Fuel Choice for FCVs: Hydrogen Infrastructure Costs

Project ID # AN6

DOE Merit Review

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Reference: D0268

Timeline

- Start date: April 2002
- End date: September 2005
- 90% Complete

Budget

- Total project funding
  - DOE share = $445,000
  - TIAX share = $167,000
- FY04 = $110,000
- FY05 = $164,000

Barriers

- Production - AD. Market and Delivery
- Delivery - A. Lack of H_2/Carrier and Infrastructure Options Analysis
- Storage - V. Life Cycle and Efficiency Analysis
- Supports the HFCIT Program target setting

Collaboration

- National Labs
- Energy Companies
- Automakers
- Hydrogen technology developers
- H2A
- UC Davis Hydrogen Pathways program

The main objective of this project is to evaluate the costs of a H_2 transition and identify pathways to minimize economic risks.

- Overall: Develop a model that can be used to determine investment risk and economic viability of natural gas to hydrogen pathways
  - Assess impact on various stakeholders and how risks could be shared and minimized
  - Identify key economic barriers and possible development paths
- Past Year: Evaluate the economic, primary energy use, and GHG impact of various transition scenarios that could improve the economic outlook
  - Mix, timing, and location of **new hydrogen infrastructure**
  - Potential for utilizing **existing hydrogen infrastructure**
- This project also supported TIAX's role in the H2A working group[1]
  - Although H2A-related activities were a significant effort this reporting period, that work will not be presented here

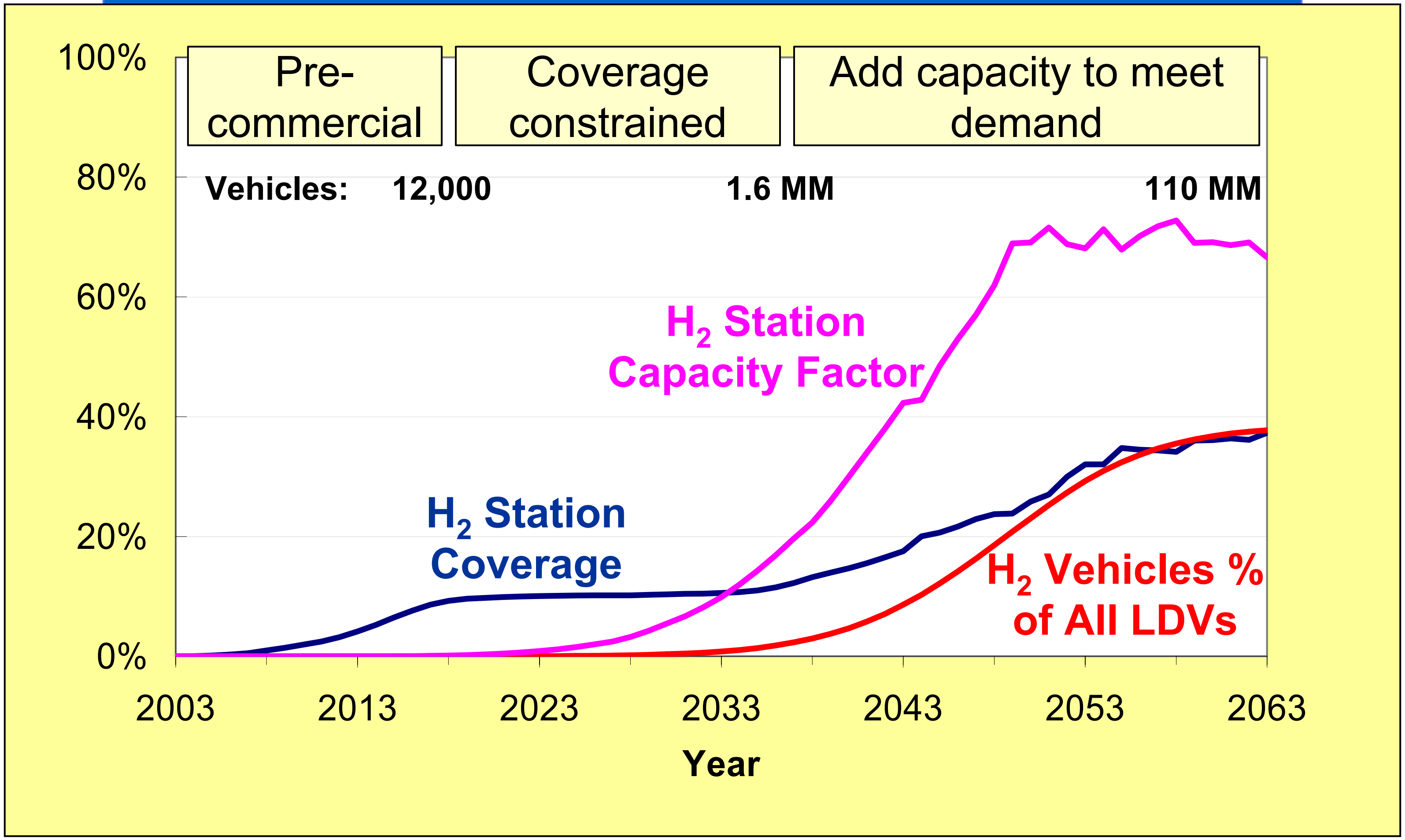
[1] The H2A effort was organized by DOE to develop the building blocks and frameworks needed to conduct rigorous analysis of a wide range of hydrogen technologies.

We have expanded our previously developed model to evaluate the economic and environmental impact of various transition scenarios.

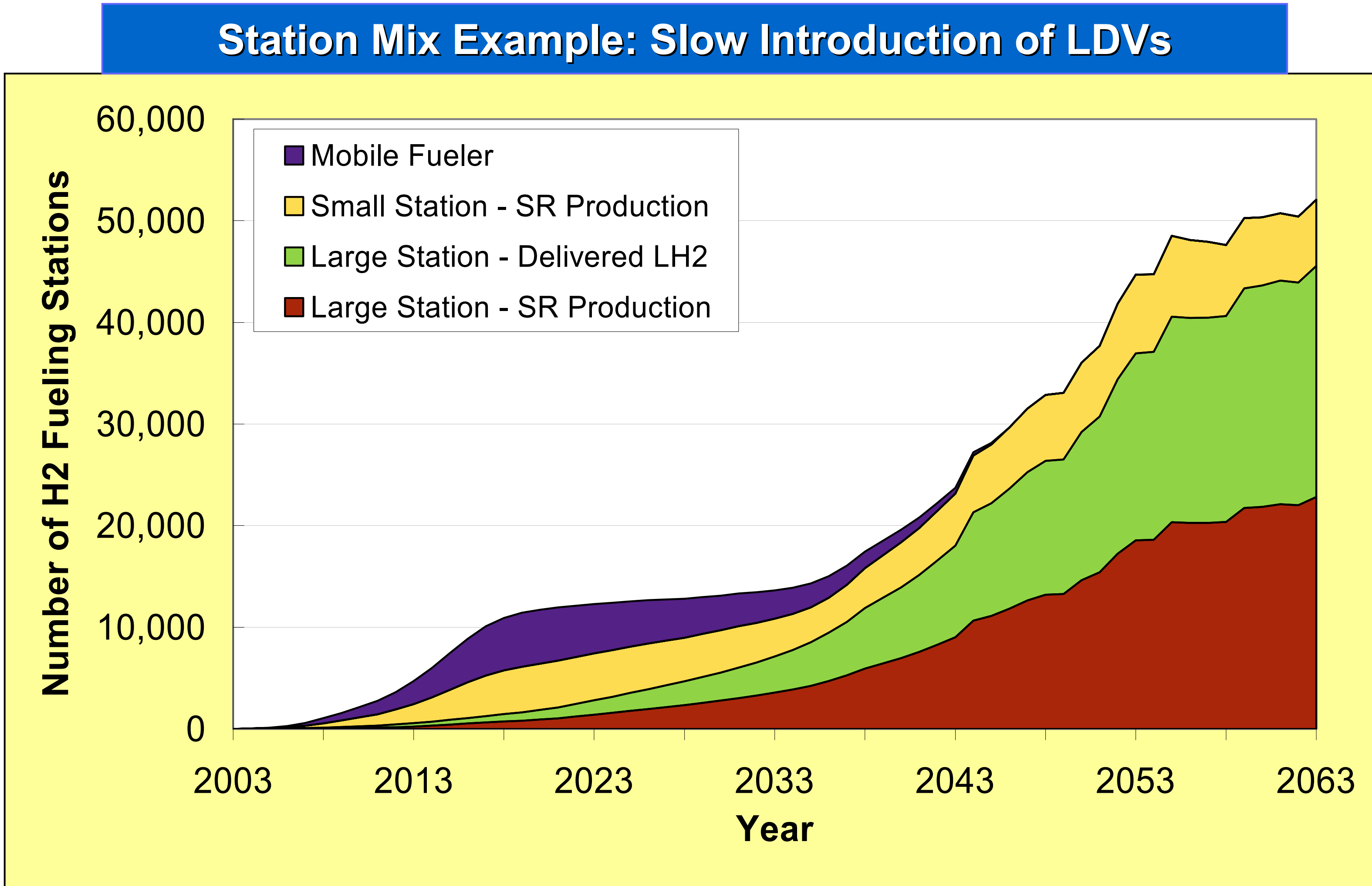
- Modified the previously developed transition cost model to evaluate:
  - **New** distributed production; central production with LH_2, tube trailer, and mobile fueler delivery
  - **Existing** excess or “moth-balled” merchant, ammonia, refinery, and methanol plant hydrogen capacity
- Developed economic, primary energy use, and GHG input assumptions for the various transition scenarios, using:
  - H2A and GREET (ANL) assumptions and results for some economic, energy use, and GHG inputs
  - Other hydrogen transition model results and industry feedback for mix, timing, and location of new production and delivery infrastructure
  - Internal analysis for additional cost and performance assumptions
  - Literature review and industry feedback for potential for utilizing existing hydrogen infrastructure

Previously, we developed a transition cost model that can be used to build and evaluate a number of hydrogen transition scenarios.

Model Example: Slow Introduction of LDVs (30% by 2050)



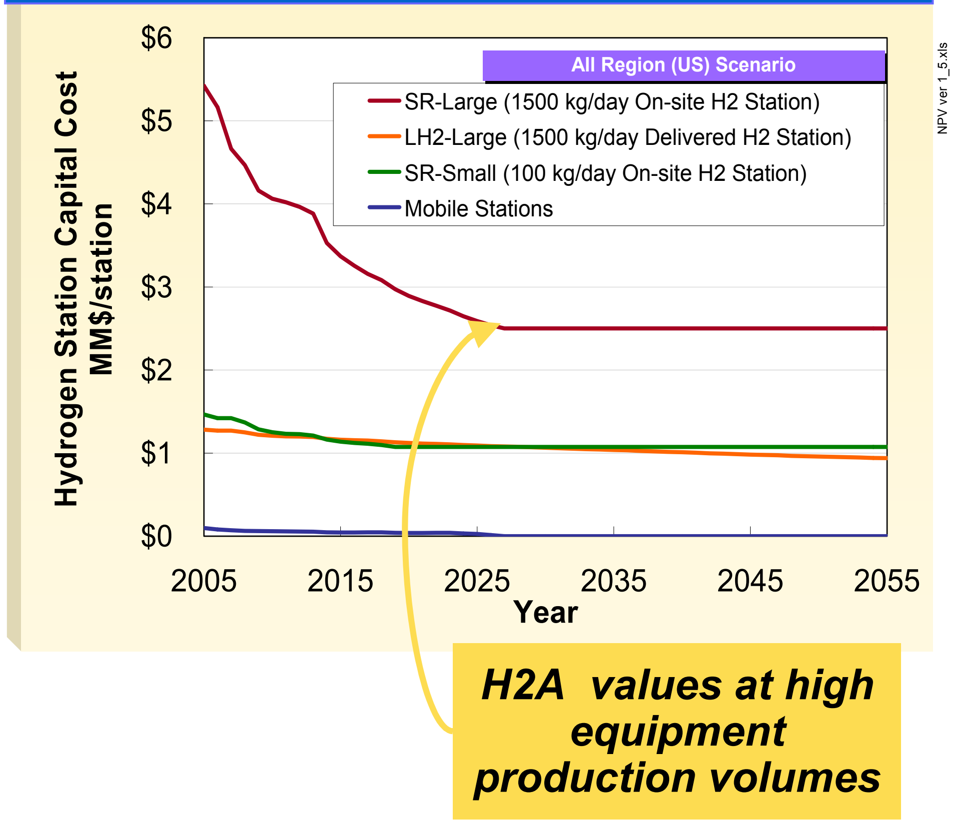
Using the model we can evaluate a mix of new H_2 infrastructure options to meet the assumed demand for various US regions.



We updated the model using the latest information for economic, energy use, and GHG input assumptions.

- Modified model inputs:
  - H2A assumptions for high volume capital costs
  - GREET (ANL) results for GHG emissions factors
- Incorporated industry feedback on mix, timing, and location of new infrastructure
- Internal analysis for additional cost and performance assumptions

Station Capital Cost Example: Slow Introduction



We have also developed a demand model to calculate the cost of delivering hydrogen from the existing infrastructure in a given region.

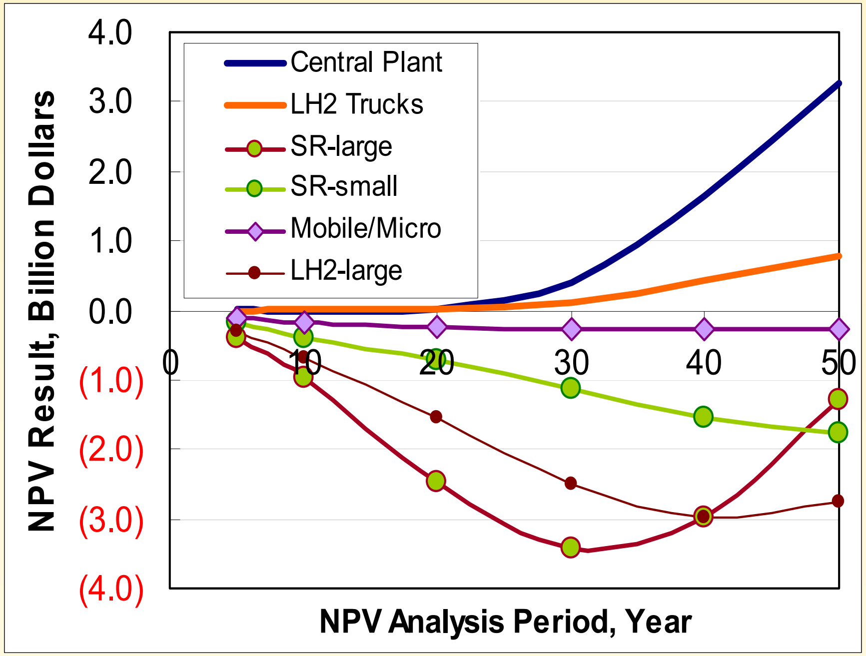
Demand Model

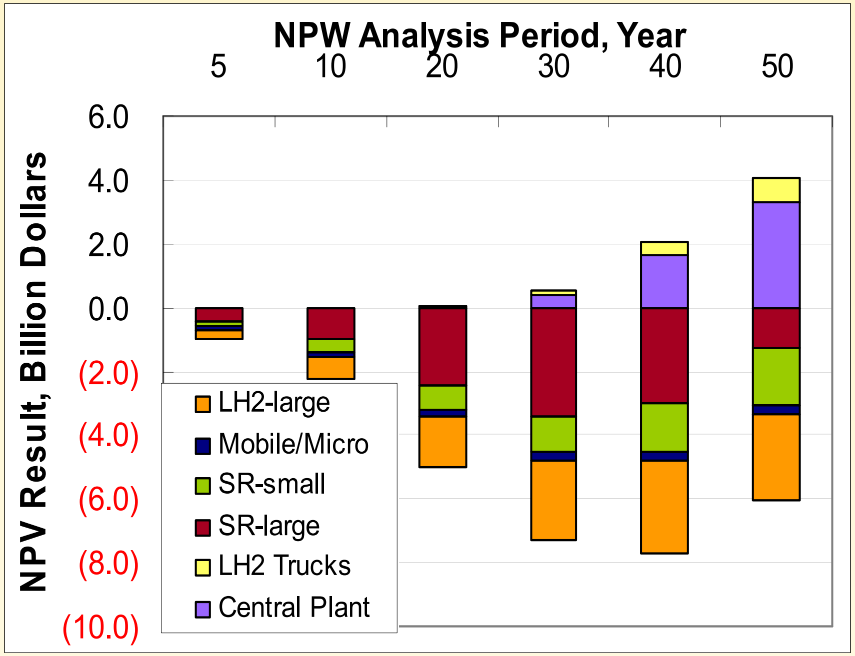
Identify potential sources and locations	→	Determine amount of excess capacity	→	Identify additional processing/ delivery equipment	→	Determine proximity to population centers	→	Calculate cost of delivering hydrogen
Ammonia, refineries, methanol plants, etc.		***Excess captive production, "moth-balled" plant capacity, etc.***		***Purification, storage, compression, liquefaction, etc.***		***Plant locations and GIS population data***		***\$/kg for LH_2 or cH_2 delivery based on distance and demand***

This excess capacity and delivery cost information has been incorporated into the transition cost model.

We have used the transition cost model to evaluate stakeholder risks and the economic viability of various pathways.

NPV Results Example: Slow Introduction of LDVs





Note: Results assume a range of hydrogen selling prices over time that are a function of gasoline price, road tax, and vehicle fuel economy assumptions only.

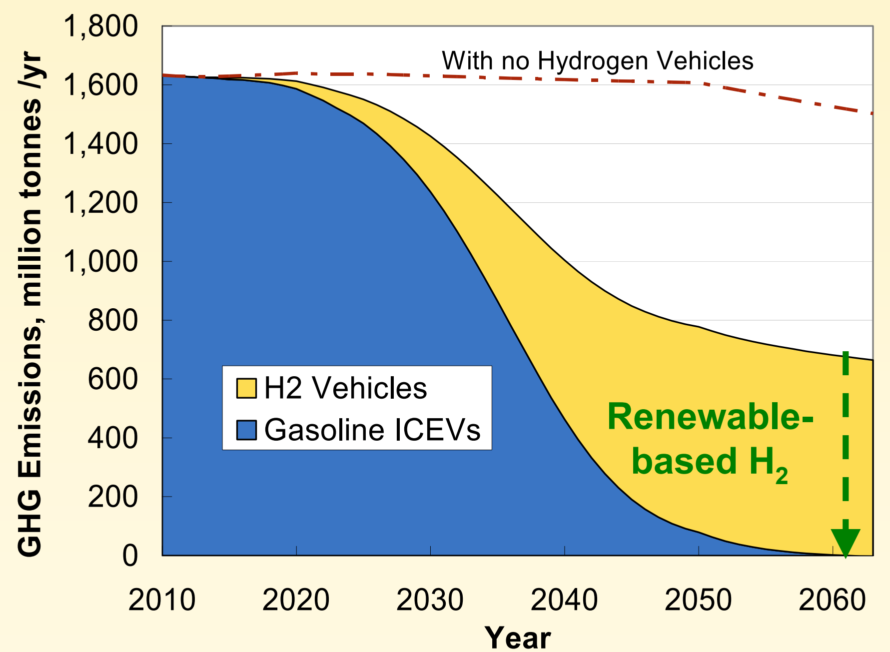
In this example, it is a very long time before any stakeholders are able to recover their investments.

The transition model is also capable of calculating the change in energy use and GHG emissions over time…

- Ultimately, efficient use of H_2 from natural gas could reduce GHG emissions by about half
  - Depends on feedstock, delivery mode, and production technology
  - Additional reductions via more aggressive fuel economy and H_2 from non-carbon sources
- However, even in a fast transition, significant GHG reductions are not realized for 25+ years

GHG Results Example: Fast Introduction of LDVs

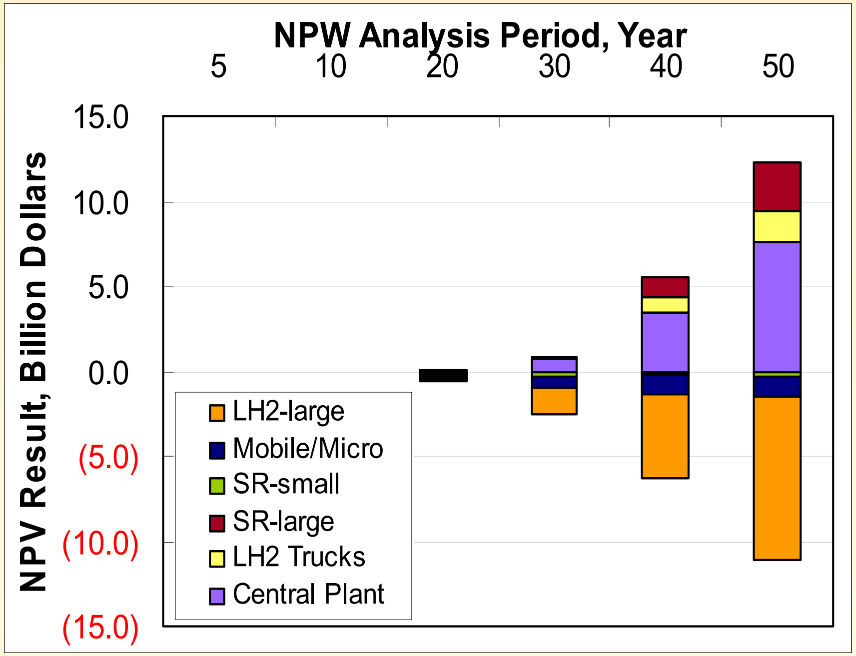
30 mpg gasoline, 75 mpg H_2 vehicles in 2060

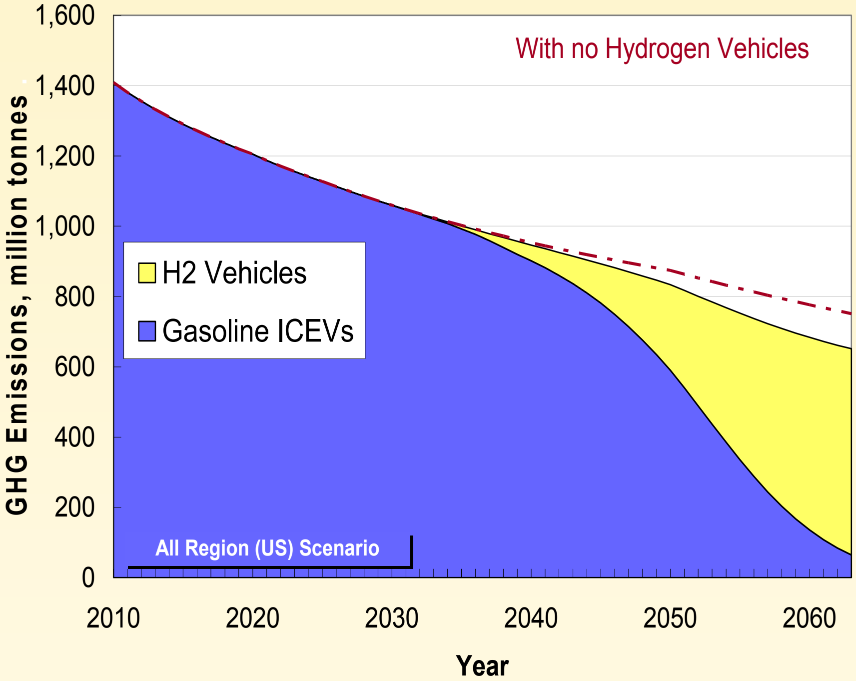


…so that the cost and impact of various policy initiatives can be assessed under different scenarios.

NPV Vs. GHG Results Example: Delayed Introduction of LDVs

60 mpg gasoline, 100 mpg H_2 vehicles in 2060 plus delay introduction by 20 years





Note: Results assume a range of hydrogen selling prices over time that are a function of gasoline price, road tax, and vehicle fuel economy assumptions only.

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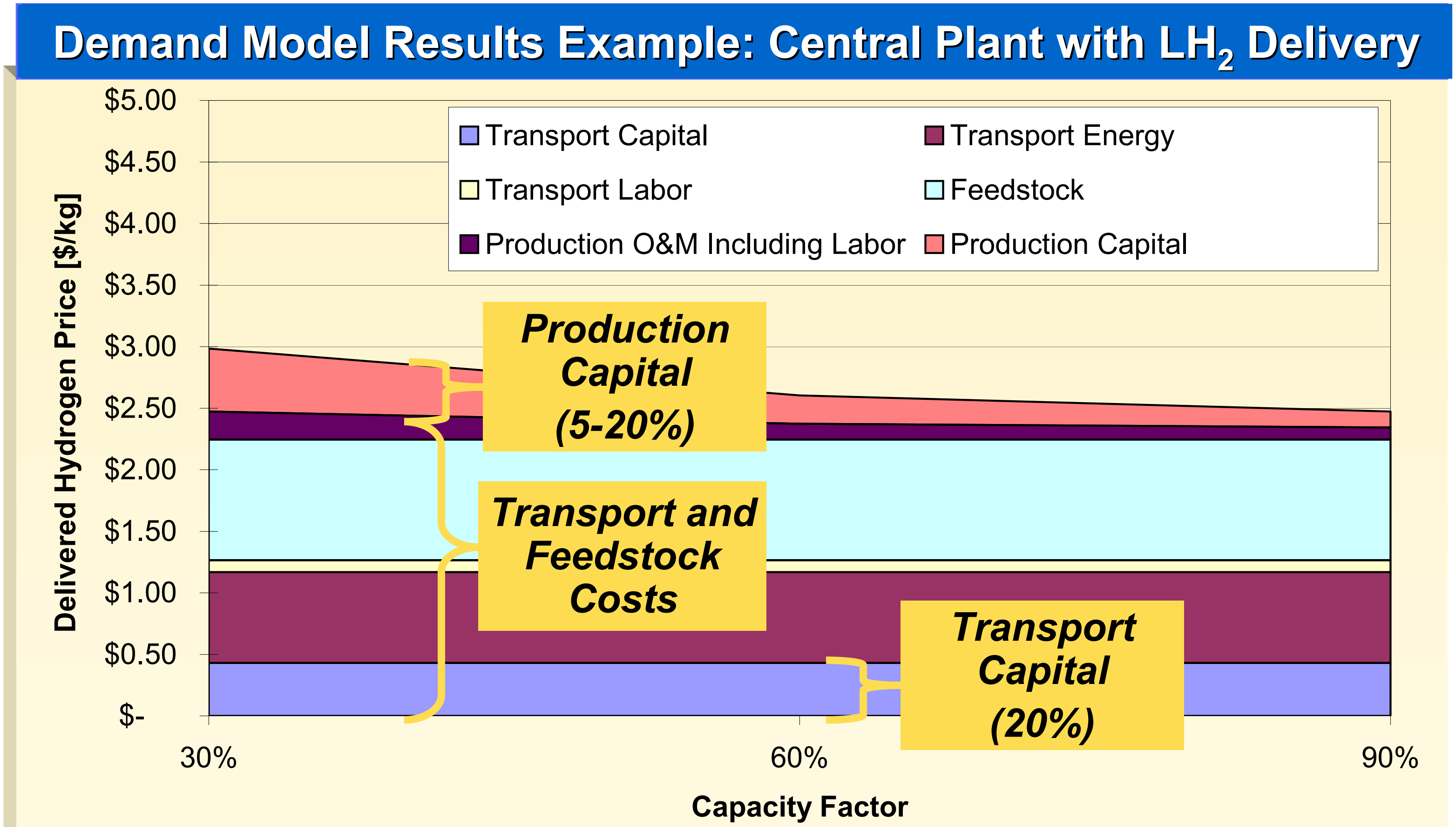
High transportation and feedstock costs will limit the potential for using existing hydrogen capacity for hydrogen vehicles.



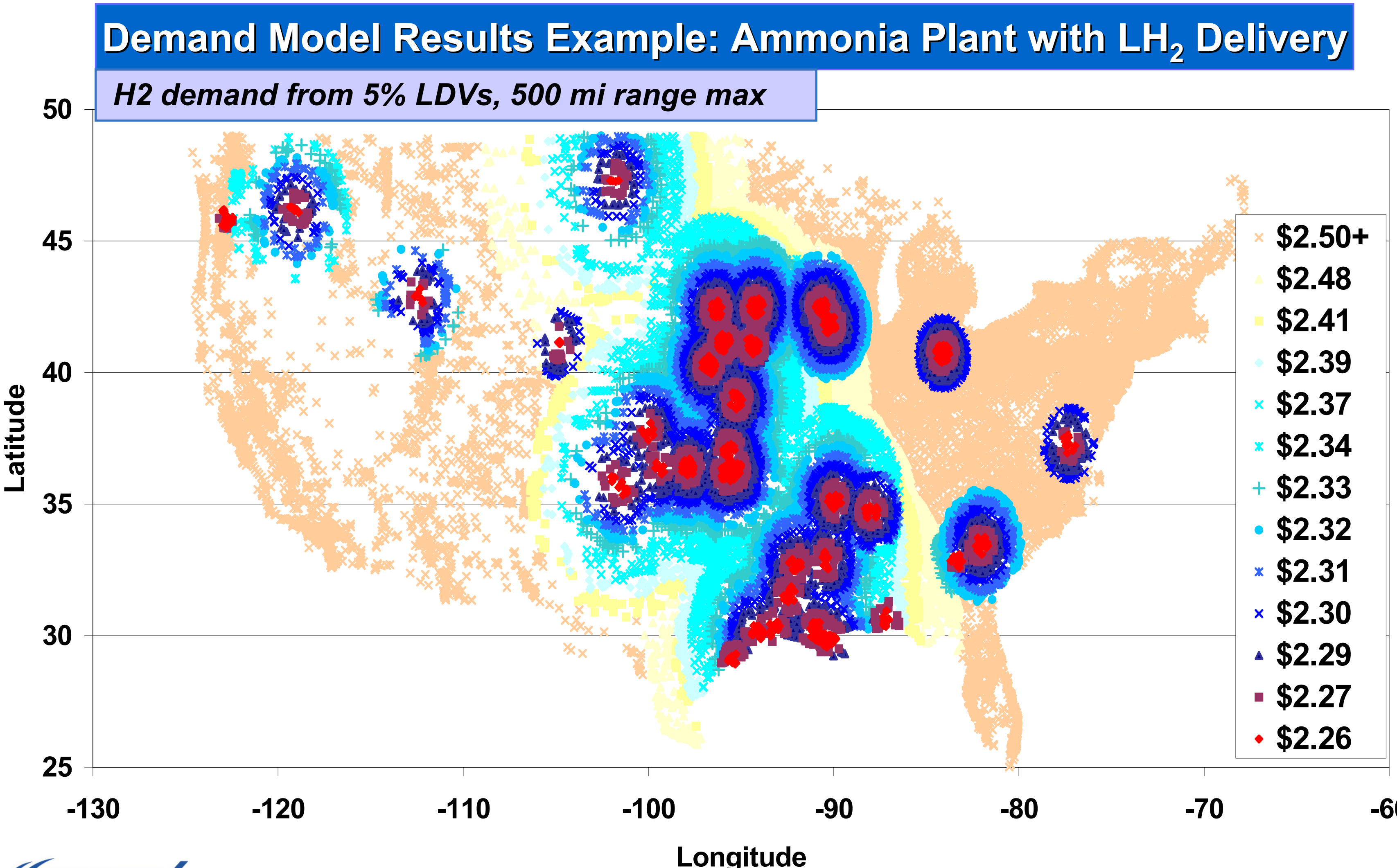
However, capital investment and risk could be significantly reduced, especially early on when new plant capacity factors could be low.

Ammonia and methanol plants are potentially the largest sources of excess H_2. Their total could supply H_2 to about 4% of US LDVs.

Estimated US H_2 Capacity	Total, kT/y	Excess, kT/y	Comments
Ammonia	2,880	1,800	US plants are operating below capacity due to the high cost of natural gas
Refining	2,800	None	Sour crude and tighter fuel specs are further increasing refinery H_2 demand
Methanol	760	400	10 of 18 plants closed in last 5 years; but not widely dispersed (75% in Texas)
Captive Chemical (Chlor-alkali)	290	None	By-product hydrogen is used in-plant to make PVC and HCl
Merchant LH_2	80	10	17% difference between merchant H_2 capacity and demand in North America
Total	**6,730**	**2,210**	4% of US LDVs assuming 2x fuel economy improvement for H_2 vehicles

Sources: US Census Bureau, STAT/USA; Praxair: Schwartz, J., Drnevich, R. “The Hydrogen Evolution: Infrastructure Growth”; SRI Consulting, *Chemical Economics Handbook 2001*, Menlo Park, CA, July 2001; and discussions with industry representatives.

Excess H_2 capacity from ammonia plants could serve at least 5% of the LDVs in the Gulf Coast, Mississippi Valley, and isolated regions.



A hydrogen transition has the potential to reduce petroleum imports and GHG emissions, but it will take time and significant investment.

- It could take many years before a hydrogen transition impacts US energy use and GHG emissions
  - Slow introduction of H_2 vehicles would do little over the next 50 years
  - Fast introduction would take 25+ years to see a significant impact
  - Market drivers are needed (e.g. high gasoline prices, carbon tax, or other hydrogen incentives)
- Investment risks are high for all stakeholders
- The appropriate mix of fueling stations can reduce overall investment, but would typically reduce the impact on energy use and GHG reductions
- Ammonia and methanol plants could potentially reduce transition and investment risk early on
  - Could supply H_2 to at least 5% of LDVs in some regions of the US
  - But, high transport and feedstock costs will limit their attractiveness

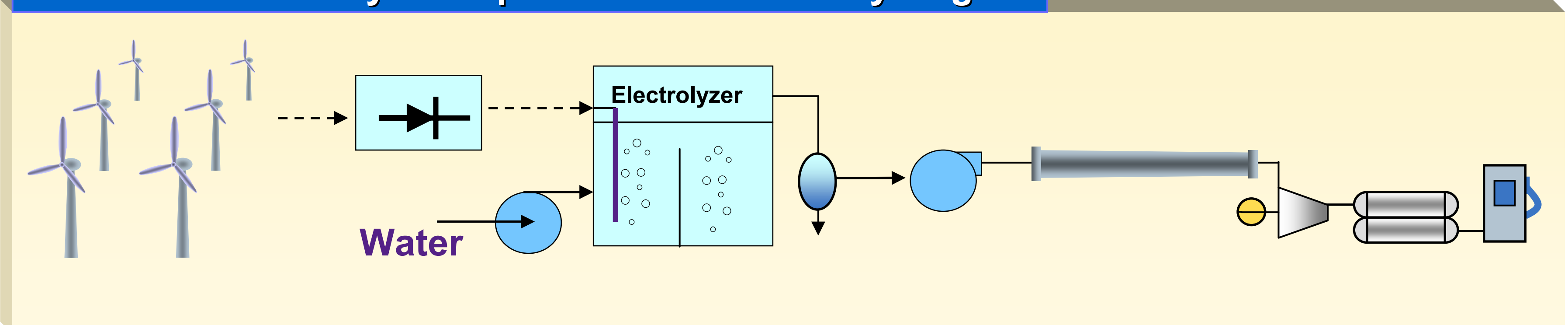
Last year's comments were very positive with a few constructive suggestions that we have addressed this year.

- Should integrate more with ongoing DOE efforts, especially H2A
  - We are actually being funded as a H2A team member as part of this contract. Now that H2A models have been developed, we are using their assumptions and results in the current analysis
  - We have also conducted briefings and data review sessions with a number of other DOE contractors including UC Davis and NREL
- Look at [the early] transition period, which may be more significant than the long-term market
  - We have evaluated the potential of using the existing H_2 infrastructure in the early part of the transition
- Plans to address areas not based on natural gas reforming
  - We have proposed to incorporate renewable pathways and evaluate how they could affect scenarios for a transition to hydrogen

Next, we will document all transition scenarios and integrate the results and conclusions into a final report.

- Document complete analysis approach, assumptions, results, and comparison to other analyses
- Refine and discuss analysis conclusions with stakeholders:
  - How investment risks can be shared and minimized
  - Key economic barriers and possible development paths
- Proposed Additional Work: Identify how renewable pathways could affect scenarios for a transition to hydrogen

Renewable Pathway Example: Wind Power to Hydrogen



We have met with stakeholders and others outside of DOE to present our results/perspectives and solicit feedback on our progress.

Product	Presentation	Meeting
Briefings and data review with: DOE, NREL, DTI, UC Davis, ChevronTexaco, GM		●
CA Hydrogen Highway Topic Teams	●	●
Unnasch, S., Lasher, et al,. "*Hydrogen Supply and Demand for Future Vehicles Use*," National Hydrogen Association Annual Meeting, Washington DC, April 2004	●	●
Unnasch, S., *"Hydrogen Transition Model H2NowNPV,"* Hydrogen Systems Modeling Workshop, U.C. Davis, September 2004	●	
Lasher, S., Unnasch, Chan, "*Hydrogen Infrastructure: Energy, Costs, and Transition*," 2004 Fuel Cell Seminar, San Antonio TX, November 2004	●	●

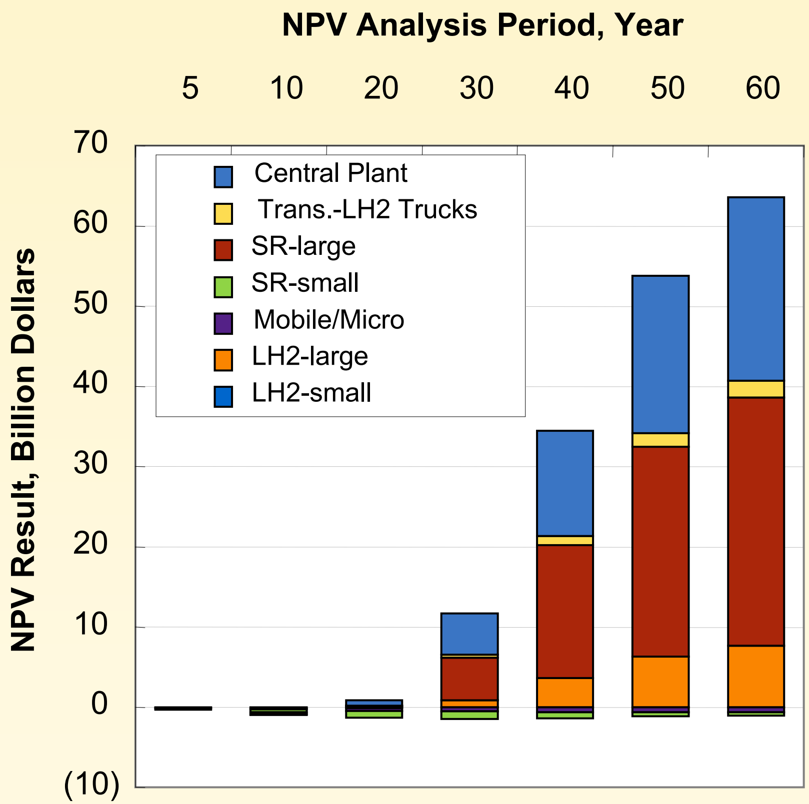
There are no safety aspects as all of the work is analysis-based.

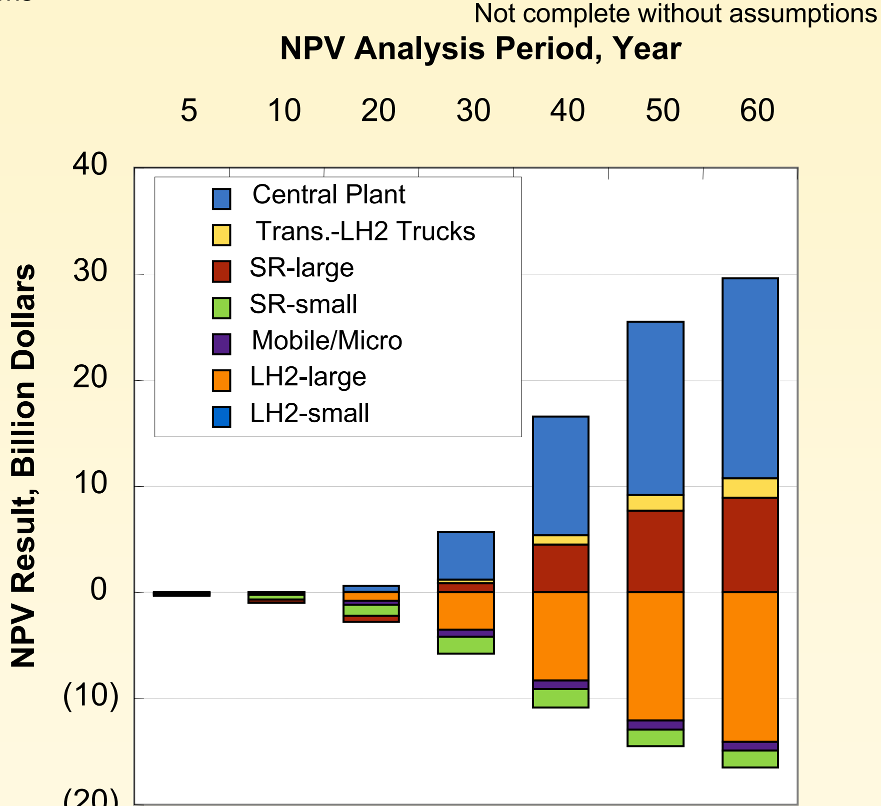
- The most significant hydrogen hazard associated with this project is:
  - None
  - This is an analysis project with no on-going or proposed hands-on laboratory or hardware development work
- Our approach to deal with this hazard is:
  - None required

A fast transition scenario improves stakeholders' economics, but hydrogen revenues are very sensitive to fuel economy assumptions.

NPV Results Example: Fast Build-up of LDVs (100% by 2050)

30 mpg gasoline, 75 mpg H_2 vehicles in 2060	***60 mpg gasoline, 100 mpg H_2 vehicles in 2060***





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