DOE Hydrogen Program

and the

Role of Systems Analysis

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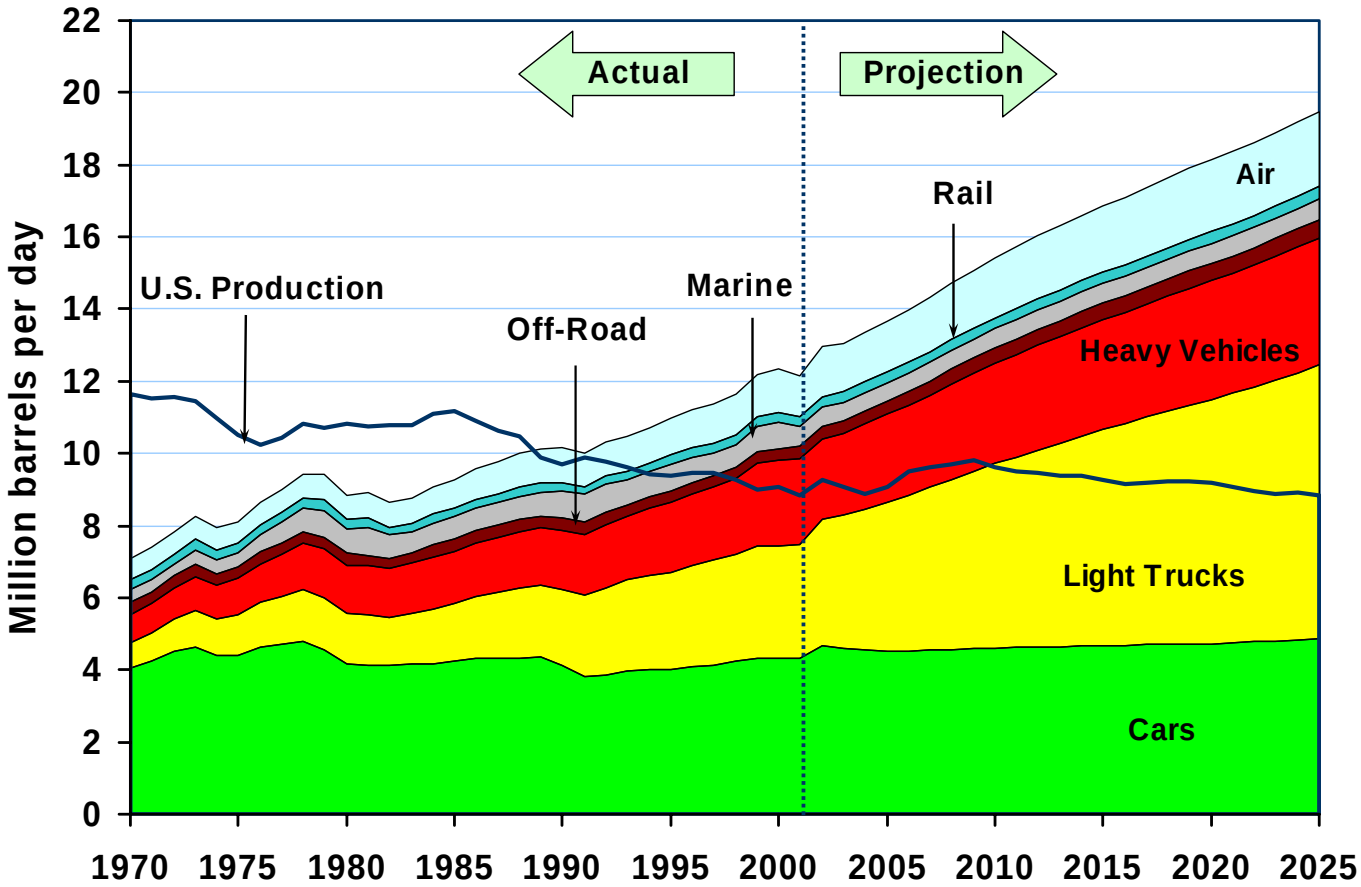
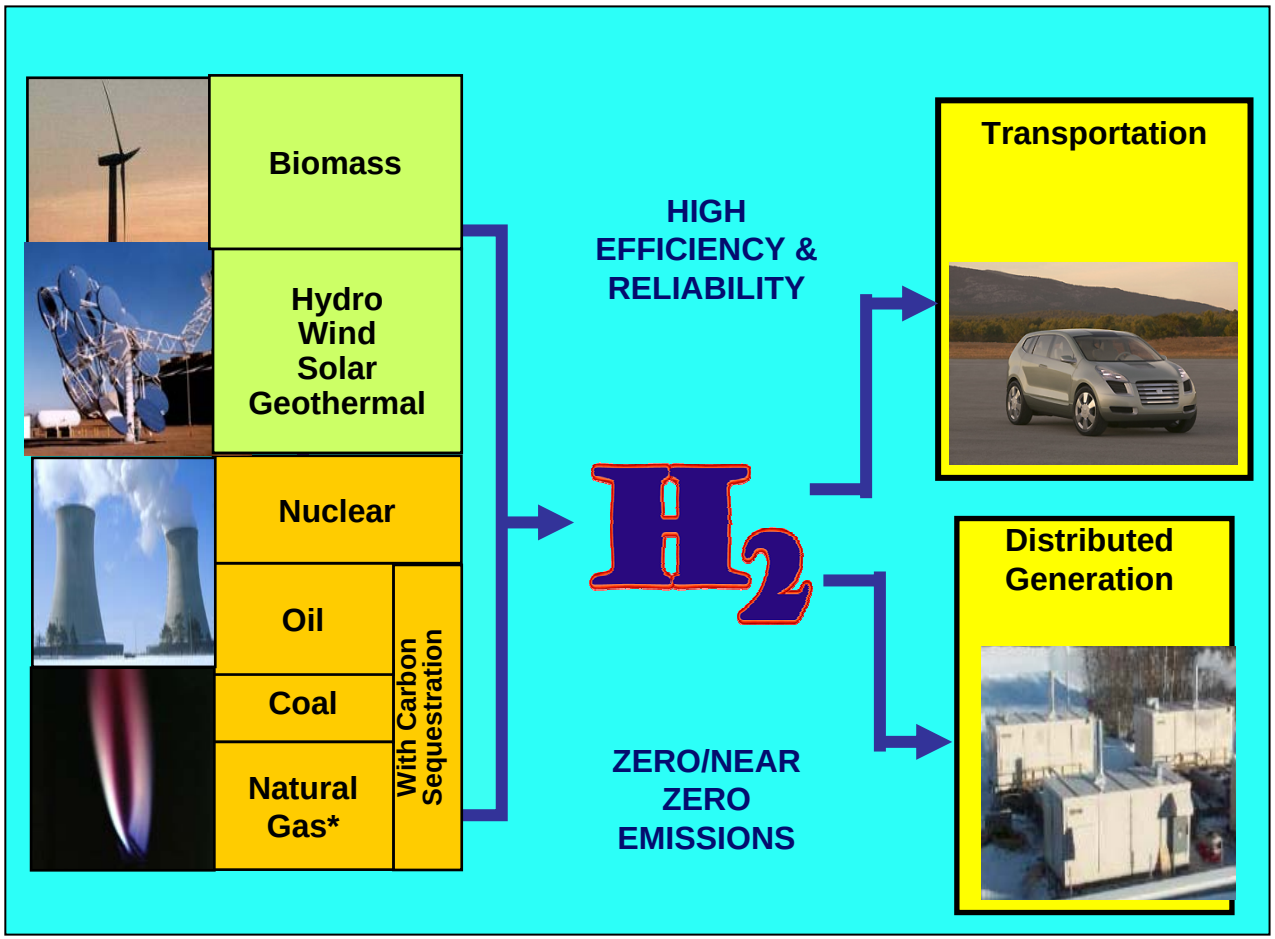
DOE Hydrogen Program
April 12, 2005

Transportation Petroleum Use by Mode (1970-2025)
2003 Total = 13.42 mbpd



Note: Domestic production includes crude oil, natural gas plant liquids, refinery gain, and other inputs. This is consistent with EIA, MER, Table 3.2. Previous versions of this chart included crude oil and natural gas plant liquids only.
Source: Transportation Energy Data Book: Edition 24, ORNL-6973, and EIA Annual Energy Outlook 2005, Preliminary release, December 2004.

Why Hydrogen?



Energy Security

- Produced from diverse domestic resources

Environment

- Mobile criteria pollutants eliminated
- Stationary emissions easier to control
- Greenhouse gas emissions reduced

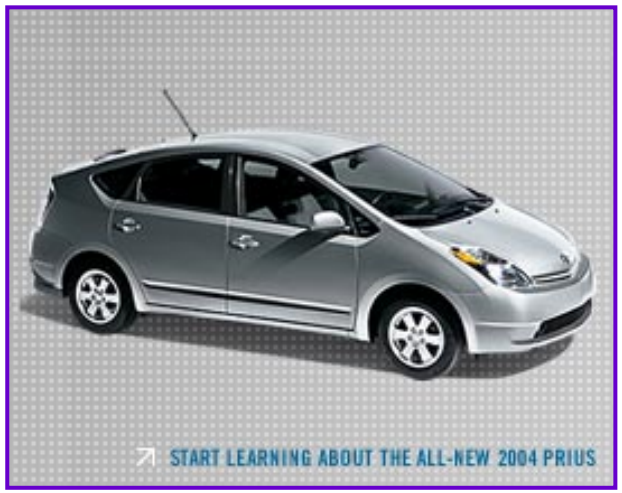
Economic Competitiveness

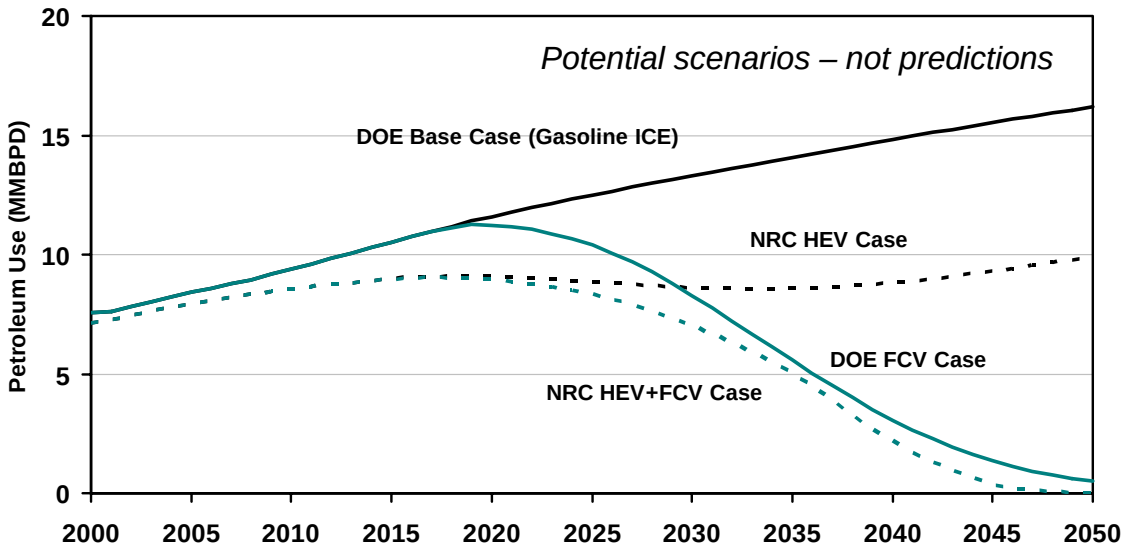
- Abundant, reliable, and affordable energy is an essential component in a healthy, global economy

It's abundant, clean, efficient, and can be derived from diverse domestic resources

Hybrids are a Bridge

***Hybrid vehicles** are a bridge technology that can reduce pollution and our dependence on foreign oil until long-term technologies like hydrogen fuel cells are market-ready.*





Hybrid/Hydrogen FCV Strategy

- Near-term focus on hybrids
  - Transition Phase to Hydrogen; decentralized H2 production from distributed natural gas
  - Long-term hydrogen fuel production from diverse domestic carbon free sources such as renewables, nuclear and coal with sequestration.

*Only carbon emissions come from energy used in hydrogen production & delivery process

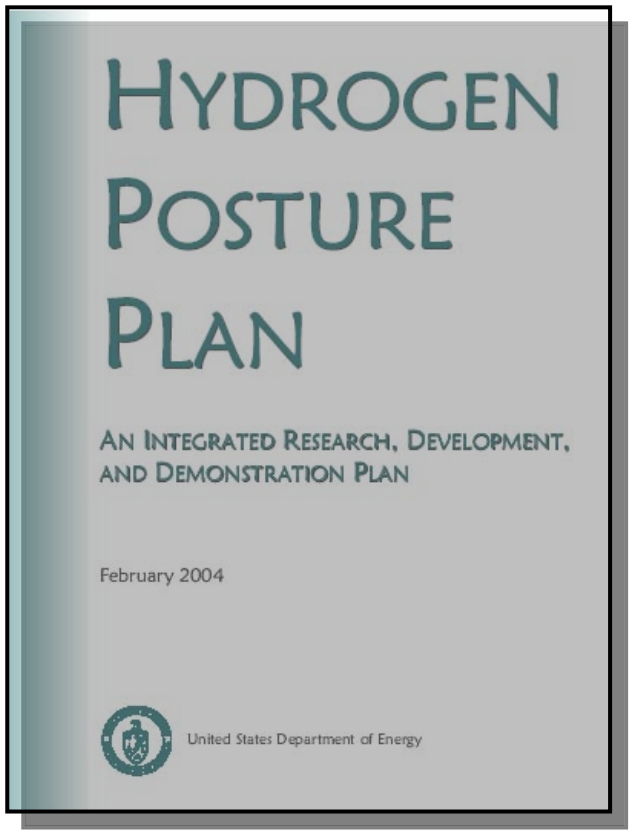
Hydrogen Infrastructure and Fuel Cell Technologies put on an Accelerated Schedule

- **President Bush commits a total $1.7 billion over first 5 years:**
  - **$1.2 billion for hydrogen and fuel cells RD&D ($720 million in new money)**
  - **$0.5 billion for hybrid and vehicle technologies RD&D**

- **Accelerated, parallel track enables industry commercialization decision by 2015.**

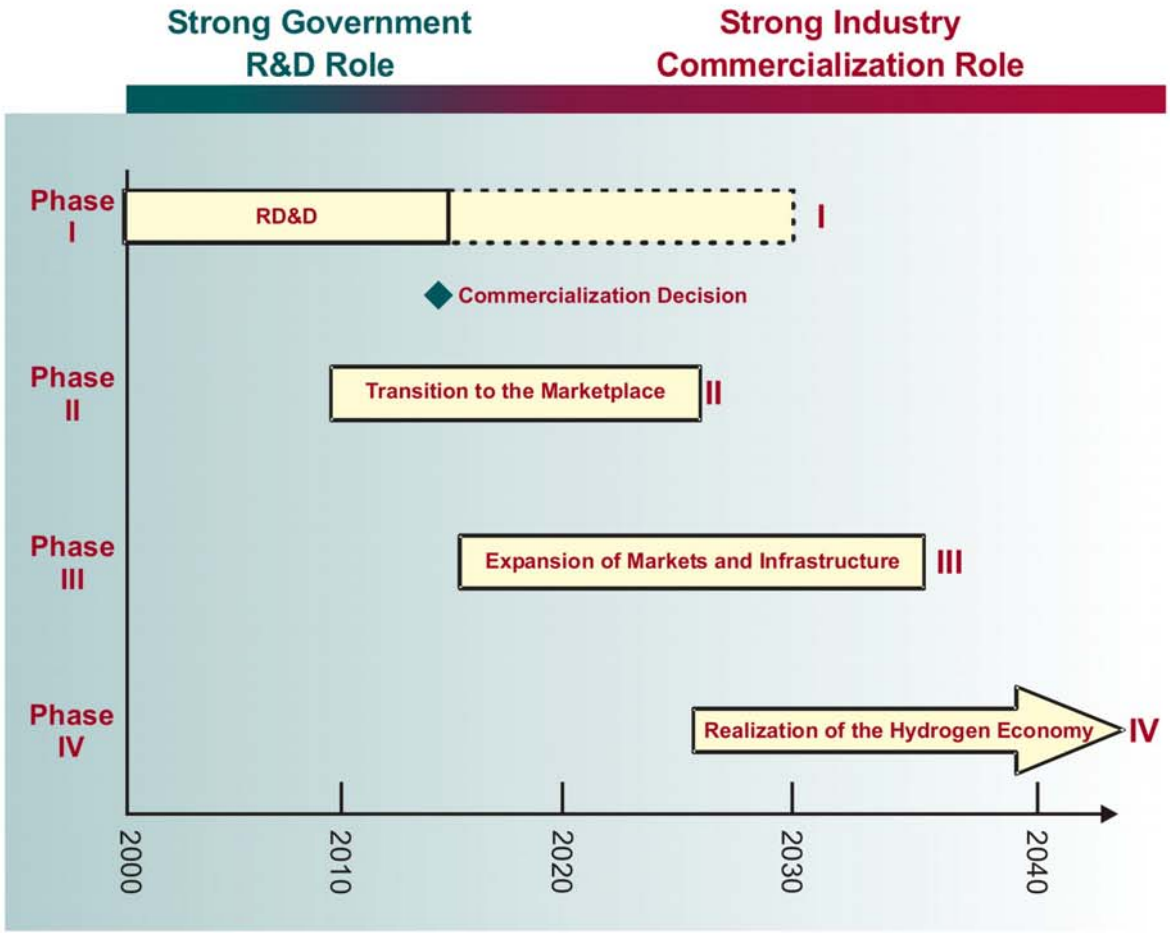
Fuel Cell Vehicles in the Showroom and Hydrogen at Fueling Stations by 2020

Integrated Plan Developed to Overcome Challenges



- Describes technology development to support commercialization decision by industry in 2015
- Covers basic research through technology validation
  - Office of Science
  - Office of Fossil Energy
  - Office of Nuclear Energy, Science and Technology
  - Office of Energy Efficiency and Renewable Energy
- Identifies performance-based milestones for stakeholders to track progress

Timeline for a Hydrogen Economy



Transitional Phases

I. Technology Development Phase

Research to meet customer requirements and establish business case lead to a commercialization decision

II. Initial Market Penetration Phase

Portable power and stationary/ transport systems begin commercialization; infrastructure investment begins with governmental policies

III. Infrastructure Investment Phase

H_2 power and transport systems commercially available; infrastructure business case realized

IV. Fully Developed Market and Infrastructure Phase

H_2 power and transport systems commercially available in all regions; national infrastructure

Positive commercialization decision in 2015 leads to beginning of mass-produced hydrogen fuel cell cars by 2020

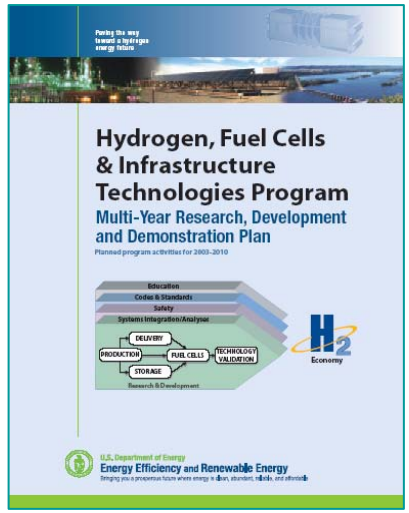
Barriers to a Hydrogen Economy

Critical Path Technology Barriers:

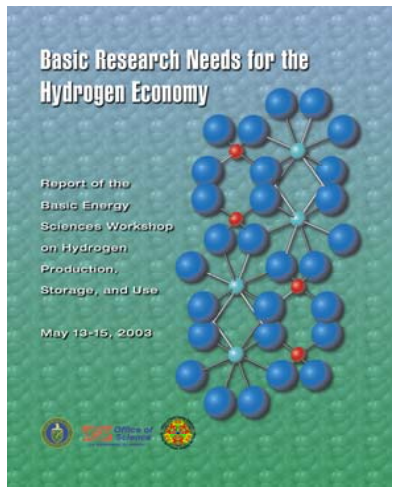
- Hydrogen Storage (>300 mile range)
- Hydrogen Production Cost ($1.50-2.00 per gge)
- Fuel Cell Cost (< $50 per kW)

Economic/Institutional Barriers:

- Codes and Standards (Safety, and Global Competitiveness)
- Hydrogen Delivery (Investment for new Distribution Infrastructure)
- Transition from a Hydrocarbon-Based Economy to a Hydrogen-Based Economy
- Education

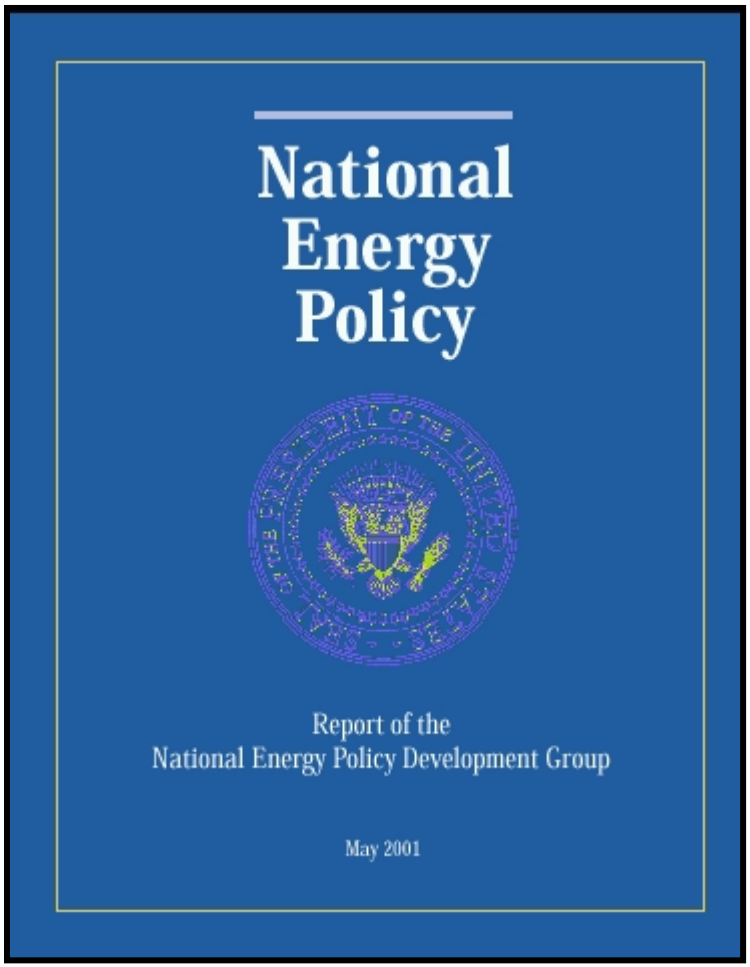


http://www.eere.energy.gov/hydrogenanfuelcells/mypp/



http://www.er.doe.gov/production/bes/hydrogen.pdf

The National Energy Plan (NEP)



NEP Recommended:

- Increasing international cooperation on finding alternatives to oil, especially for the transportation sector
- Promotion of market-based solutions to environmental concerns
- Support of exports of U.S. clean energy technologies and encourage overseas development activities,
- To explore collaborative international basic research and development in energy alternatives and energy-efficient technologies,
- Exploration of innovative programs to support the global adoption of these technologies.

FreedomCAR and Fuel Partnership Established

bp ChevronTexaco ConocoPhillips ExxonMobil

DaimlerChrysler Ford GM

New Energy Company/DOE Technical Teams

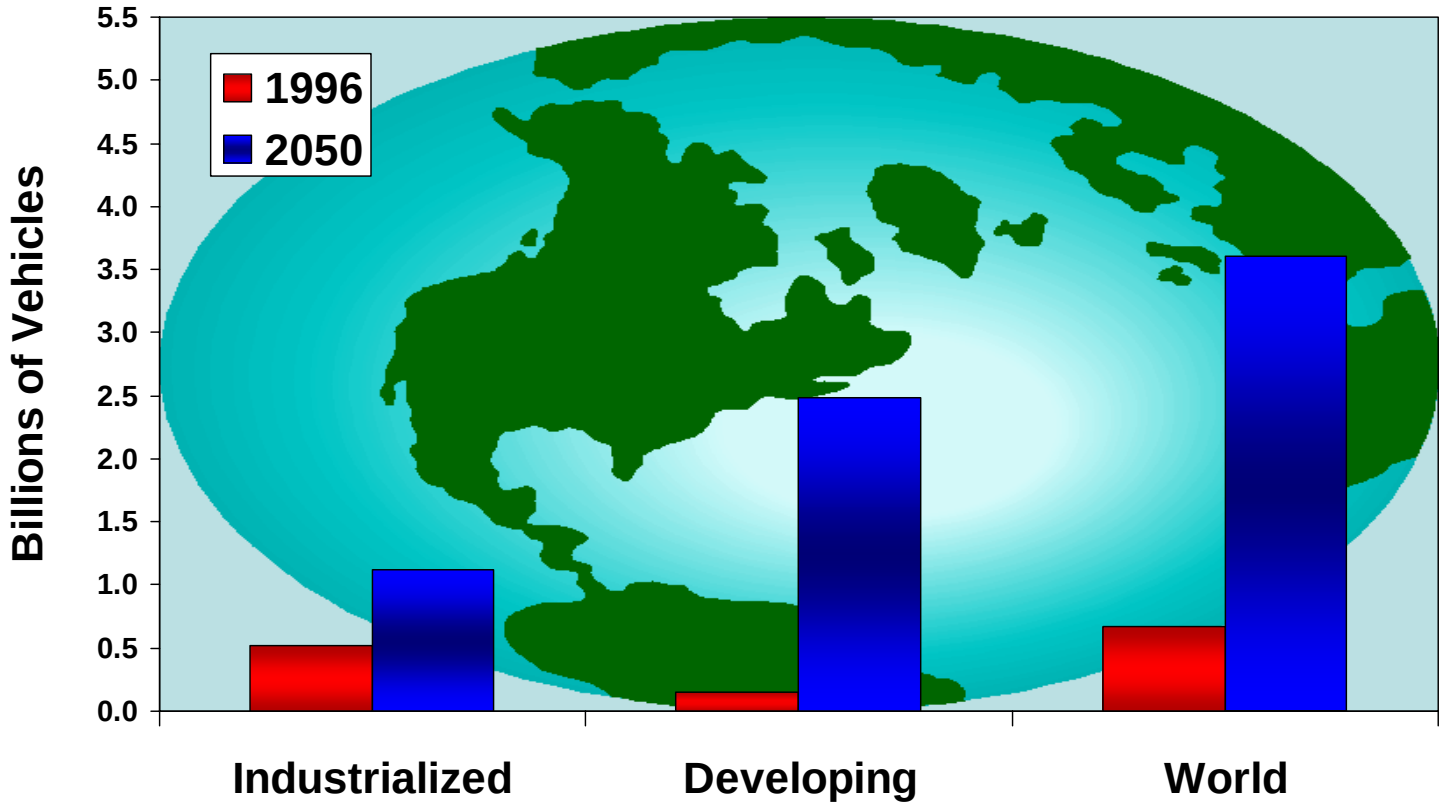
- Production
- Delivery
- Fuel Pathway Integration

New Joint Auto/Energy/DOE Technical Teams

- Codes and Standards
- Storage

Global Perspective

. . . the Number of Vehicles in the World Is Growing



Source: EE Analytic Team

Many countries have concerns about energy and environmental security related to transportation/mobility

International Partnership for the Hydrogen Economy

Russian Federation

USA

Canada

Iceland

Japan

South Korea

China

India

Australia

Brazil

Norway

European Commission

United Kingdom

France

Germany

Italy

IPHE Partners' Economy:

- Over $35 Trillion in GDP, 85% of world GDP
- Nearly 3.5 billion people
- Over 75% of electricity used worldwide
- > 2/3 of CO_2 emissions & energy consumption

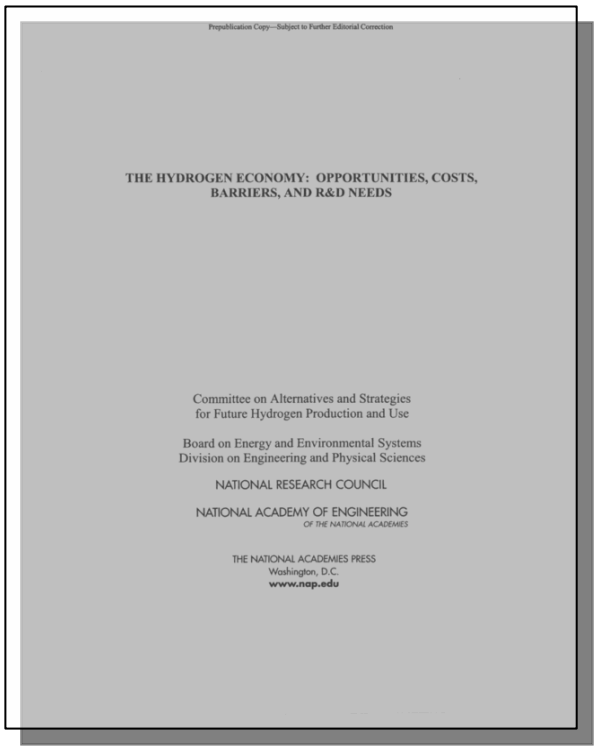
IPHE Vision:

"… consumers will have the practical option of purchasing a competitively priced hydrogen power vehicle, and be able to refuel it near their homes and places of work, by 2020."

- Secretary Abraham, April 2003

DOE Requested the National Academies to Evaluate its Hydrogen Planning

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine



"A transition to hydrogen as a major fuel in the next 50 years could fundamentally transform the U.S. energy system, creating opportunities to increase energy security through the use of a variety of domestic energy sources for hydrogen production while reducing environmental impacts …"

"This committee believes that investigating and conducting RD&D activities to determine whether a hydrogen economy might be realized are important to the nation."

DOE is Evolving its H_2 Program to Respond to NRC Recommendations

- Focus on the "transition" to a hydrogen economy, critical issues needed for 2015 decision
  - Exploratory research on hydrogen storage and fuel cell cost & durability
  - "Laser-like" focus on distributed hydrogen infrastructure. Lower capital costs & increase efficiency of natural gas reformers and electrolyzers
- Let the long-term hydrogen economy "evolve"
  - Fundamental and exploratory research on coal/carbon capture sequestration, photoelectrochemical, photobiological, thermochemical, etc.

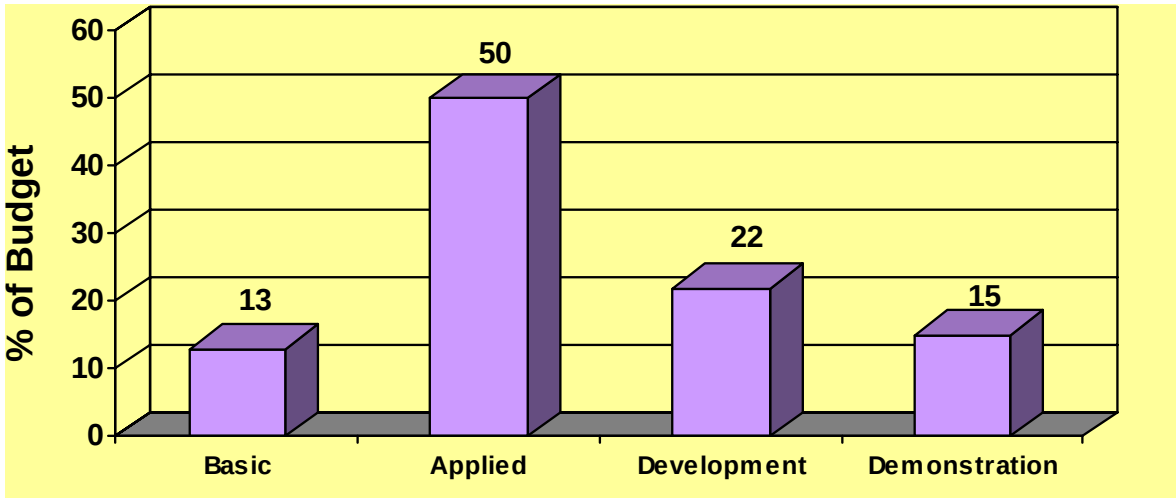
The National Academies' conclusions support the President's vision.
DOE concurs fully with 35 of 43 recommendations.
Currently evaluating other 8 for implementation.

Path Forward to Implement the NRC Recommendations

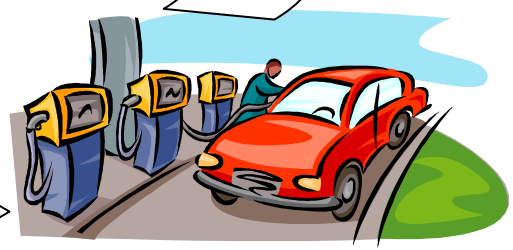
- Use hydrogen storage model to shift emphasis in fuel cells to exploratory research for cost & durability
- Increase investments in natural gas reforming and electrolyzers (treat these as critical path)
- Employ systems analysis to map out options and a transition plan consistent with developing infrastructure
- Strengthen infrastructure program (storage, purity, pipeline materials, compressors, leak detection, permitting, and codes/standards)
- Increase underlying safety research and analysis
- Establish fundamental science efforts in longer term hydrogen production concepts, storage, fuel cells, etc.
- Integrate with carbon capture/sequestration and across all department programs

Balanced Program Being Implemented

FY 2006 Total Budget Request by Category ($259.5M)



Research & Development



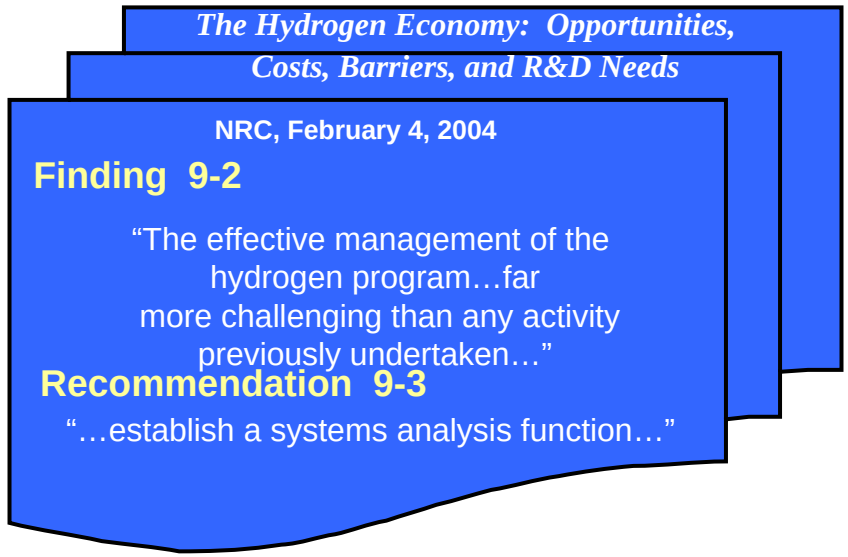
Technology Validation through "Learning Demonstrations"

Systems Analysis

Introduction

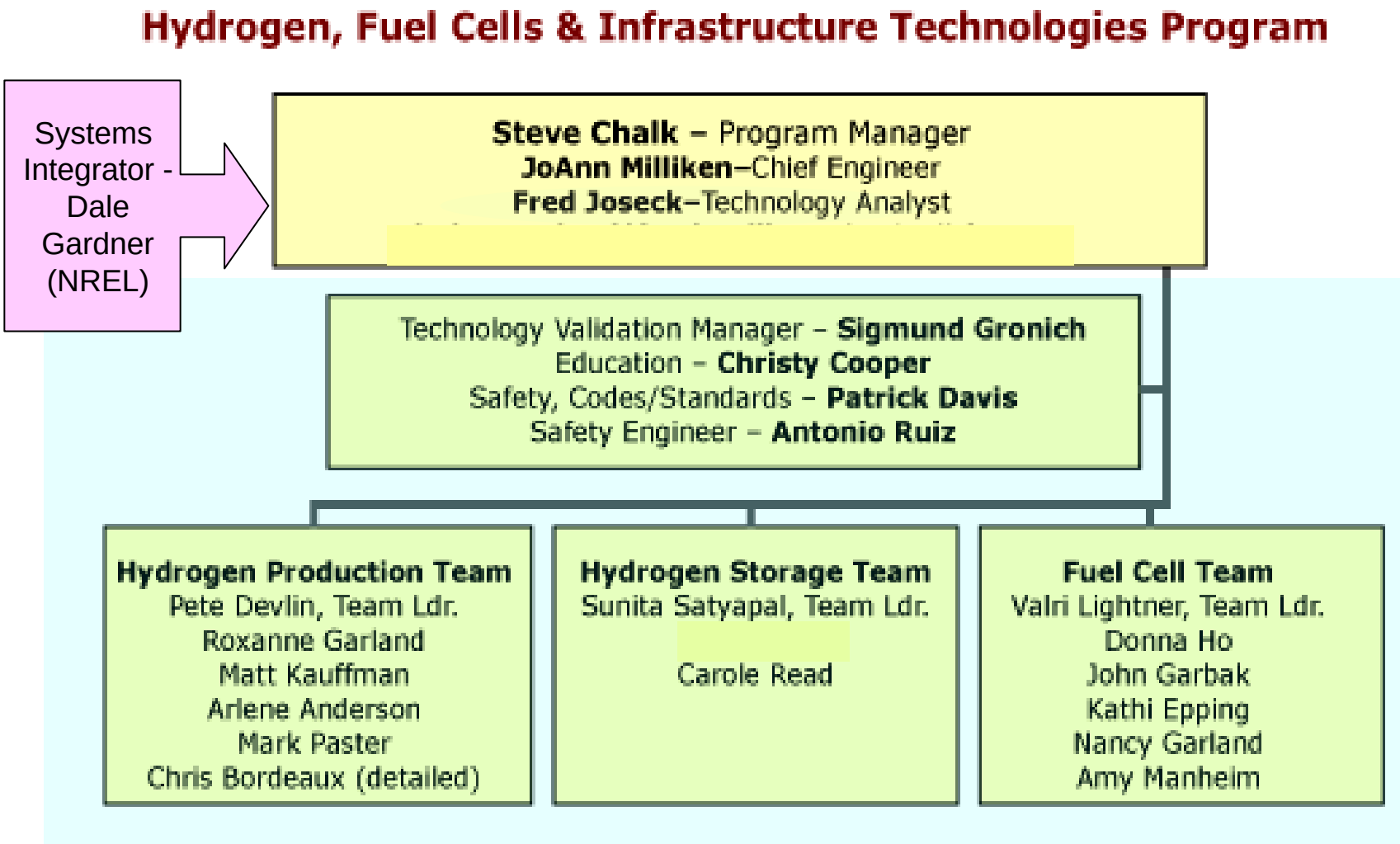
Systems Analysis

- **Coordinated, comprehensive analytical and modeling function for the DOE Hydrogen Program.**
- **Integrated process linking modeling tools and resources.**
- **Foundation for decision making from a consistent set of inputs.**



- **The importance and need of a robust Systems Analysis capability, supporting the DOE Hydrogen Program, was identified in the National Research Council and National Academy of Engineering report (The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs, February 2004).**

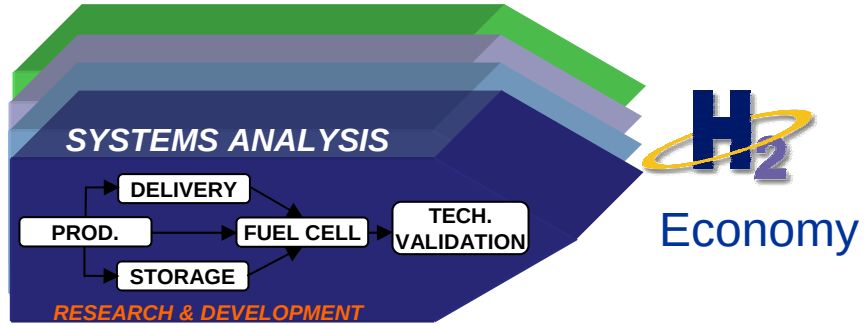
Organization



Systems Analysis

Purpose

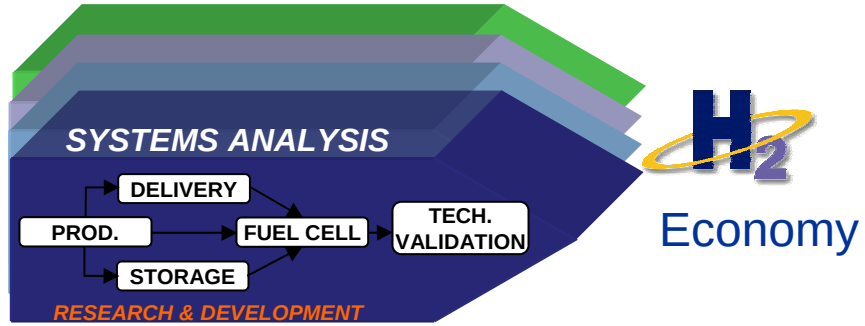
- Identify the impacts of various hydrogen technology pathways.
- Identify the key costs, associated cost elements and the cost drivers.
- Evaluate the research and development status and priorities.
  - Evaluate the significance of R&D results.
  - Assess and make recommendations concerning the progress of R&D efforts.



Key Barriers and Systems Analysis

Key Barriers to be addressed through Systems Analysis

- Infrastructure requirements and development
- Transition
  - Understanding the transition from a hydrocarbon based economy to a hydrogen based economy.
  - Vehicle penetration



Means

- Modeling
- Analysis
- Analysis community

Systems Analysis

Systems Analysis Projects in 2005

Project	Organization	Project Type/Description
Macro-System Model	NREL	Model development for overarching modeling of infrastructure, transition and production.
Transitional Analysis	DTI	Transition Analysis with available resources and infrastructure.
Transitional Analysis	EEA	Transitional analysis with Markal model with focus on competition between H2 production with respect to demand.
Transitional Analysis	RCF	New model for transition analysis will be built with an AGENT based modeling philosophy.
Emissions Analysis	ANL	Analyze the WTW emissions for various production, delivery and transition scenarios.
Fuels Choice	TIAX	Risk based analysis for fuels choice options.
Infrastructure Anal.	NREL	Analysis of infrastructure with the Geographic Information System.
HyDS	NREL	Model development for the optimization of hydrogen production, delivery and infrastructure using the WINDS framework.

Summary

Cost Reduction is a Primary R&D Driver

Hydrogen Production and Delivery

Cost of hydrogen must be competitive with gasoline, without adverse environmental impacts

- **$1.50/gge-$2.00/gge untaxed**

Hydrogen Storage

Capacity must enable >300-mile range, and meet packaging, performance, and cost requirements

- **$2/kWh (~ $300 for 5-kg H_2 storage system)**

Fuel Cells

System cost must be competitive with ICE and meet performance and durability requirements

- **$30/kW (~ $2400 for an automotive fuel cell system)**

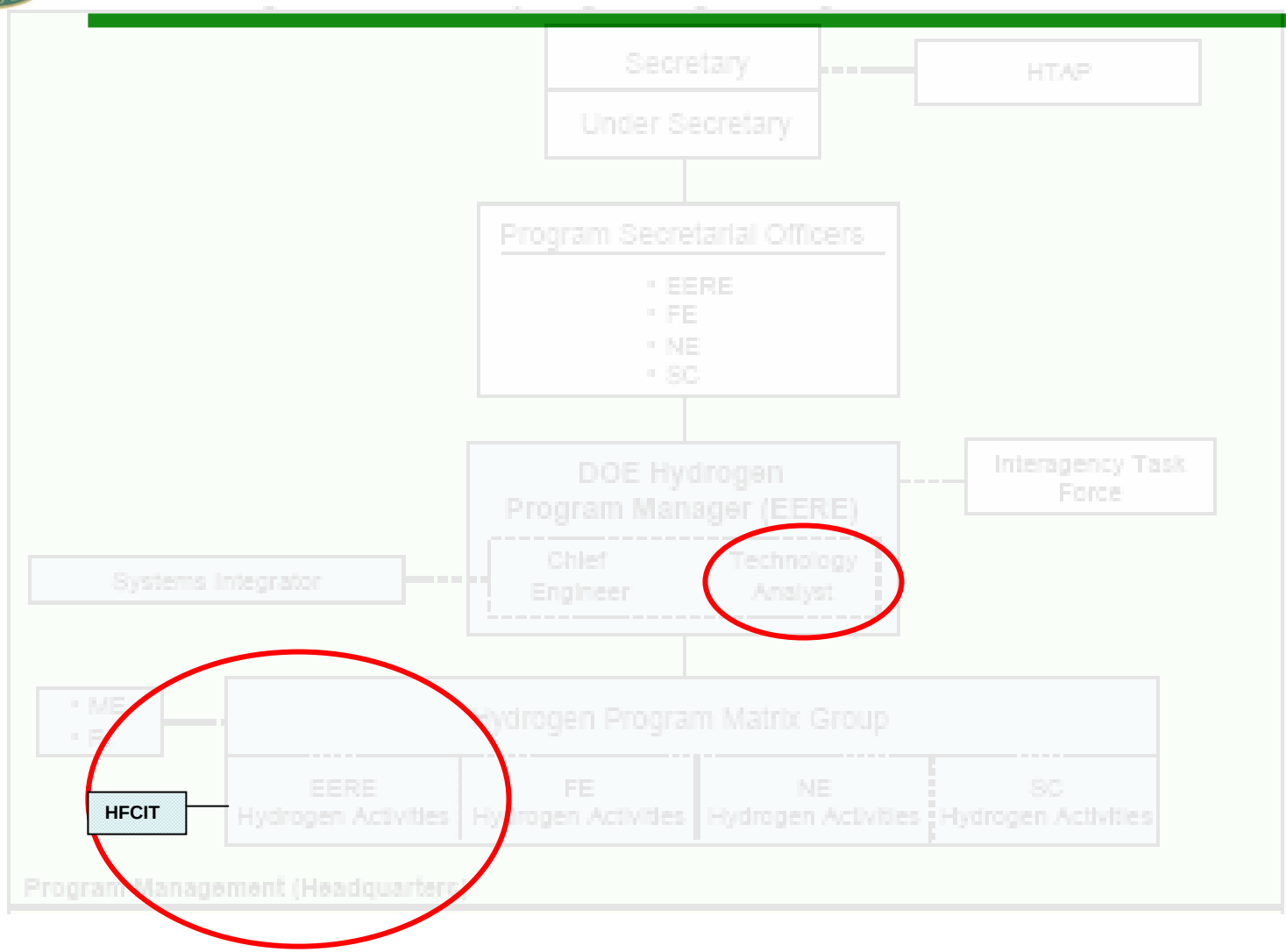
High-volume manufacturing processes are critical to meeting cost targets.

Systems Analysis will be focusing on infrastructure and transition analysis.

A lot of work ahead…

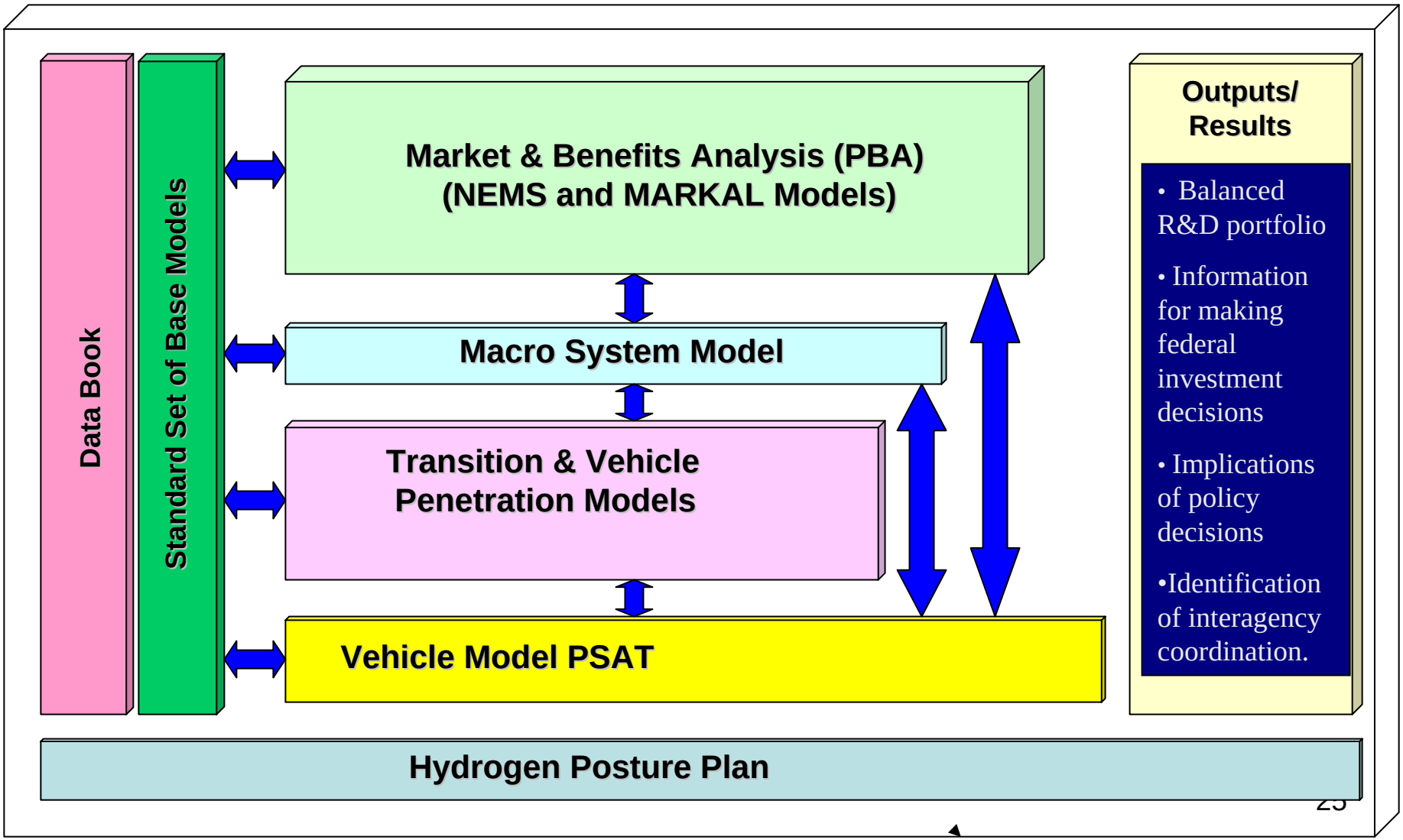
Backup

Organization



Systems Analysis

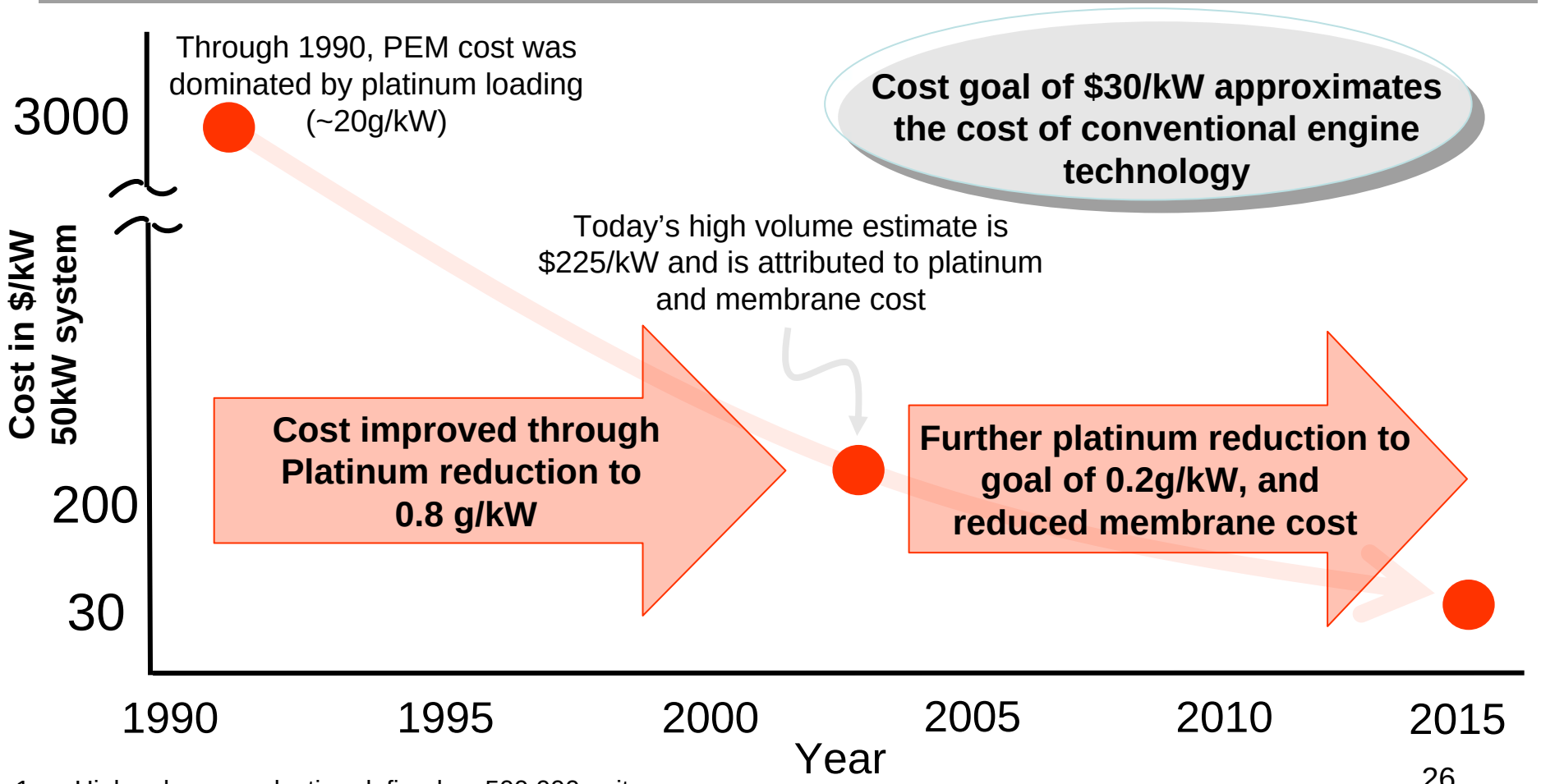
Hydrogen Modeling Methodology Overview



PEM Fuel Cell Cost

7X gap between today's high volume cost & our target

Cost of a fuel cell prototype remains high (~$3,000/kW), but the high volume[1] production cost of today's technology has been reduced to $225/kW



1. High volume production defined as 500,000 units per year
2. Cost estimated by Tiax with enhanced hydrogen storage.

Distributed Hydrogen Production From Natural Gas On Target

- **APCI validated $3.60/gge hydrogen – delivered, untaxed, co-producing electricity at 8¢ per kWh.**
- **$3.00/gge target in 2005 within reach**
- **Reformer research**
  - **Optimized desulfurization, reformer, and shift catalysts**
  - **Improved heat recovery system**
- **PSA research**
  - **99.999% pure H_2**
  - **3x cost reduction compared to commercial units**
  - **Decreased size**
  - **82% efficiency (64% in 2003)**

Las Vegas station

PSA Unit

In 2025, assuming FCVs represent 12% of LDV inventory, EIA estimates only 2.8% increase in natural gas demand compared to reference case

Analysis Roles & Responsibilities

TECHNOLOGY ANALYST

- **Accountable for analysis activities**
- **Provide inputs/priorities to the Analysis Agenda**
- **Advises PM on policy issues**
- **Assure communication of a consistent data and info**
- **Provide analysis that is inherent Govt responsibility**
- **Provide analysis in response to short-term and urgent requests (quick-response tasks)**
- **Primary direction/guidance interface with TDMs/subprograms and Tech Teams**
- **Provide analysis coordination within DOE (EERE programs, Offices, PBA, EIA)**
- **Interpret analysis scenarios provided by SI**

Analysis Roles & Responsibilities

NREL SYSTEMS INTEGRATION

- **Develop Analysis Agenda (including technical and time pathways)**
- **Develop, maintain, resolve consistent data sets/info and standard analysis assumptions and guidelines**
- **Provide independent analysis (policy-related issues, Go/No-Go recommendations, H2 in the context of larger energy markets, etc.)**
- **Ensure tools/models are developed, maintained, available, validated**
- **Provide independent review of analysis results**
- **User and/or requestor of info generated by TA (especially from other parts of DOE)**
- **Define analysis scenarios**