The U.S. Hydrogen Program

Working Toward a Hydrogen Future

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U.S. Department of Energy

Drivers, Benefits, Timeline

President Bush Launches the Hydrogen Fuel Initiative

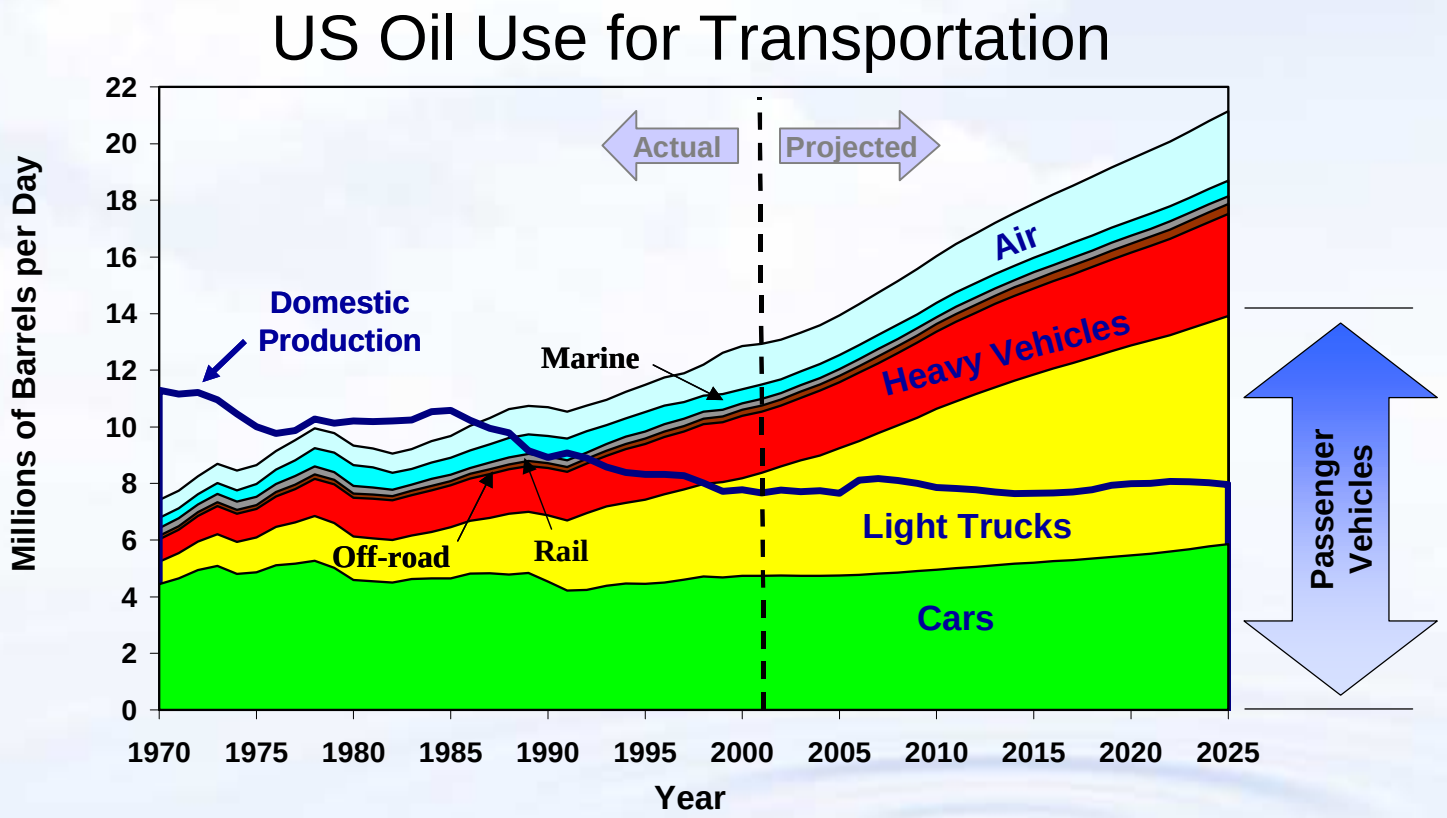
"Tonight I am proposing $1.2 billion in research funding so that America can lead the world in developing clean, hydrogen-powered automobiles."

"A simple chemical reaction between hydrogen and oxygen generates energy, which can be used to power a car producing only water, not exhaust fumes. With a new national commitment, our scientists and engineers will overcome obstacles to taking these cars from laboratory to showroom so that the first car driven by a child born today could be powered by hydrogen, and pollution-free."

"Join me in this important innovation to make our air significantly cleaner, and our country much less dependent on foreign sources of energy."

President George W. Bush
2003 State of the Union Address
January 28, 2003

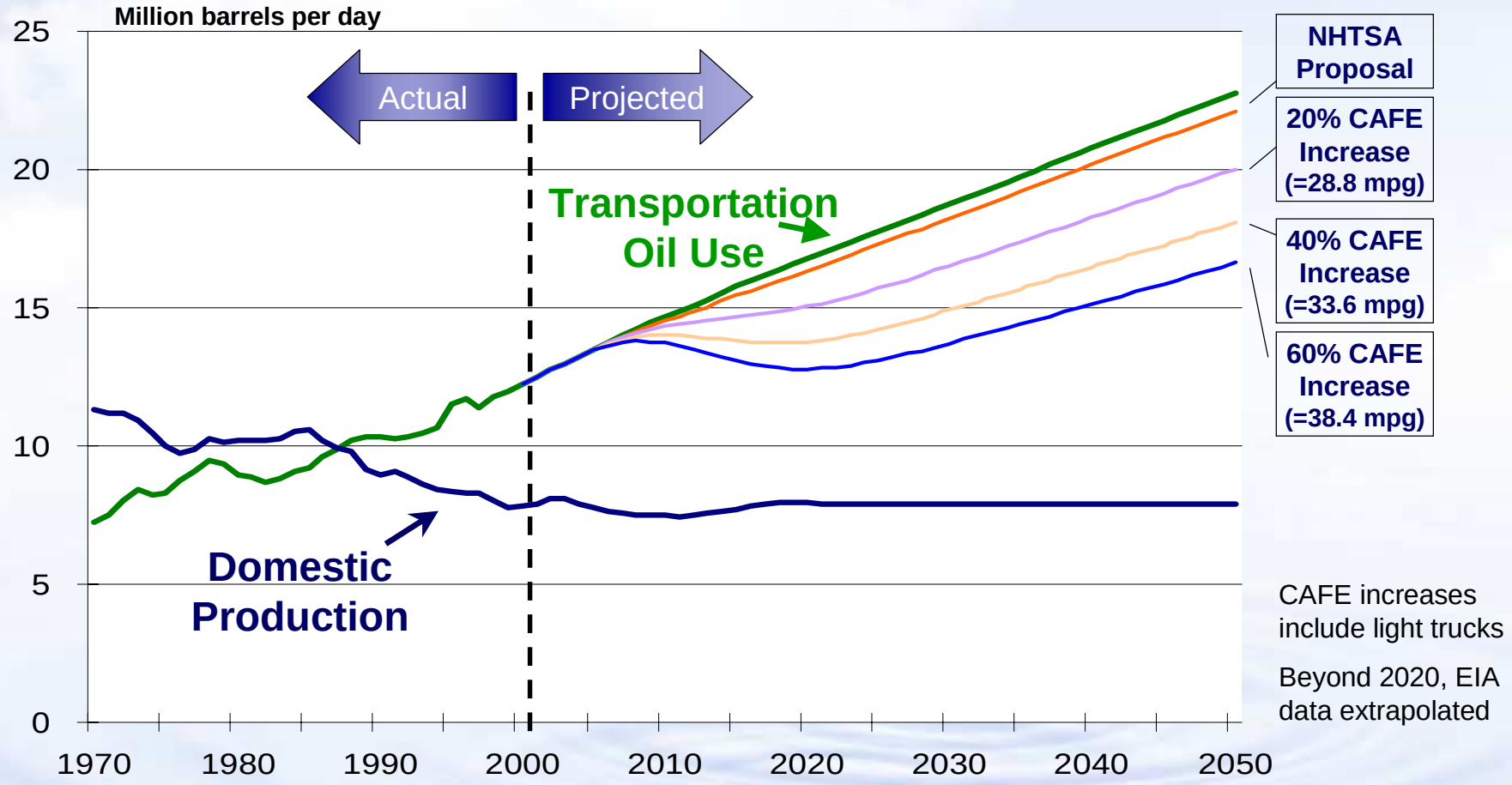
U.S. Energy Dependence is Driven By Transportation



Source: Transportation Energy Data Book: Edition 22, September 2002, and EIA Annual Energy Outlook 2003, January 2003

- **Transportation accounts for 2/3 of the 20 million barrels of oil our nation uses each day.**
- **The U.S. imports 55% of its oil, expected to grow to 68% by 2025 under the status quo.**
- **Nearly all of our cars and trucks currently run on either gasoline or diesel fuel.**

Increasing Fuel Economy Helps Reduce Oil Use in Near Term, but Substitution for Petroleum is Required for Long-term Energy Independence



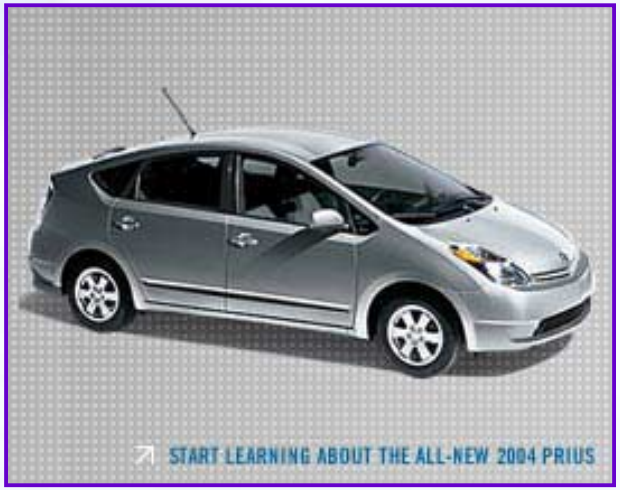
CAFE increases include light trucks

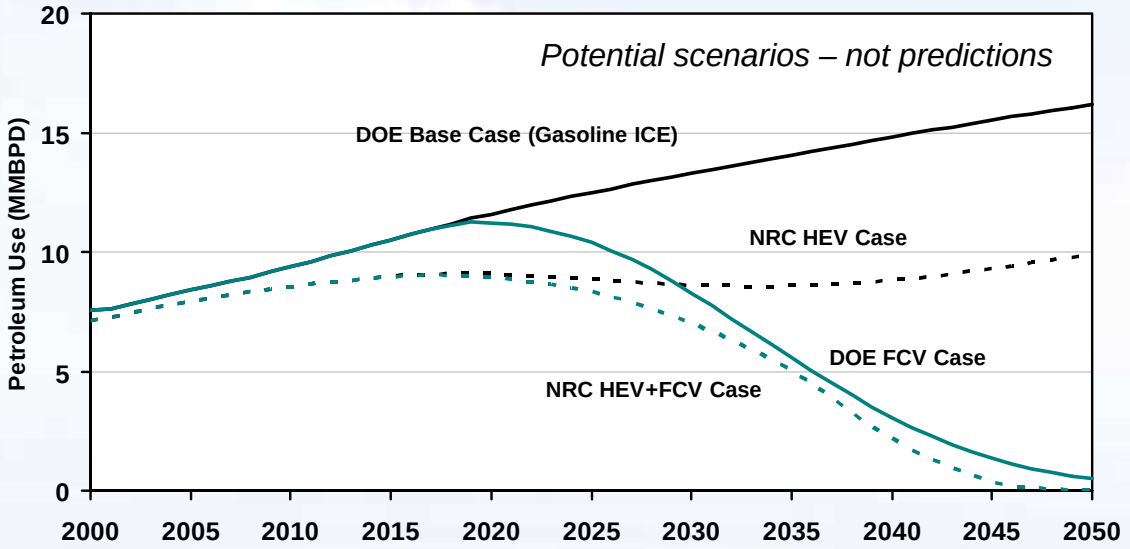
Beyond 2020, EIA data extrapolated

DOE is promoting hybrid vehicles in near-term and hydrogen research for long-term.

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 H_2 production from distributed natural gas**
- **Long-term hydrogen fuel production from diverse domestic carbon-free sources such as renewables, nuclear, and coal with sequestration.**

Hydrogen is the Key to a Secure and Clean Energy Future

- **Energy Security**

Can be produced from a variety of domestic sources

- **Environmental**

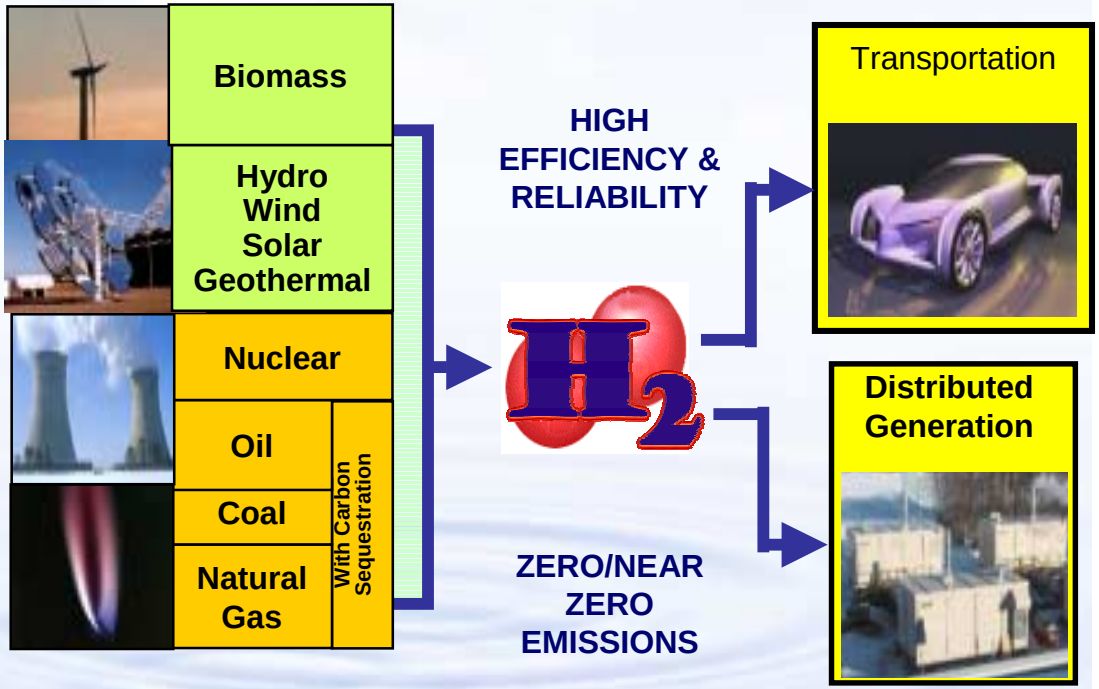
Criteria pollutants from mobile sources eliminated

Emissions from stationary H_2 production sites easier to control

Greenhouse gas emissions significantly reduced

- **Economic Competitiveness**

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

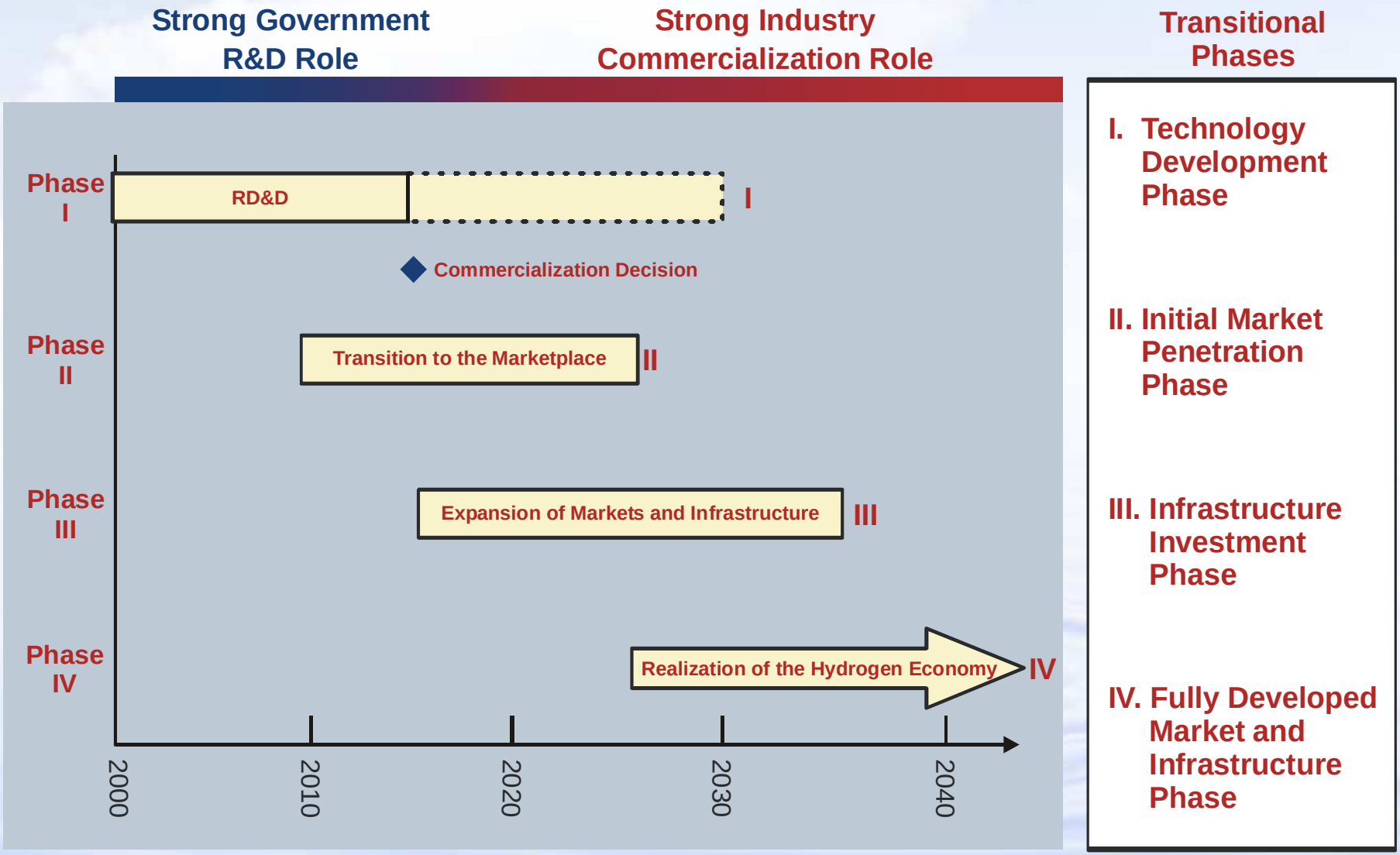


Hydrogen Infrastructure and Fuel Cell Technologies put on an Accelerated Schedule

- **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

Timeline for the Hydrogen Economy



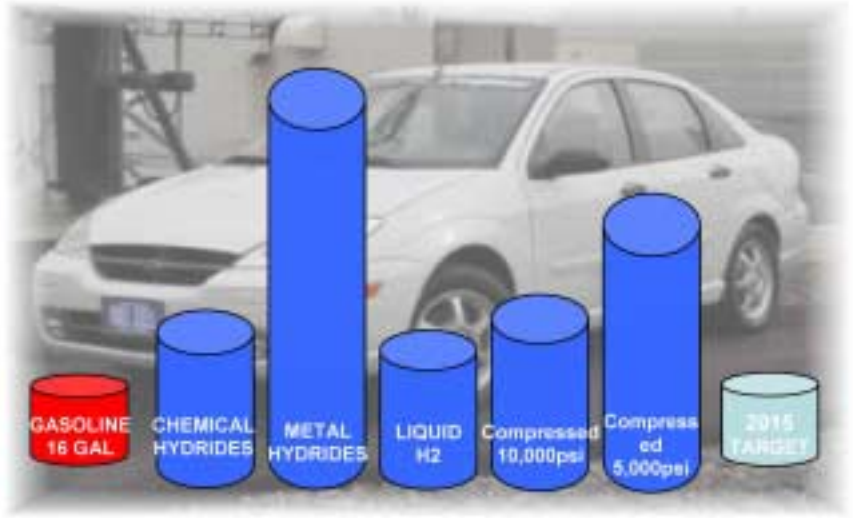
Challenges

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)

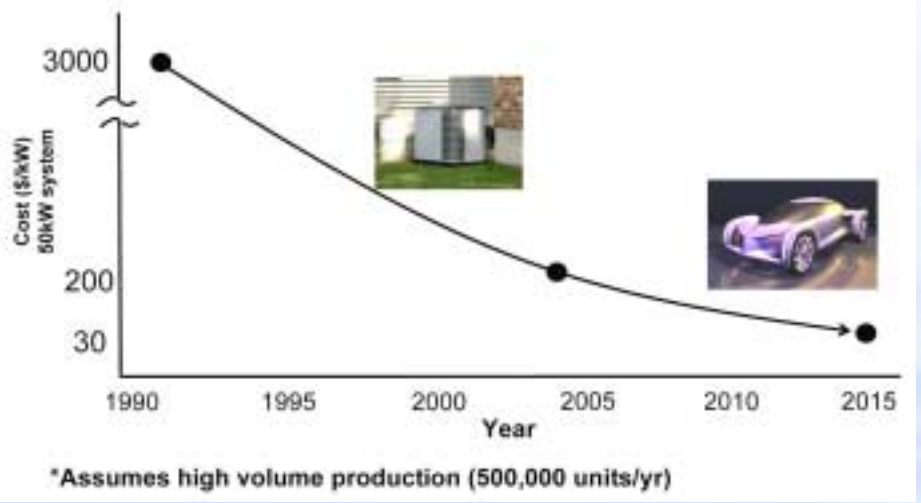
Storage Volume for >300 Mile Range



Economic/Institutional Barriers:

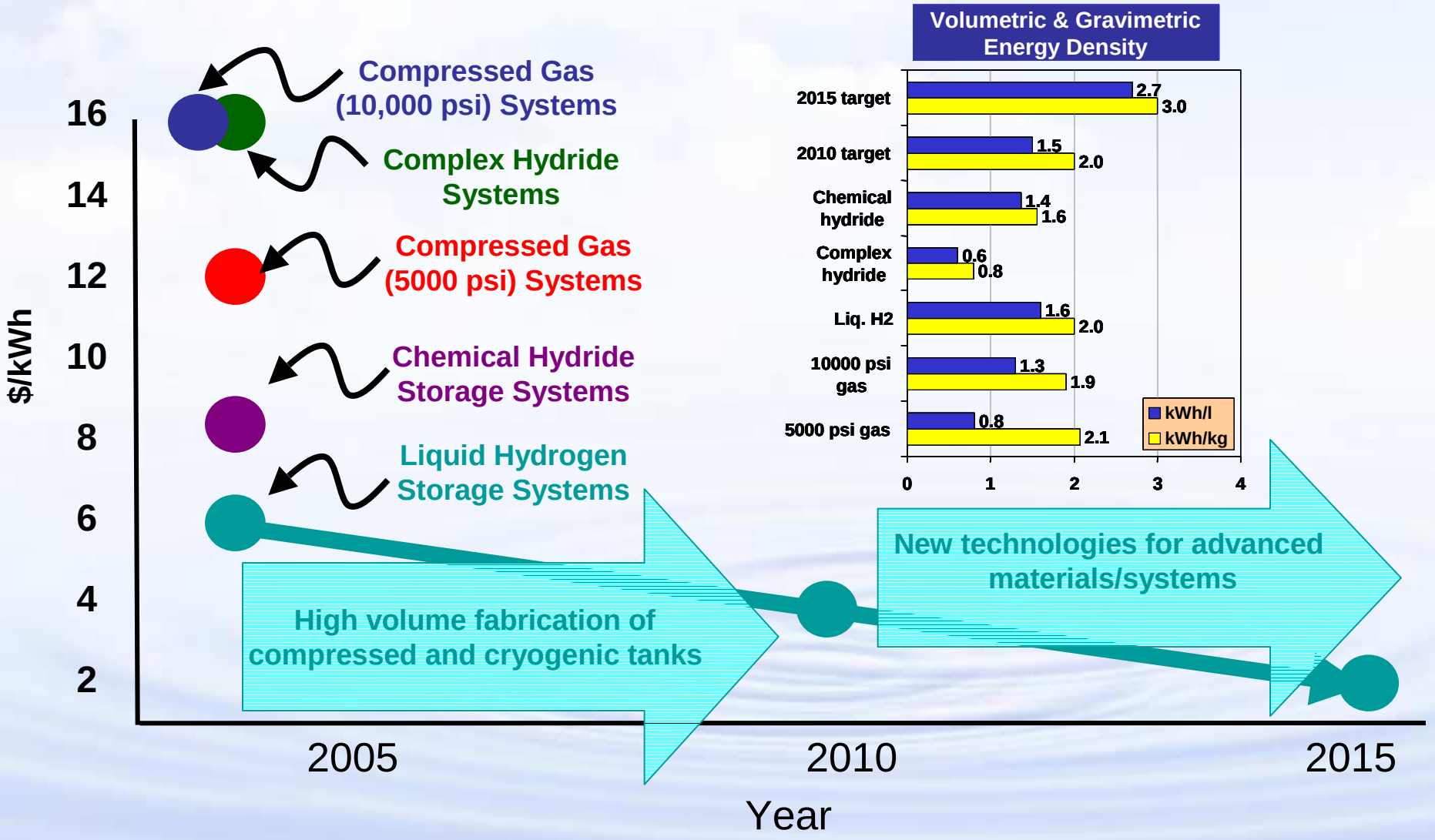
- Safety, Codes and Standards (Safety and global competitiveness)
- Hydrogen Delivery (Investment for new distribution infrastructure)
- Education

Fuel Cell Cost



Hydrogen Storage

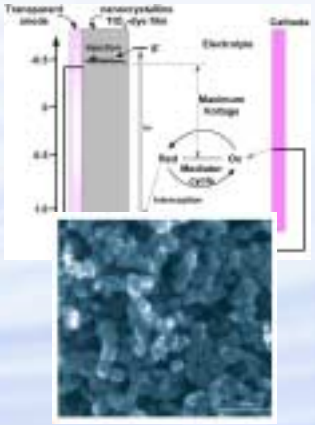
3-8X gap between today's storage system cost and target



H_2 Production Strategies

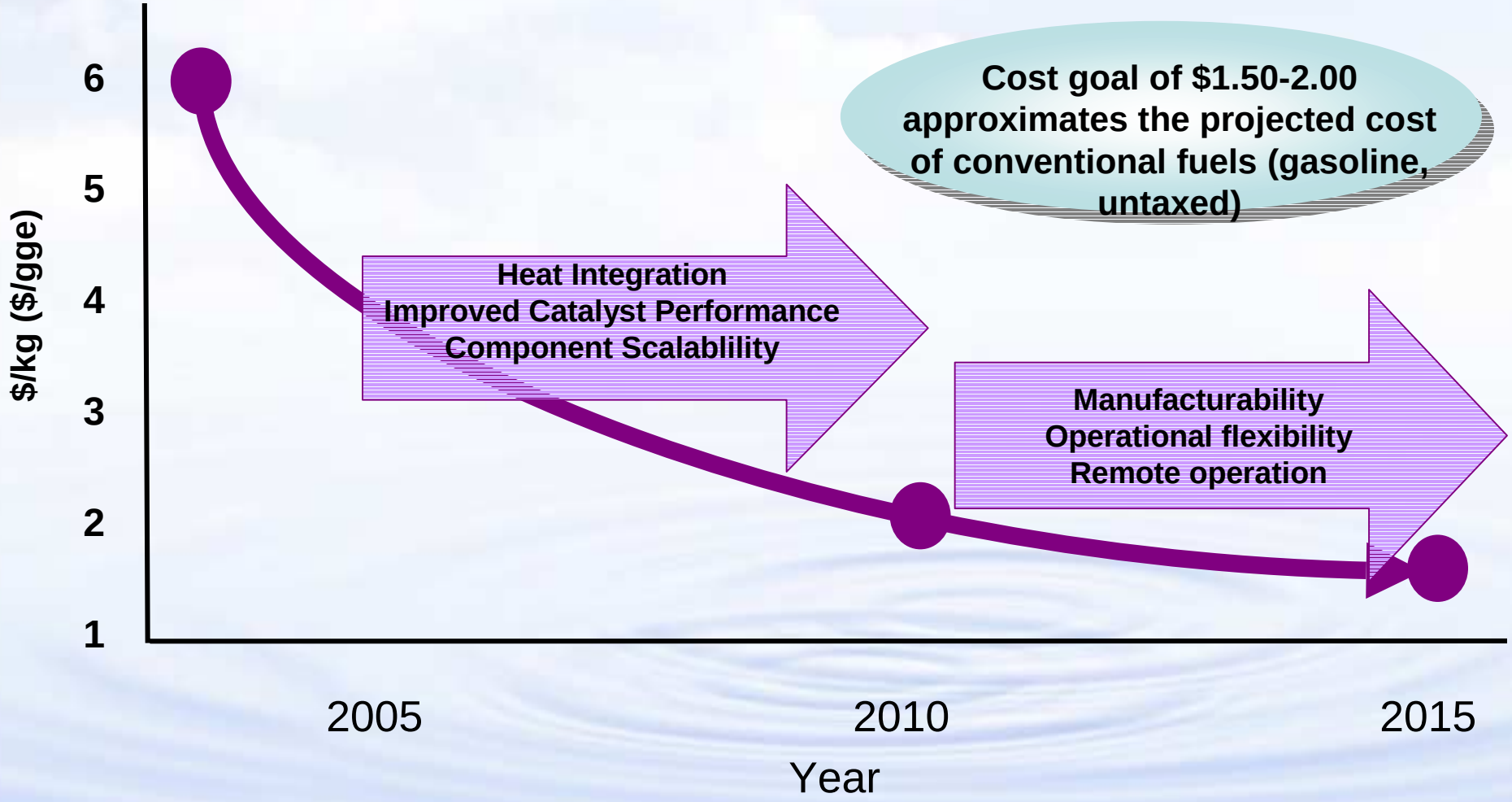
Distributed natural gas and electrolysis economics are important for the "transition"

Energy resource diversification is important for the long-term



Hydrogen Production

3-4X gap between today's high volume cost and target



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)**

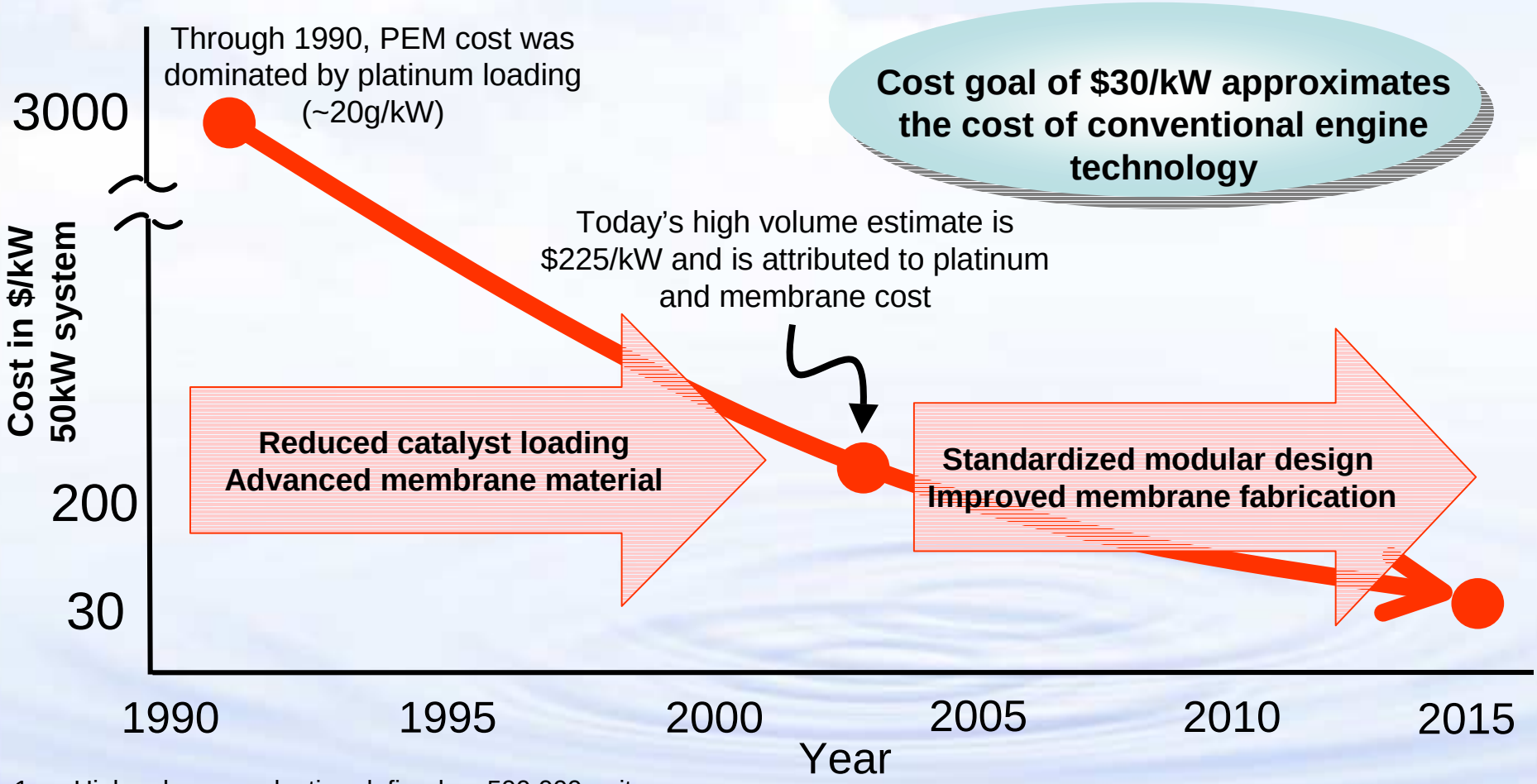
Las Vegas station

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

PEM Fuel Cells

7X gap between today's high volume cost and target



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

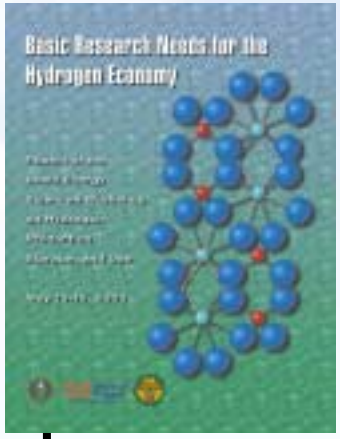
Progress

Summary of U.S. Planning and Implementation

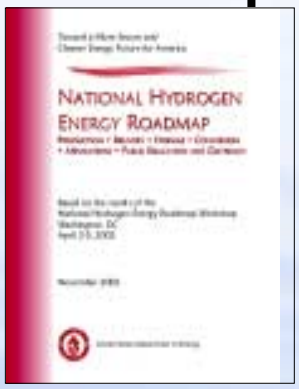
President's Hydrogen Fuel Initiative

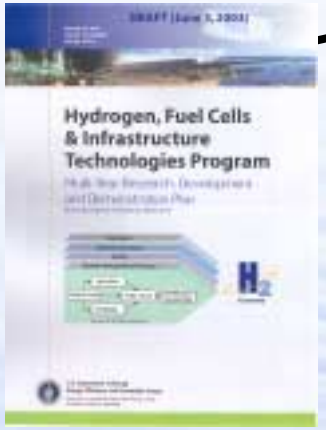
FreedomCAR

FutureGen



Jan'02 | Nov'02 | Jan'03 | Feb'03 | May'03 | Nov'03 | Feb'04





International Partnership for the Hydrogen Economy

FreedomCAR and Fuel Partnership Established

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

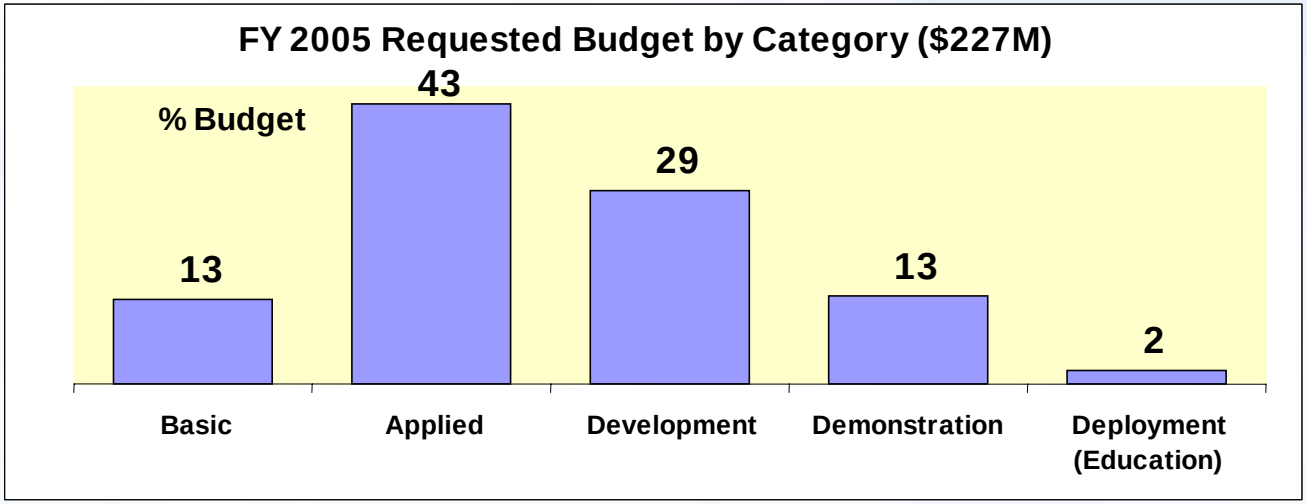
Complementary Strategies

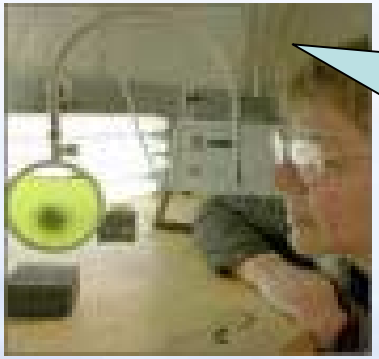
FutureGen is an initiative to build the world's first integrated sequestration and hydrogen production research power plant. The $1 billion dollar project is intended to create the world's first zero-emissions fossil fuel plant. When operational, the prototype will be the cleanest fossil fuel fired power plant in the world.

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

DOE sponsors a broad portfolio of activities, including promoting **energy efficiency** in buildings & industrial processes, and supporting development of **renewable energy** including wind, solar, and geothermal. Because most forms of renewable energy are intermittent, hydrogen actually could makes renewables more attractive for peak power.

Balanced program is being implemented





Basic & Applied Research

Technology Development

Technology Validation through "Learning Demonstrations"

Participation of Labs, Academia, and Commercial Sector on New Hydrogen Projects

Hydrogen Storage - $150M over 5 years

- Three Consortia for exploratory research; individual projects to explore new materials for hydrogen storage ($25M in cost share)

Vehicle and Infrastructure "Learning" Demonstration - $190M over 5 years

- Automobile/energy company teams will demonstrate integrated systems in real world environments ($190M in cost share)

Fuel Cell Research - $13M over 2 years

in addition to $75M awarded in FY2003

- Consumer electronics, fuel cells for auxiliary power generation, and off-road fuel cell R&D ($9.5M in cost share)

Hydrogen Education - $4.5M over 5 years

- Curricula and teacher professional development, education materials, co-sponsorship of events ($800K in cost share)

Production and Delivery- $77.3M over 4 years

- Recent announcement of projects

"Today, the Department of Energy has selected recipients for $350 million of research grants…the administration is now acting upon the Congress' appropriation. … We want to be the country that leads the world in innovation and technological change."

- President George W. Bush
April 26, 2004

Note: Private sector cost share amounts are in addition to government amounts

Vehicle Infrastructure "Learning Demonstrations"

- Ford Motor Co./BP
- FC: Ballard
- Stations in
  - Detroit, MI
  - Orlando, FL
  - Sacramento, CA

- General Motors/Shell
- FC: GM
- Stations in
  - Washington, DC/Fort Belvoir, VA
  - Detroit, MI
  - New York, NY
  - Los Angeles, CA

- DaimlerChrysler/BP
- FC: Ballard
- Stations in
  - Los Angeles, CA
  - Detroit, MI
  - Sacramento, CA

- Air Products, Conoco-Phillips, Toyota, Honda, Nissan, BMW
- FC: UTC, others
- Stations in
  - Northern CA
  - Southern CA
  - Las Vegas, NV

- Texaco Energy Systems/Hyundai
- FC: UTC Fuel Cells
- Stations in
  - Northern CA
  - Southern CA


IPHE
International Partnership
for the Hydrogen Economy

IPHE Ministerial

The IPHE Ministerial was held November 19-21, 2003 in Washington DC, USA.

- Signing of the Terms of Reference
- 700+ delegates and participants representing approximately 30 countries
- Public-Private Dialogue Sessions
- IPHE Committee meetings
    - Steering Committee
    - Implementation-Liaison Committee

IPHE Partners

Russian Federation

USA

Canada

Iceland

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 and energy consumption

Japan

Republic of Korea

China

India

United Kingdom

France

Germany

Italy

Australia

Brazil

Norway

European Commission

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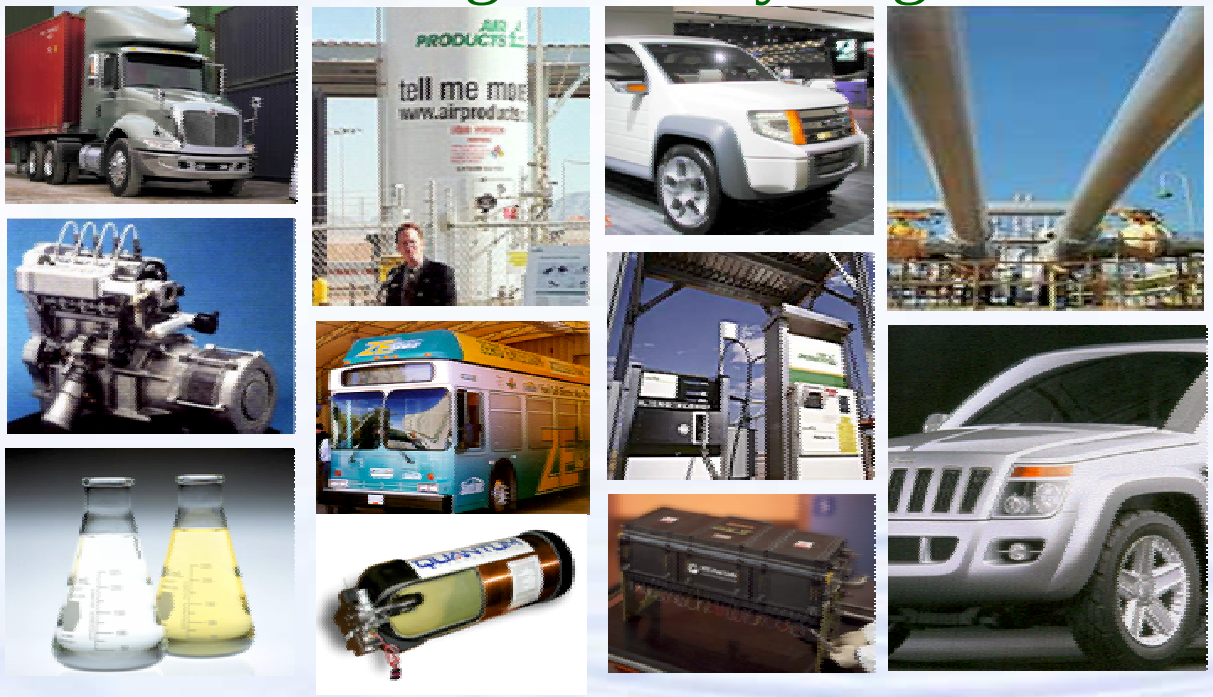
For More Information

www.eere.energy.gov/hydrogenandfuelcells
www.eere.energy.gov/vehiclesandfuels (FreedomCAR)
www.sc.doe.gov/bes/hydrogen.html



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