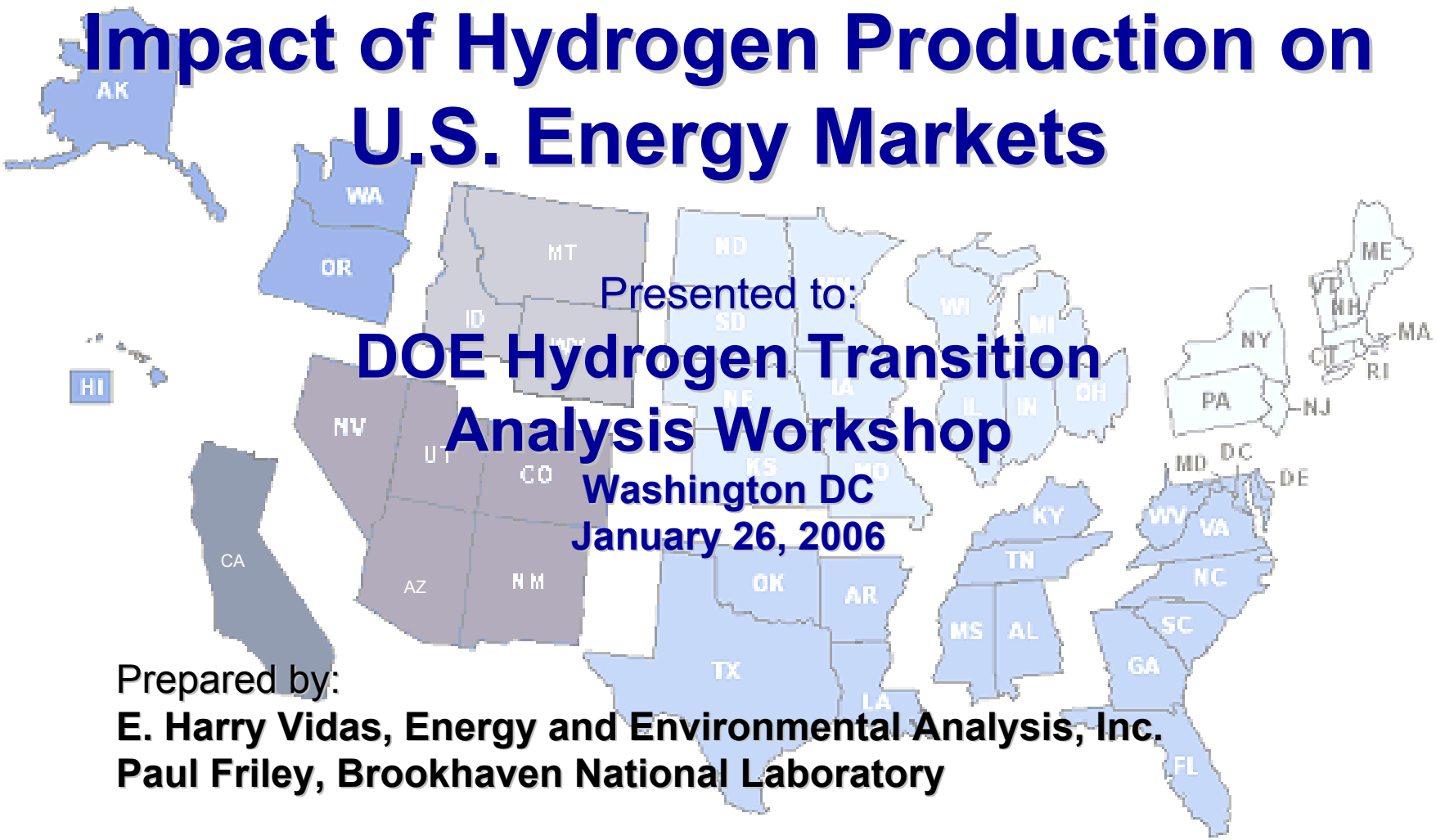
Impact of Hydrogen Production on U.S. Energy Markets



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Prepared by:

E. Harry Vidas, Energy and Environmental Analysis, Inc.

Paul Friley, Brookhaven National Laboratory

BROOKHAVEN NATIONAL LABORATORY

Project Scope

- 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.
- Evaluate impacts on U.S. energy markets including price and consumption changes for coal, natural gas, renewables, and electricity, and the impact of inter-sectoral competition.
- Identify most economic routes, financial risks of hydrogen production, and evaluate impacts of various scenarios of developing a supply infrastructure.

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

Approach

- Primary modeling framework will be the MARKAL model.
- Additional analyses on natural gas markets will be performed using models from Energy and Environmental Analysis, Inc. (EEA). Key relationships will be incorporated/calibrated into MARKAL.
- Additional analyses on coal and electricity markets will be performed using models from PEAR. Key relationships will be incorporated/calibrated into MARKAL.

MARKAL for Integrated Market Analysis

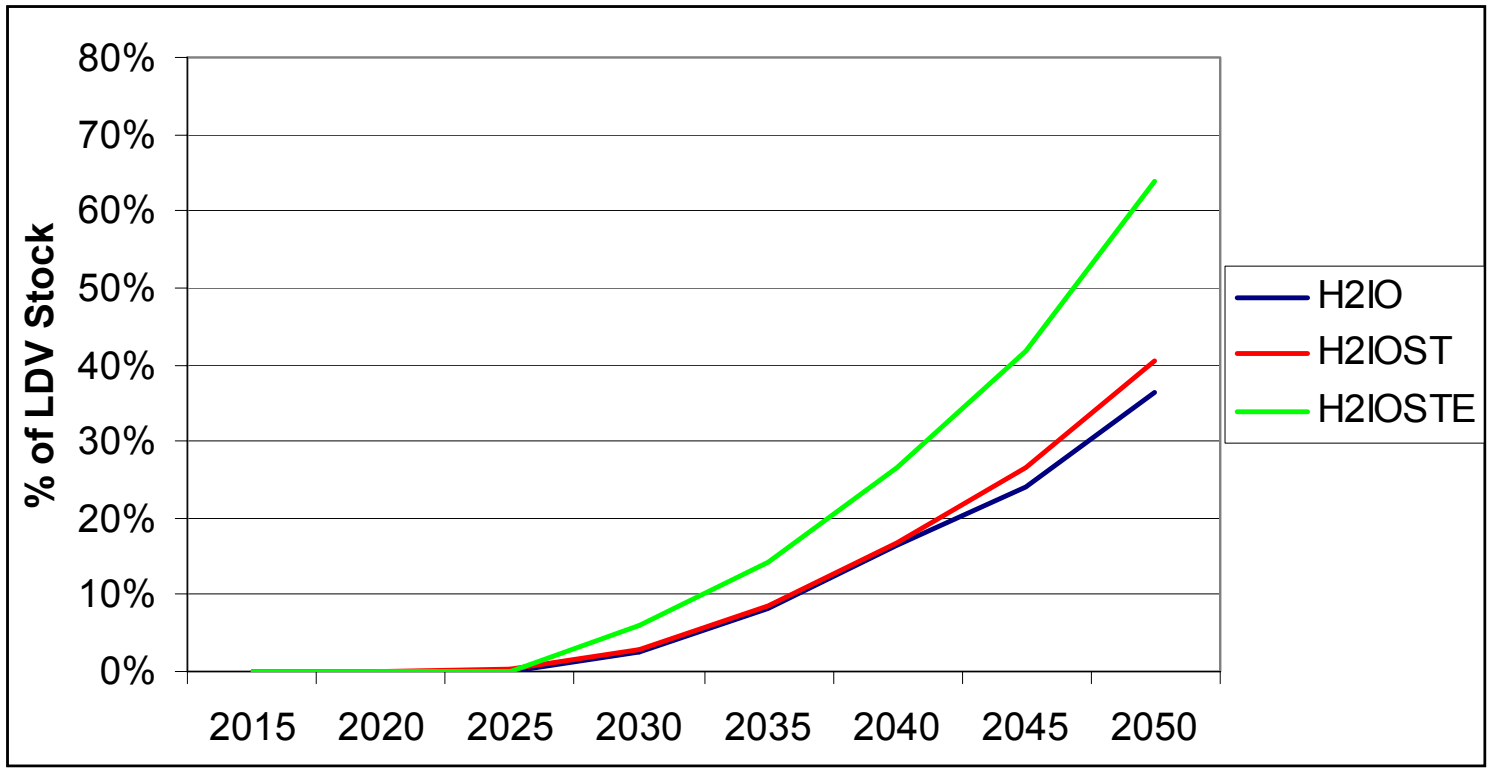
- Generates ***least-cost*** energy path based on ***life-cycle costs*** of technologies
- Utilizes a ***bottom-up*** approach to identify an ***optimal technology/resource mix*** to meet demands in a balanced energy market
- Consists of a ***dynamic integrated framework*** to assess ***market competition***,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

Preliminary MARKAL Analysis

- All scenarios based on AEO2005 High "B" Oil Price Scenario
- IEA cost data from "Prospects for Hydrogen and Fuel Cells"
- Unless otherwise noted, gasoline HEVs and H2 FCVs are assumed to be 1.5 & 2.0 times as efficient than gasoline ICE vehicles

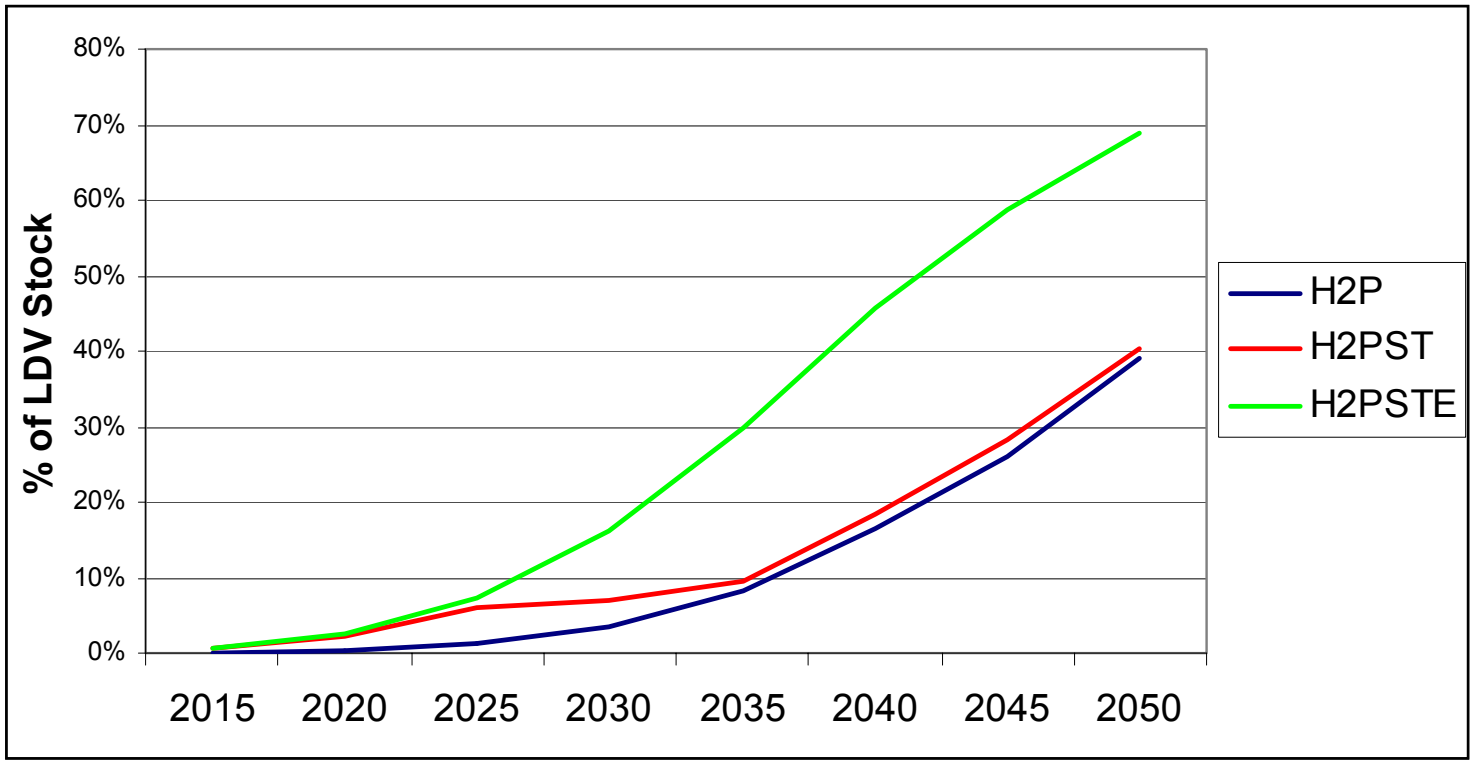
H2IO	- IEA "Optimistic" fuel cell costs
H2IOST	- H2IO + vehicle subsidy ($3,000 for 2015 & 2020, $1,500 for 2025) and H2 fuel taxes at ½ level of gasoline.
H2IOSTE	- H2IOSTE + H2 FCV assumed to be 3.0 times as efficient as gasoline ICE vehicles.
H2P	- HFCIT Program goals for fuel cell costs
H2PST	- H2P + vehicle subsidy ($3,000 for 2015 & 2020, $1,500 for 2025) and H2 fuel taxes at ½ level of gasoline.
H2PSTE	- H2PST + H2 FCV assumed to be 3.0 times as efficient as gasoline ICE vehicles.

Preliminary LDV Market Shares
IEA "Optimistic" Fuel Cell Costs



% of LDV Stock	2015	2020	2025	2030	2035	2040	2045	2050
H2IO	0.0%	0.0%	0.0%	2.4%	8.2%	16.4%	24.2%	36.4%
H2IOST	0.0%	0.0%	0.3%	2.8%	8.5%	16.7%	26.4%	40.5%
H2IOSTE	0.0%	0.0%	0.0%	5.9%	14.4%	26.5%	41.9%	63.8%

Preliminary LDV Market Shares
HFCTP Fuel Cell Cost Goals



% of LDV Stock	2015	2020	2025	2030	2035	2040	2045	2050
H2P	0.0%	0.2%	1.2%	3.5%	8.1%	16.4%	25.9%	38.9%
H2PST	0.6%	2.1%	6.0%	7.0%	9.5%	18.5%	28.2%	40.3%
H2PSTE	0.6%	2.4%	7.2%	16.3%	29.9%	45.6%	58.7%	69.0%

Unique Features of Project

- Integrates supply/demand and various fuel markets
- 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