Impact of Hydrogen Production on U.S. Energy Markets

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This presentation does not contain any proprietary or confidential information

Project ID #
AN2

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Overview

Timeline

- Project start May 2005
- Project end date is September 2008

Budget

- Total project funding is $1.3 million
- EEA funding for FY05 $250K
- BNL funding for FY05/FY06 - $220K

Partners

- EEA Inc.
- Brookhaven National Laboratory
- Power & Energy Analytic Resources

Barriers

- Lack of Consistent Data, Assumptions, and Guidelines
- Lack of Macro-Systems Model
- Lack of Understanding of Transition of a Hydrocarbon-Based Economy to a Hydrogen-Based Economy

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Objectives

- Develop a consistent, integrated framework for evaluation of impacts of hydrogen production within U.S. energy markets.
- Evaluate costs and timeliness of various scenarios of a developing hydrogen supply infrastructure.
- Evaluate impacts on U.S. energy markets including price and consumption changes for coal, natural gas, renewables and electricity.
- Identify most economic routes and financial risks of hydrogen production.

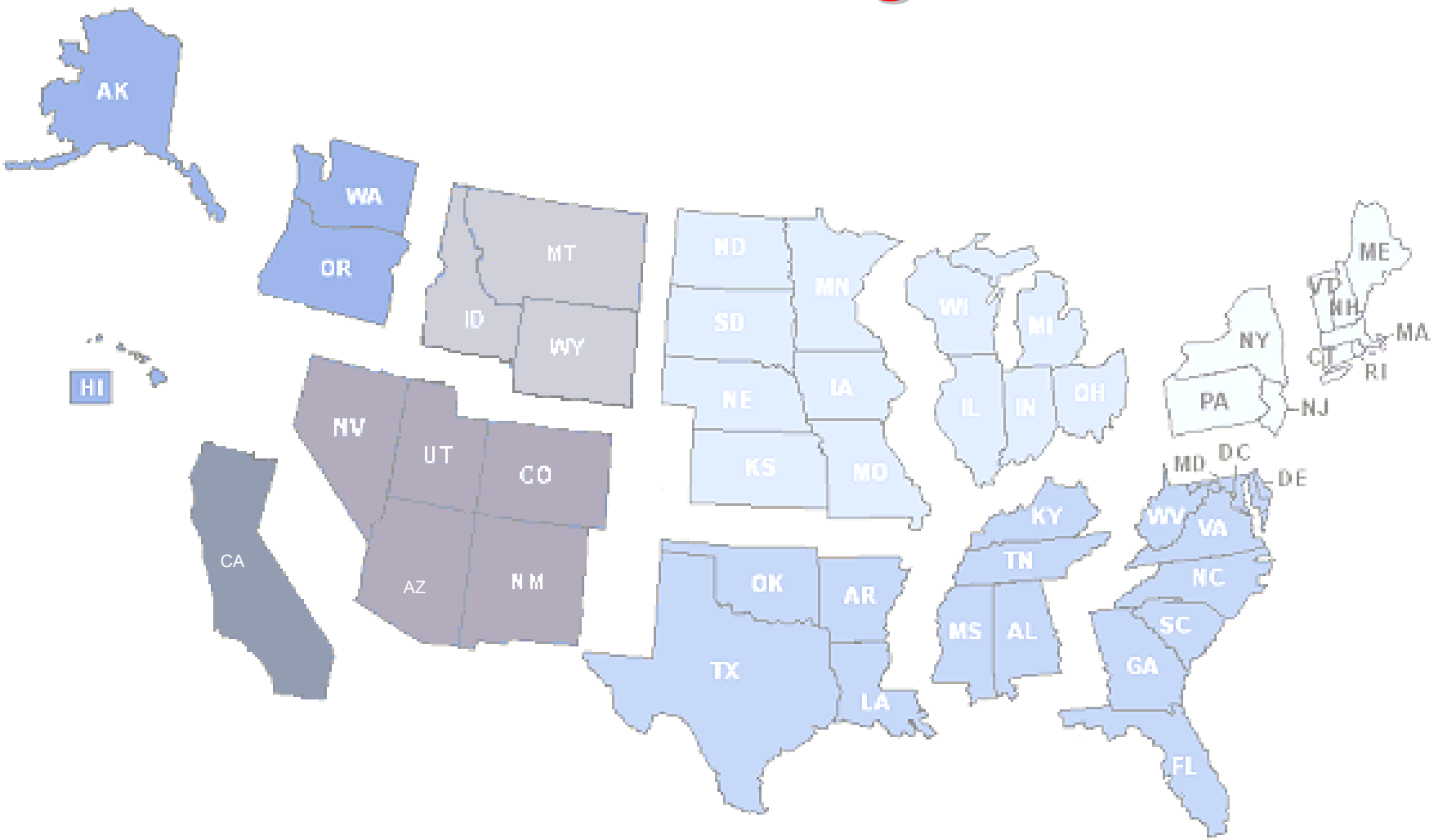
Approach

- Focus will be on competition between hydrogen production and distribution technologies with respect to hydrogen fuel demand, technology cost, regional mix, and impact on feedstock prices.
- Primary modeling framework will be the MARKAL model.
- MARKAL will be modified to incorporate latest and most consistent cost and performance data for alternative hydrogen production technologies.
- Additional analyses on natural gas markets will be performed using models from EEA. Key relationships will be incorporated/calibrated into MARKAL

Approach (cont.)

- Additional analyses on coal and electricity markets will be performed using models from PEAR. Key relationships will be incorporated/calibrated into MARKAL.
- Scenario analyses and sensitivity analyses to be performed with MARKAL.
- Initial work to be done using existing version of MARKAL with later work based on a new regionalized version of the model.
- Results to be presented in series of briefings and reports.

MARKAL Regions



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A Regional Analytical Approach

The hydrogen value chain is very sensitive to regional differences, and thus the project integrates models with strengths that will help better address regional factors affecting the production and distribution with respect to hydrogen fuel demand, and impact on feedstock prices

- Key Inter-Regional Differences
  - Fossil fuel and renewable resource availability
  - Economic and population growth rates
  - End-use demand patterns and levels of energy intensity
  - Energy infrastructure and transportation options and costs
- Key Intra-Regional Differences
  - Rural versus urban population density
  - Distribution costs

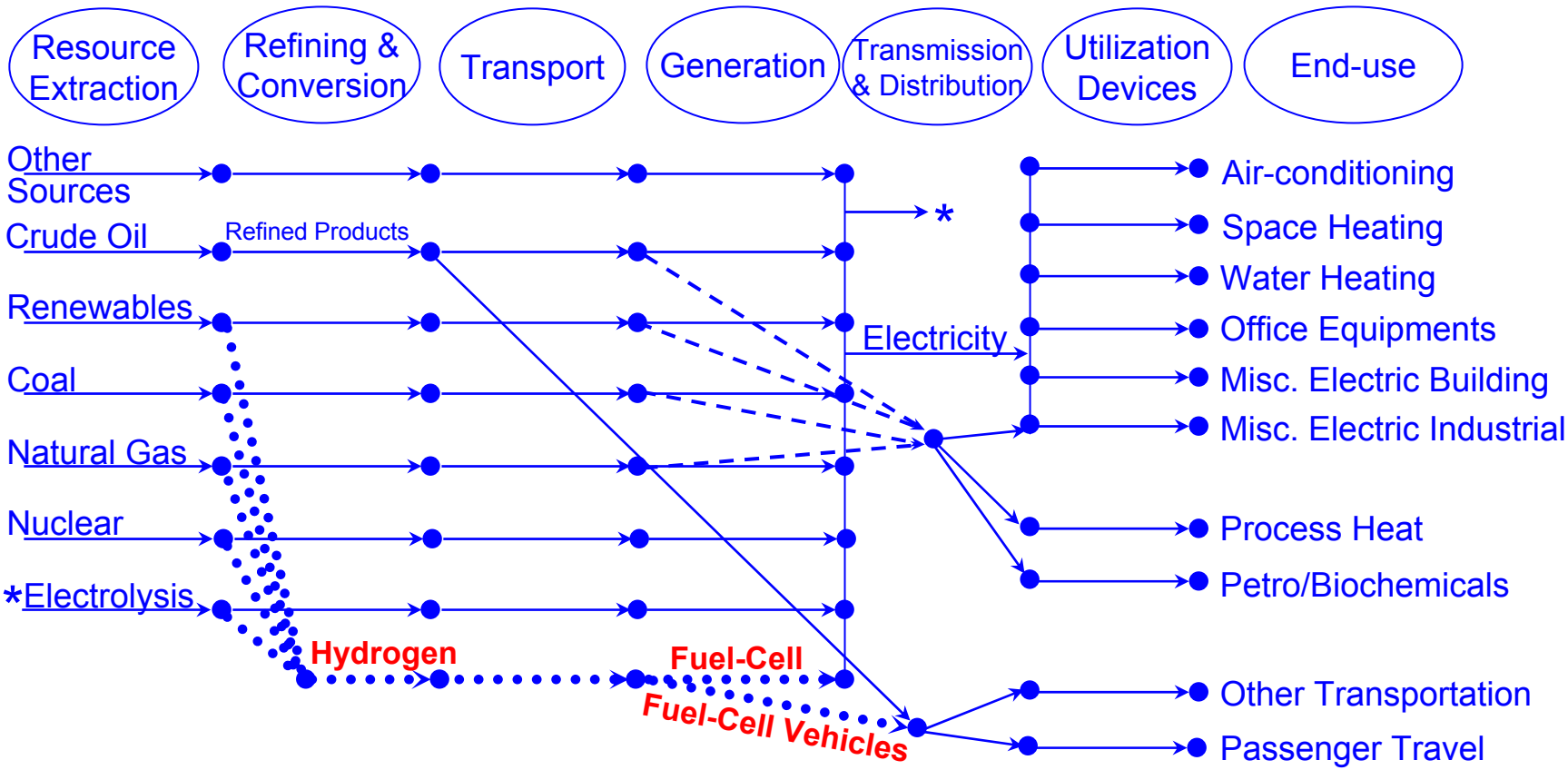
Models

- A portfolio of models will be employed to project demands for hydrogen as a fuel, and impacts on feedstock price and supplies under alternative technological, regulatory and market scenarios.
  - U.S. DOE MARKAL model
  - Hydrocarbon Supply Model (HSM)
  - Gas Market Data Forecasting System (GMDFS) model
  - Power & Energy Analytic Resources (PEAR) Coal Compliance Options and Competitive Generation Cost models

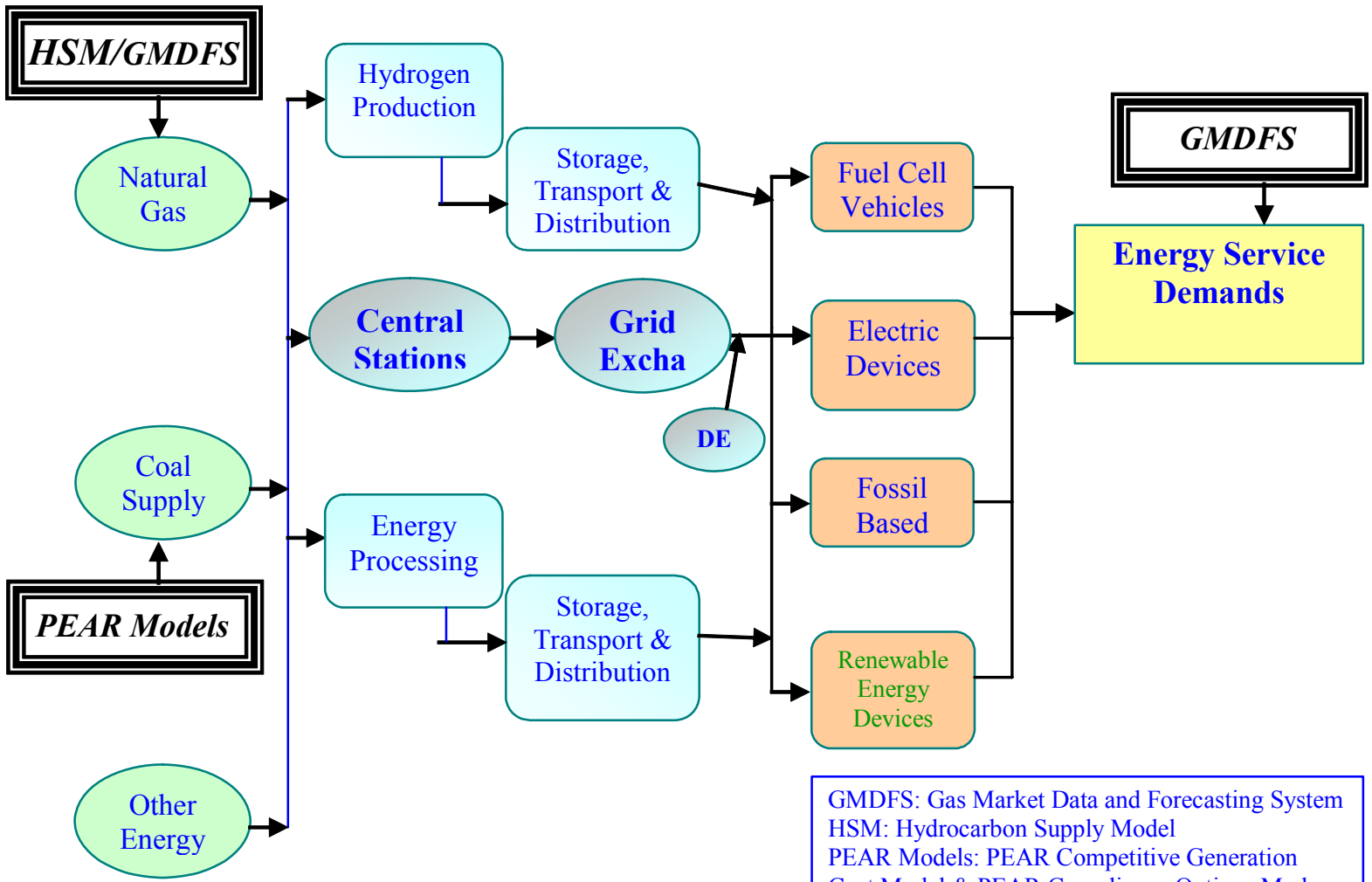
MARKAL for Integrated Market Analysis

- Generates ***least-cost*** energy path based on ***life-cycle costs*** of technologies
- Utilizes a ***bottom-up*** approach to identify an ***optimal technology/resource mix*** to meet demands in a balanced energy market
- Consists of a ***dynamic integrated framework*** to assess ***market competition***, ***technology diffusion*** and ***emission accounting***
- Produces outputs that facilitate the analysis of ***economic tradeoffs*** among alternative energy infrastructure systems

MARKAL for Integrated Market Analysis



Model Interactions in Hydrogen Market Analysis



GMDFS: Gas Market Data and Forecasting System
HSM: Hydrocarbon Supply Model
PEAR Models: PEAR Competitive Generation Cost Model & PEAR Compliance Options Mode

Accomplishments in Last Year

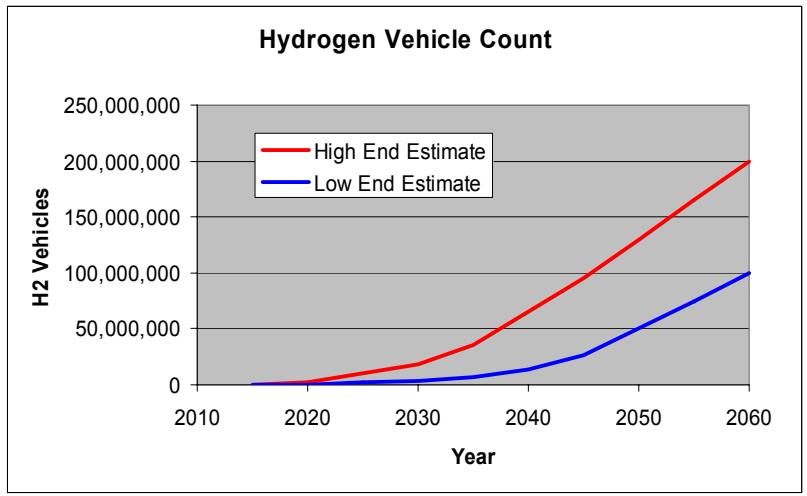
- Researched **coal resource base** descriptions, size estimates and cost distributions. Developed initial MARKAL regional inputs.
- Researched historical **coal transportation costs** and developed modeling algorithms.
- Created more consistent performance and cost inputs for coal-to-hydrogen and other **coal conversion technologies** in MARKAL.
- Researched **terrestrial sequestration** cost and maximum storage capacities by region.

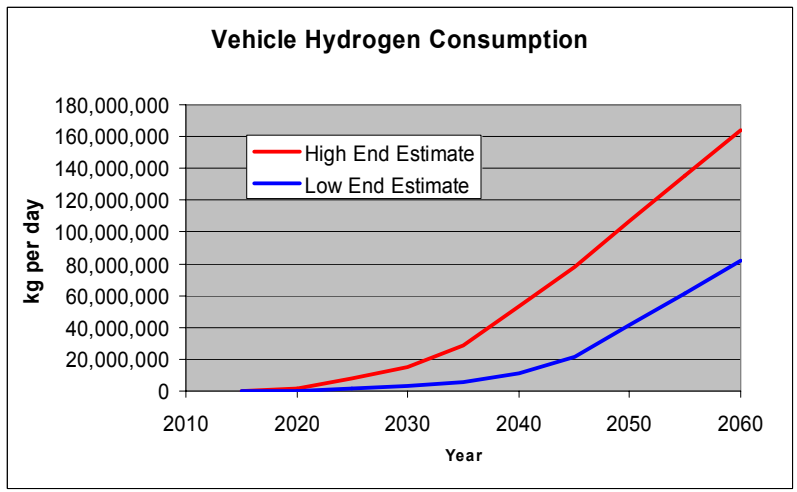
Accomplishments (continued)

- Researched **biomass resource base** descriptions, regional availability estimates and cost distributions.
- Created initial **infrastructure design scenarios** for metropolitan market area hydrogen demand through 2060.
- Developed suite of **distance-based costing algorithms** to allow specification of cost tradeoffs of infrastructure location and size.
- Used current version of MARKAL model to investigate **integrated hydrogen scenarios** based on 2005 AEO and 2006 AEO.

Infrastructure Design Scenarios

- Based on 2006 AEO LDV assumptions through 2030 and extrapolations to 2060.
- Initial year to 2025 based on NAS planning ranges recommended to DOE.
- Market for 2060 assumed to be between 100 million and 200 million vehicles.
- Hydrogen demand will depend on VMT and efficiency. For design scenarios, hydrogen use 300 kg/year is assumed for each vehicle.





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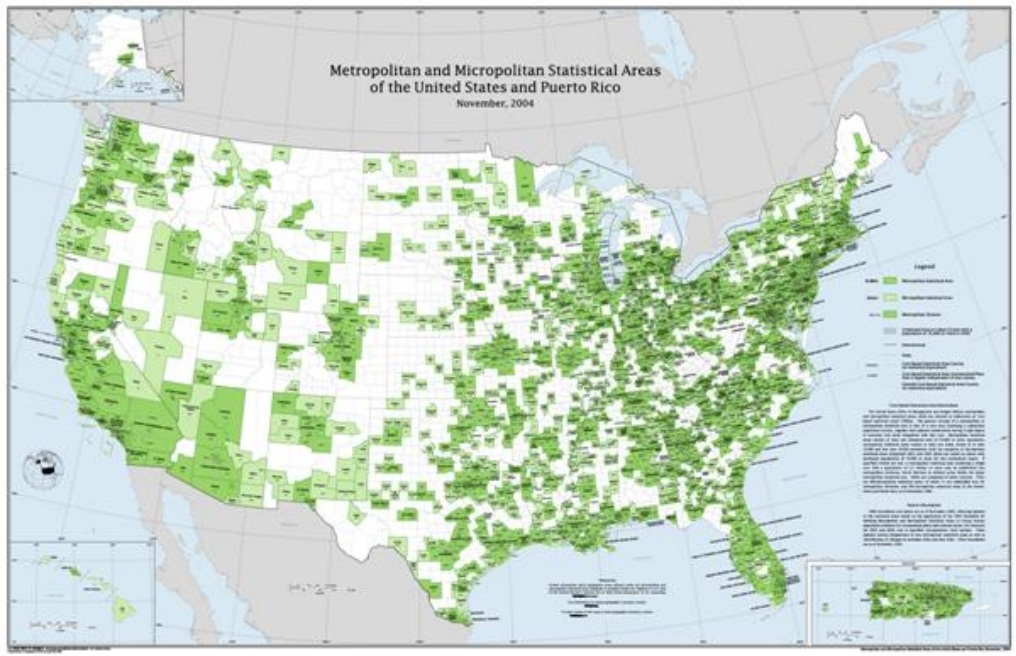
Detailed Market Areas

- U.S. hydrogen demand is being allocated to metropolitan areas to determined regional dispersion and density.
- Allocation based on Census business and population information and AEO regional vehicle fuel consumption forecast.



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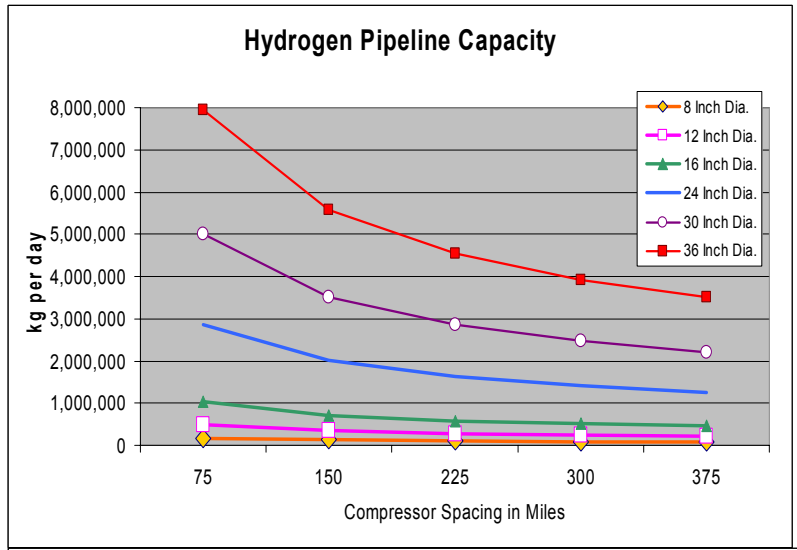
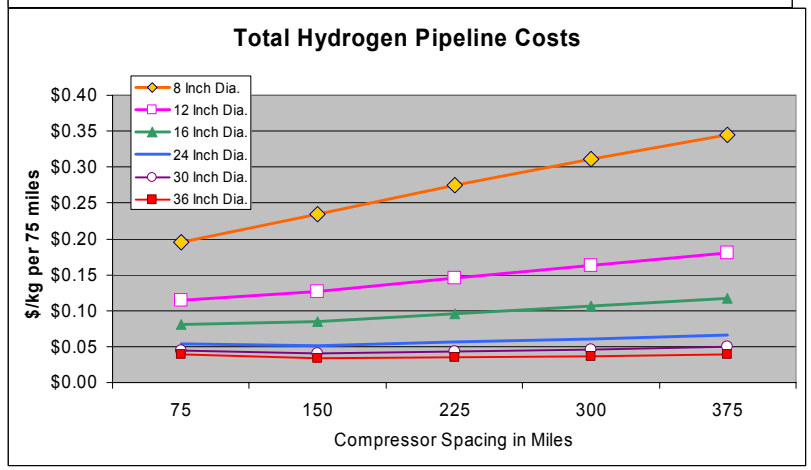
Hydrogen Pipeline Costs

- Gas industry practice is to build pipelines without full compression and then to add compression as flow rates increase.
- Similar practice will probably evolve in transition to hydrogen.
- Our design scenarios assume market areas are often connected by pipelines to share central production facilities and storage.





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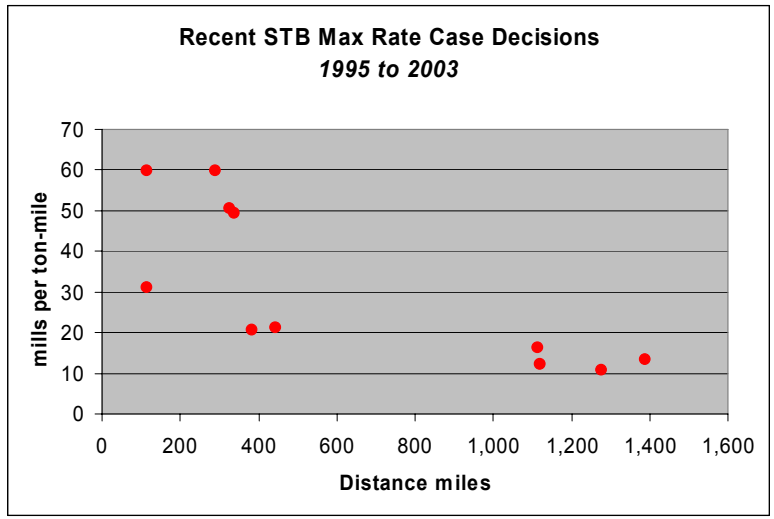
Coal Transportation Costs

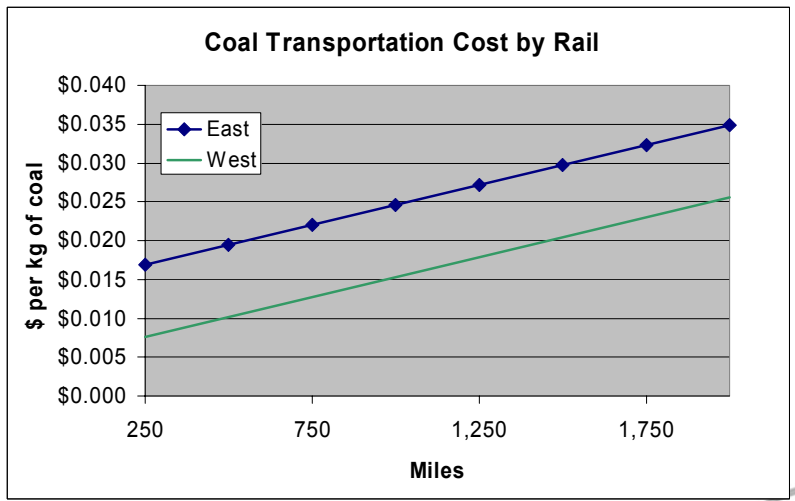
- Historical and projected interregional coal transportation by all modes from PEAR coal model
- Algorithms developed to analyze shipping economics for each major market area in each region.
- For example for rail:

Eastern rate per short ton = 11.50 + .0093*Miles + .0025*$/gallon*Miles

Western rate per short ton = 3.10 + .0093*Miles + .0025*$/gallon*Miles

Fuel cost in $/gallon of diesel fuel





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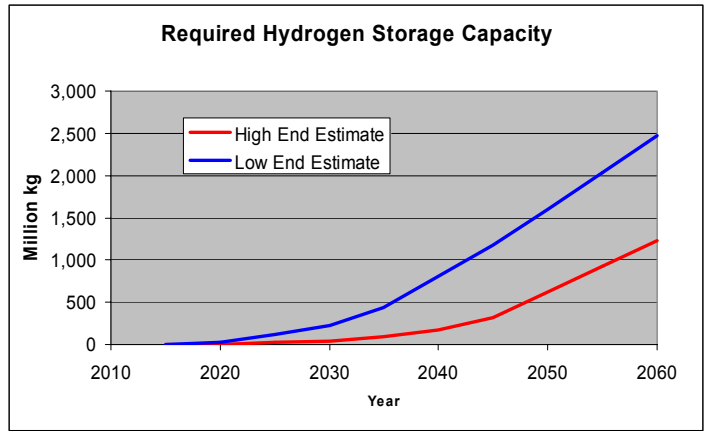
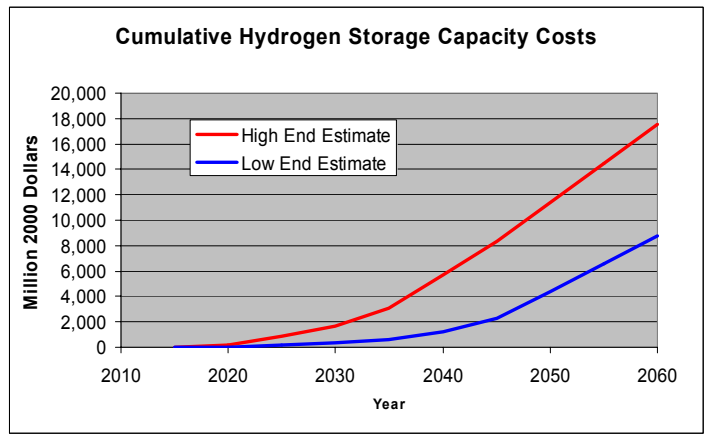
Hydrogen Storage Requirements and Costs

- U.S. primary gasoline storage levels represent 21 to 25 days of demand.
- Will hydrogen require similar levels of storage for seasonal variations, supply reliability and price stability?
- Design scenarios assuming 15 day storage (beyond in-transit volumes) lead to need for 1.2 to 2.5 billion kg of storage capacity at cost of between $8.8 and $17.6 billion.





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Preliminary MARKAL Analysis

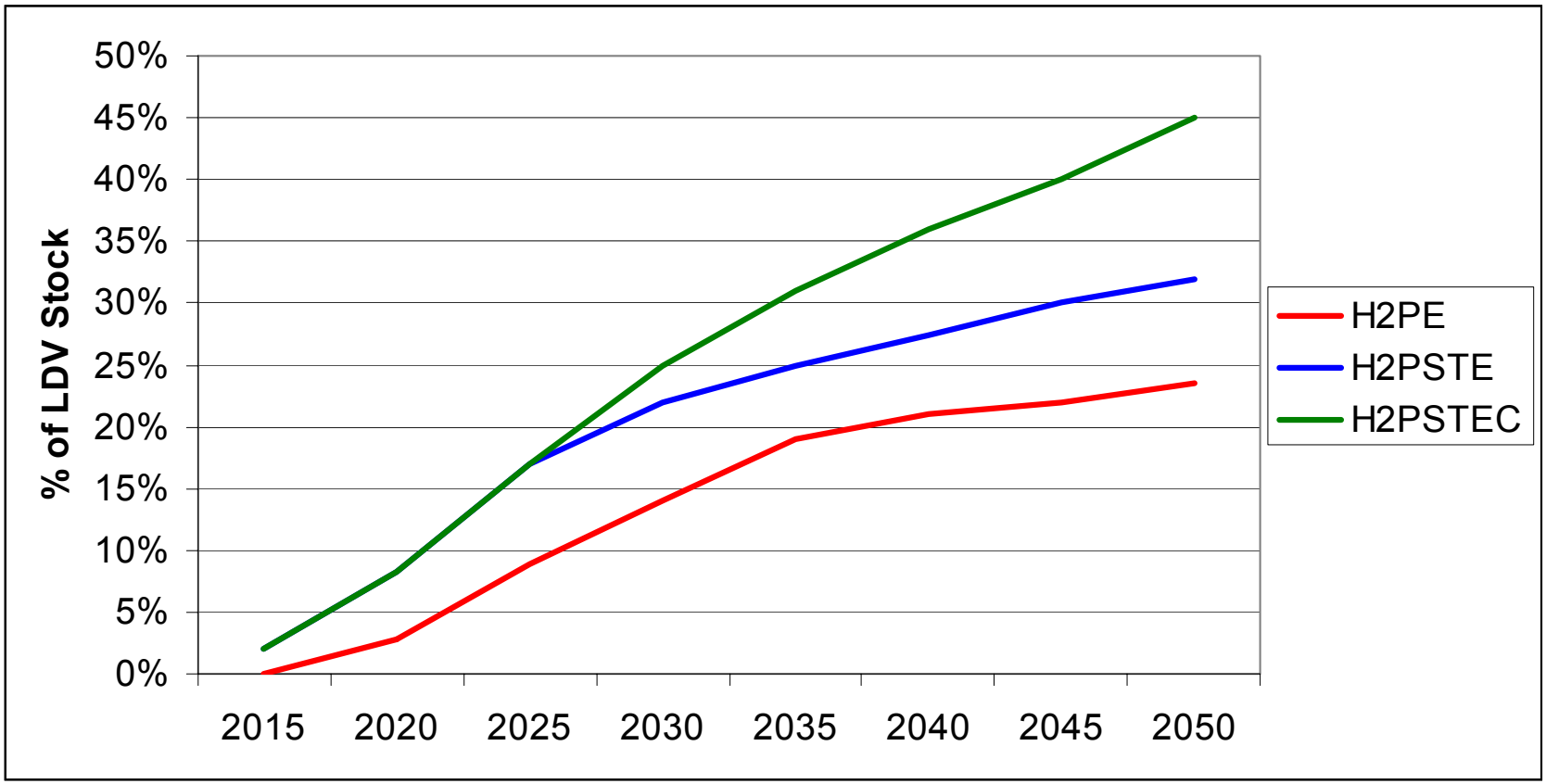
- All scenarios based on AEO2006 Reference Case
- H2 FCVs are assumed to be 3.0 times as efficient than gasoline ICE vehicles
- H2 distribution, storage and dispensing costs set at Program goals

H2PE - HFCIT Program goals for fuel cell costs

H2PSTE - H2P + vehicle subsidy ($3,000 for 2015 & 2020, $1,500 for 2025) and H2 fuel taxes at ½ level of gasoline.

H2PSTEC - H2PSTE + $50 carbon tax

Preliminary LDV Market Shares HFCTP Fuel Cell Cost Goals



Future Work

Remainder of FY 2006

- Complete scenario design for hydrogen demand by region and year and translate into daily volumes by market areas.
- Develop production, distribution, storage and dispensing “design” and cost estimates of each region based on natural gas, coal and biomass feedstocks.
  - Regional analysis will include carbon sequestration costs and geologic capacities.
- Translate costs into MARKAL algorithms for various levels of market penetration.

FY 2007

- Implement and test regionalized version of MARKAL.
- Examine alternative integrated scenarios and sensitivities with MARKAL.

Unique Features of Project

- Integrates supply/demand and various fuel markets
- Employs an inter-temporal approach that looks at technology evolution and stranded investments
- Evaluates energy markets over the long-term (2005 - 2050)
- Examines alternative scenarios and sensitivities
- Focuses of on the competition among production technologies
- Considers hydrogen demand levels, technology costs, regional cost variations, and feedstock prices
- Estimates impact of hydrogen production on hydrogen feedstock prices and consumption changes in other energy markets

Supplemental Slide

Publications and Presentations

- "Impact of Hydrogen Production on U.S. Energy Markets", P. Friley, E. H. Vidas, T. Huetterman, International Energy Workshop, July 2005.

Supplemental Slide
Hydrogen Safety

- There are no hydrogen safety issues related to this project.