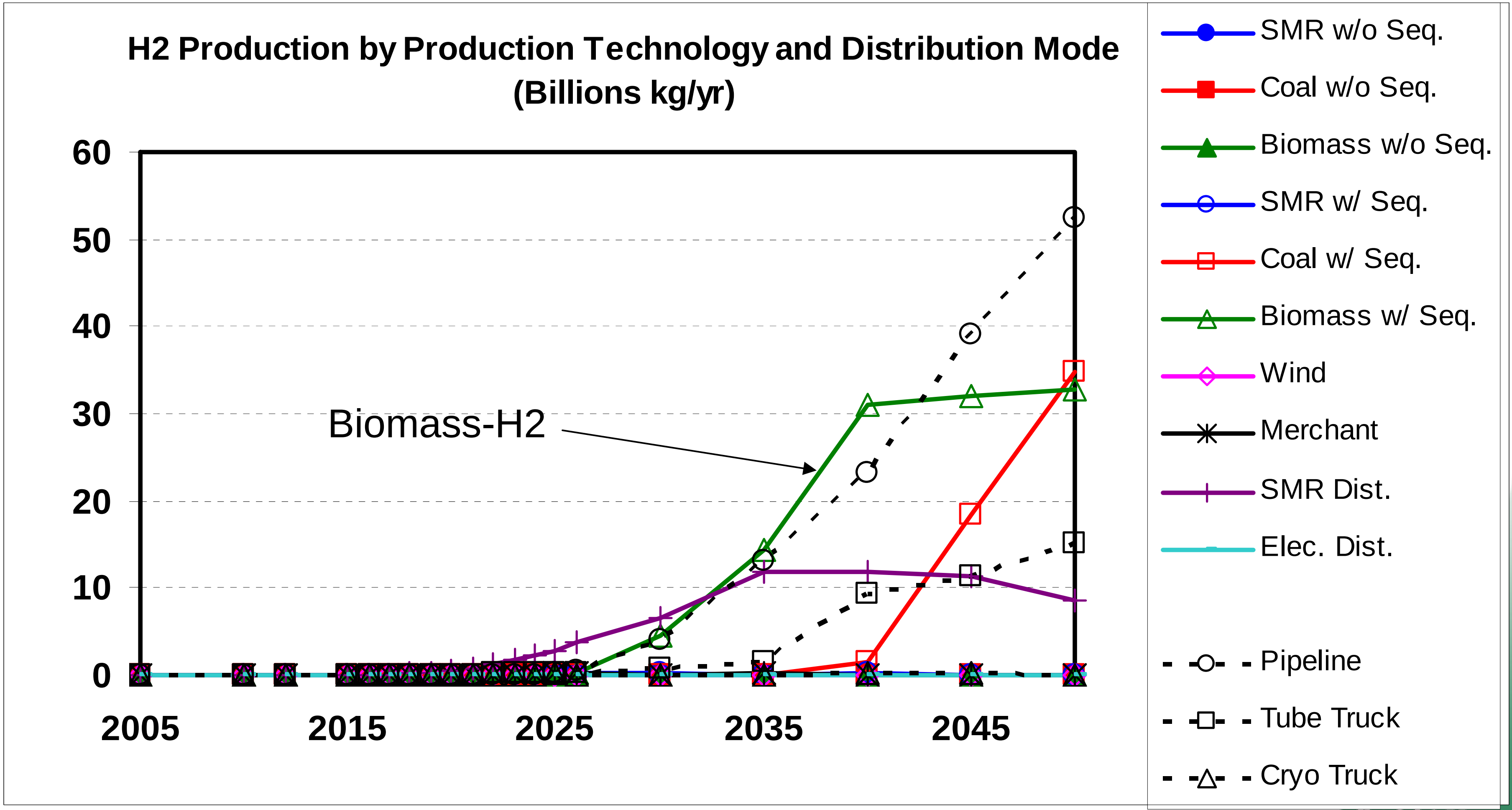
Note that vehicles costs are a much larger part of barrier than fuel/infrastructucture costs

Meaningful carbon mitigation policy is necessary to achieve dramatic reductions in GHG emissions.



- Scenario 0 $25/MT -> no transition policies with a carbon tax.
- Scenario 3 $00/MT -> no carbon policy, hydrogen may be produced from carbon-intensive sources such as coal without sequestration.
- In Scenario 3 transition policy + $25/MT (phased in) -> 2/3 C reduction by 2050.

Carbon-constraining policy has strong effect on evolution of H2 production sources.



Integrated analysis provided useful insights.

- **Meeting federal program goals important to achieving a sustainable transition to hydrogen vehicles.**
  - Missing individual tech goals does not appear to be a show stopper.
  - Success of competing technologies creates strong competition.
- **The transition analysis provides a plausible vision of the transition.**
  - “Chicken-or-egg” barriers represented in integrated market model.
  - Involvement of stakeholders + detailed assessments enhance credibility.
- **Costs of early transition policies appear to be feasible: $10B to $50B over 14 yrs.**
  - **NRC 2008 similarly estimated ~$55 bill**
- **High oil prices are helpful, may not be essential.**
- **Meaningful GHG mitigation policies enable nearly carbon-free hydrogen powered vehicles.**

Lessons for CA Development of Low-C/Renewable Hydrogen

- **Analysis and policy experiments highlight CA as key "lighthouse"**
  - Technology and infrastructure development provides "external" benefits to all firms/consumers, & outside CA
  - Value of CA as national incubator.
- **Leveraging role demonstrated by the impact of early programs**
  - For FCVs
  - For PEM FCs in non-highway applications
  - For production cost reductions in distributed and central pathways
- **Issue of how hard to push emerging technologies**
  - SB 1505 acknowledged this to some extent, with exemptions and threshold deferrals if needed to "accelerate deployment" of FCVs
- **Countervailing consideration:**
  - Clean fuel incentives helpful to avoid major market investments H2 technology pathways with much less CO2 reduction benefit

THANK YOU.

leibypn@ornl.gov
dlgreene@ornl.gov

We are very grateful for the research support of the

U.S. Department of Energy Fuel Cell Technologies Program

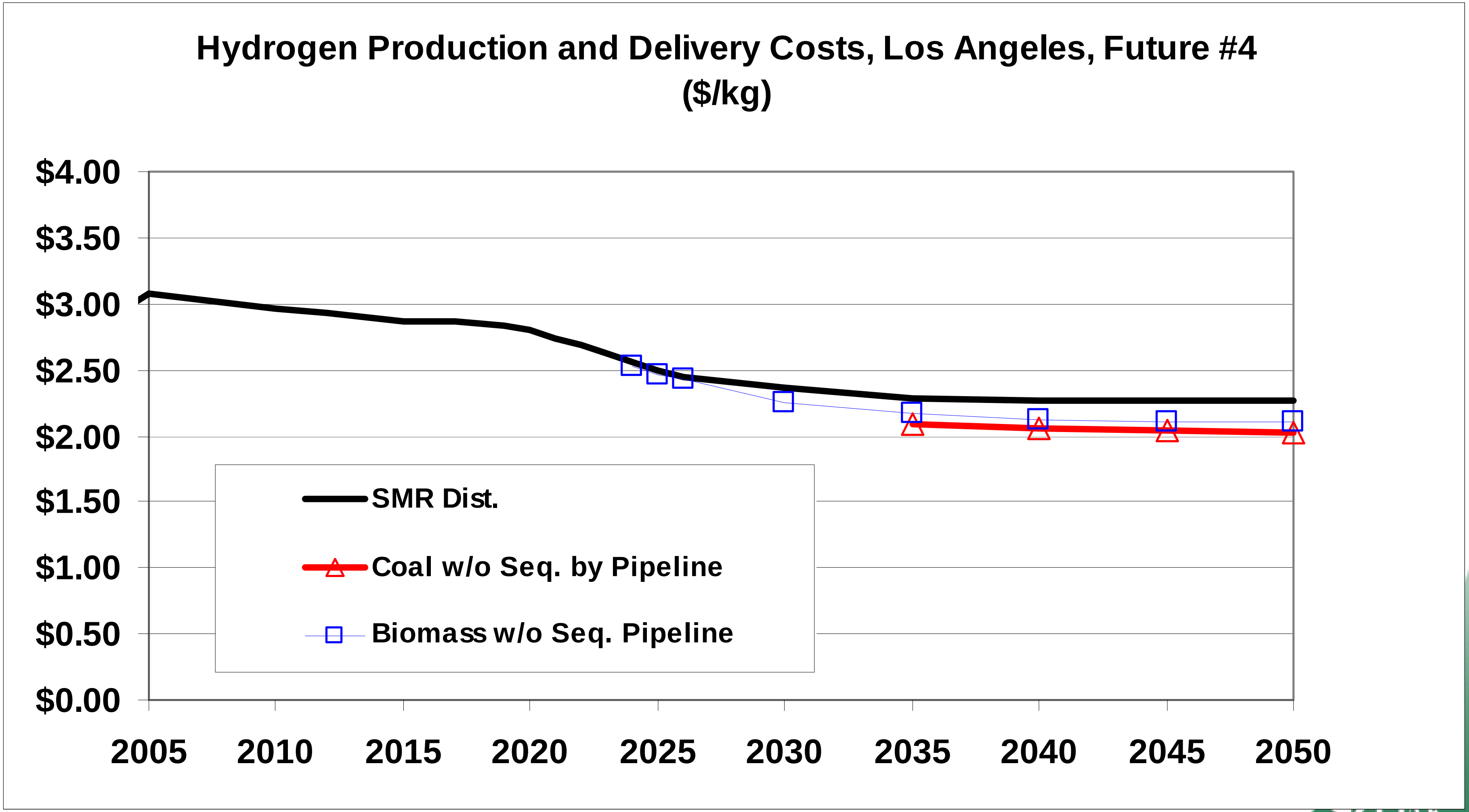
The views presented here are the authors and not necessarily those of DOE.

Backup

The Hydrogen Scenarios Team

- Sigmund Gronich
- Shawna McQueen
- David Greene
- Paul Leiby
- Brian James
- Julie Perez
- Margo Melendez
- Amelia Milbrandt
- Stefan Unnasch
- Matthew Hooks

Economies of scale were the chief factor in reducing hydrogen supply costs.



Policy Case 2 provides a reasonable assessment of the costs the government might shoulder to induce a transition to hydrogen.

- **Assumes "Fuel Cell Success"**
- **FCV vehicle production costs (vs advanced HEV) shared**
  - 50% total vehicle cost through and including 2017
  - Tax credit covers 100% of incremental cost 2018 to 2025
- **Station capital cost starts at $3.3 million, declining to $2.0 million**
  - Cost share $1.3 million/station, 2012-2017
  - Cost share $0.7 million/station, 2018-2021
  - Cost share $0.3 or 0.2 million/station, 2022-2025
- **H2 fuel subsidy**
  - $0.50/kg through 2018
  - Declines to $0.30/kg by 2025

The analysis responded to the NAS' call to better understand what a transition to hydrogen powered vehicles would require.

- **NAS 2004 Hydrogen Economy report**

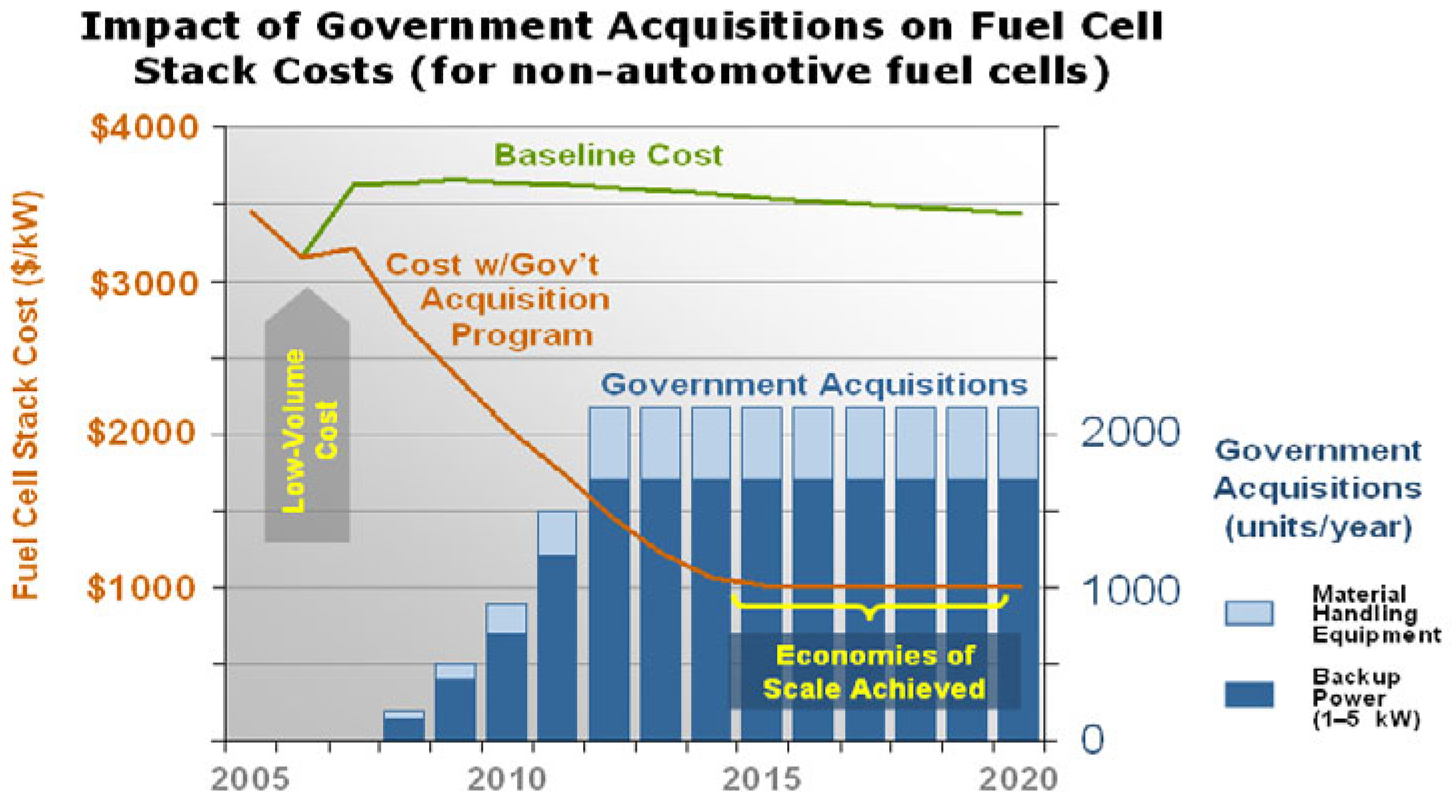
  "…the DOE should map out and evaluate a transition plan consistent with developing the infrastructure and hydrogen resources necessary to support the (NAS) committee's hydrogen penetration scenario (Scenario 3 of the analysis) or another similar demand scenario. The DOE should estimate what levels of investment over time are required…"
- **Engage the stakeholder community in creating a vision of how the market transformation could happen.**
- **Create useful systems analysis tools capable of representing the "chicken or egg?" dilemma.**
- **Test whether DOE's program goals are sufficient to enable the transition.**

Engaging stakeholders in reviewing scenarios, premises and methods was a key strategy.

- **Select vehicle penetration rates assumptions for 3 scenarios**
- **Formulate "lighthouse" market development strategy**
- **Review key components**
  - **H2A Hydrogen production/delivery technology**
  - **PSAT vehicle technology simulations**
  - **DTI analysis of refueling options and costs**
  - **NREL analysis of refueling network evolution**
- **Over 60 participants from Energy and Automotive Industries, Industrial Gas Companies, Fuel Cell Technology Companies, Federal and State Governments, National Laboratories and Academia participated in 4 workshops.**

Market transformation: Could a government acquisition program for non-automotive PEM fuel cells create a sustainable North American market?

- A rapid study **focused on three markets**: 1 kW and 5 kW Backup-Power, 5kW Materials Handling Equip.
- Government acquisitions could significantly reduce the cost of fuel cells through learning and economies of scale, and help to support a growing supplier base.



(ORNL study, graphic by DOE)