The U.S. Department of Energy Hydrogen and Fuel Cells

Mark Paster
U.S. Department of Energy
Hydrogen, Fuel Cells and Infrastructure Program

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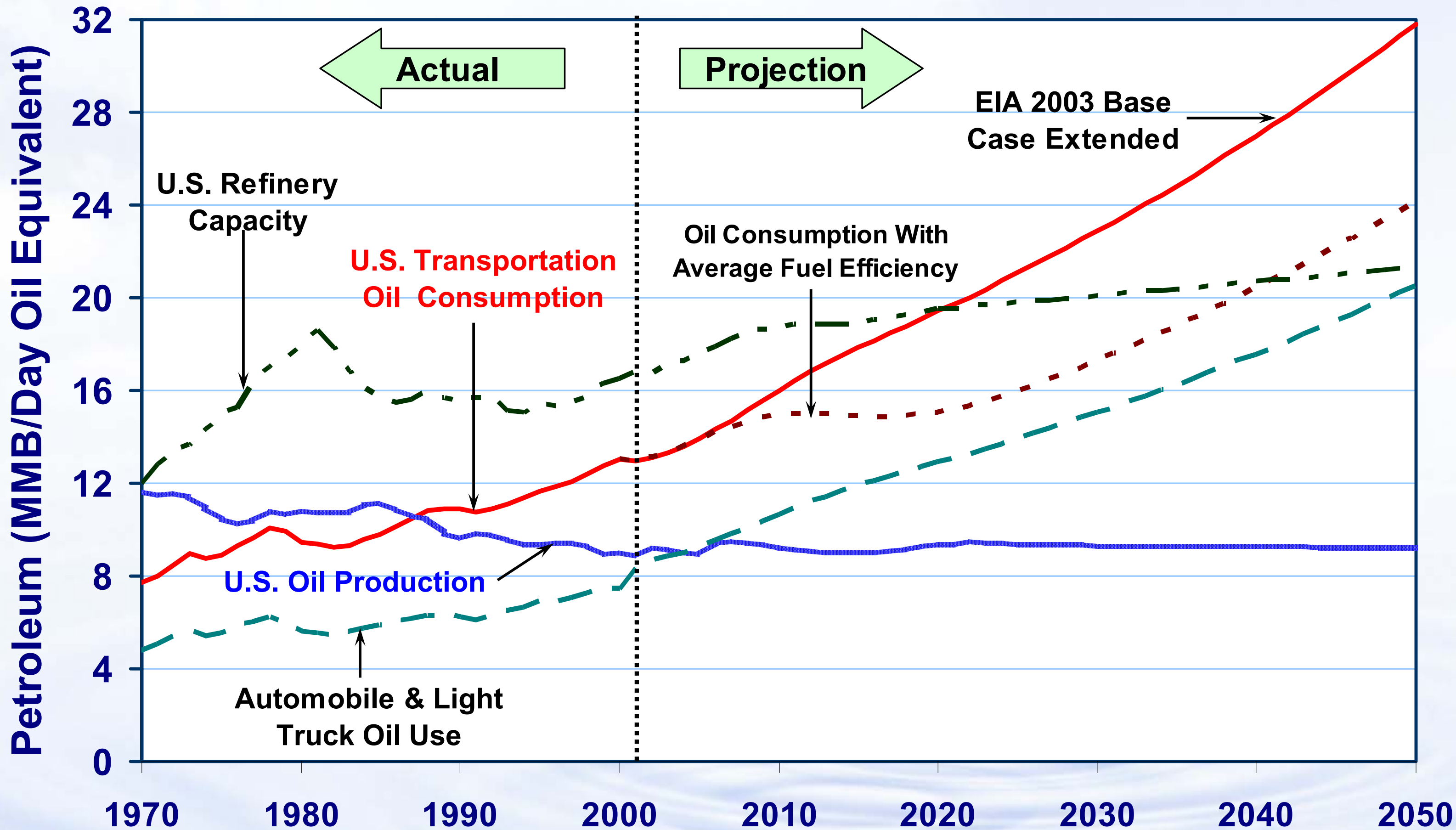
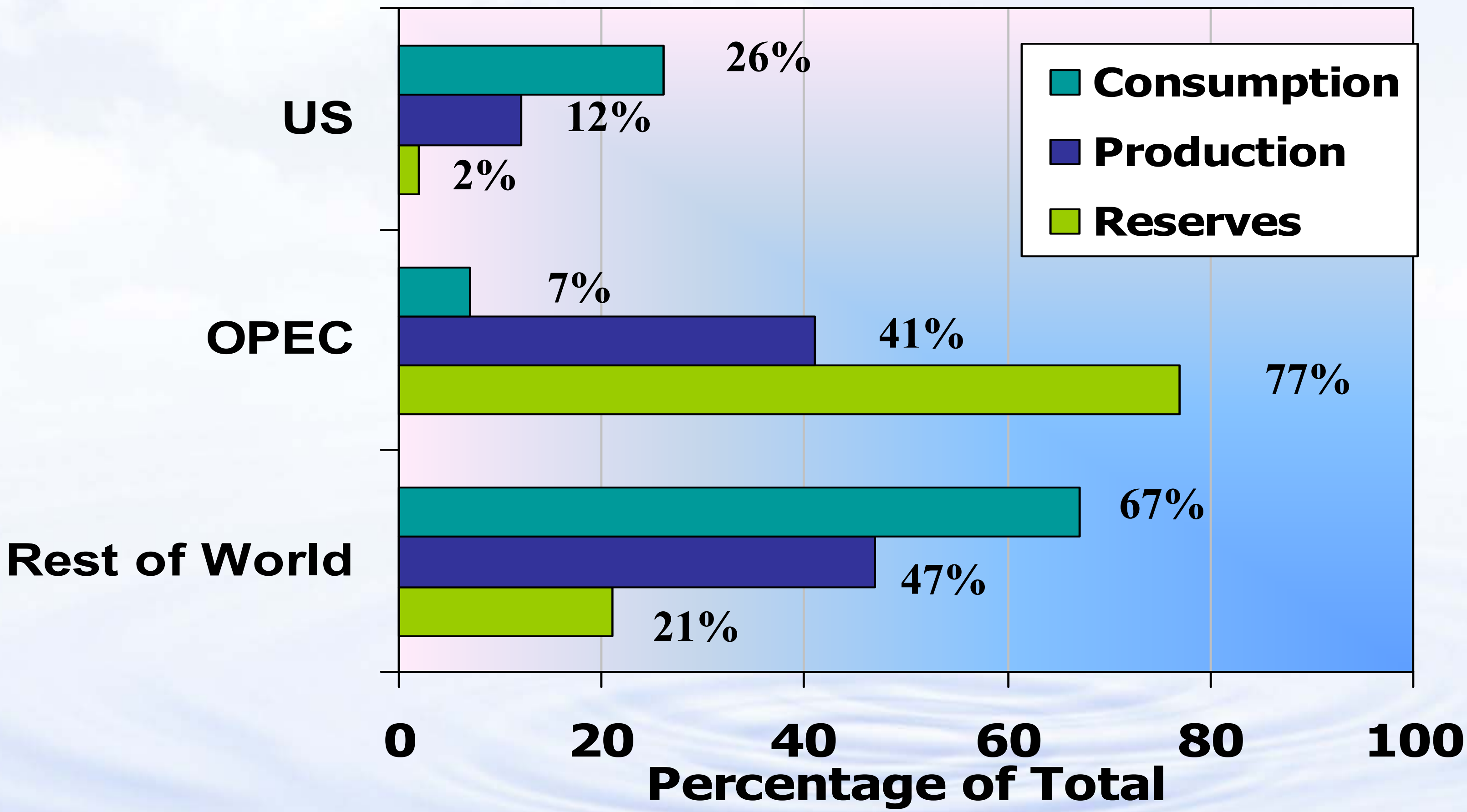
A Bold New Approach is Required

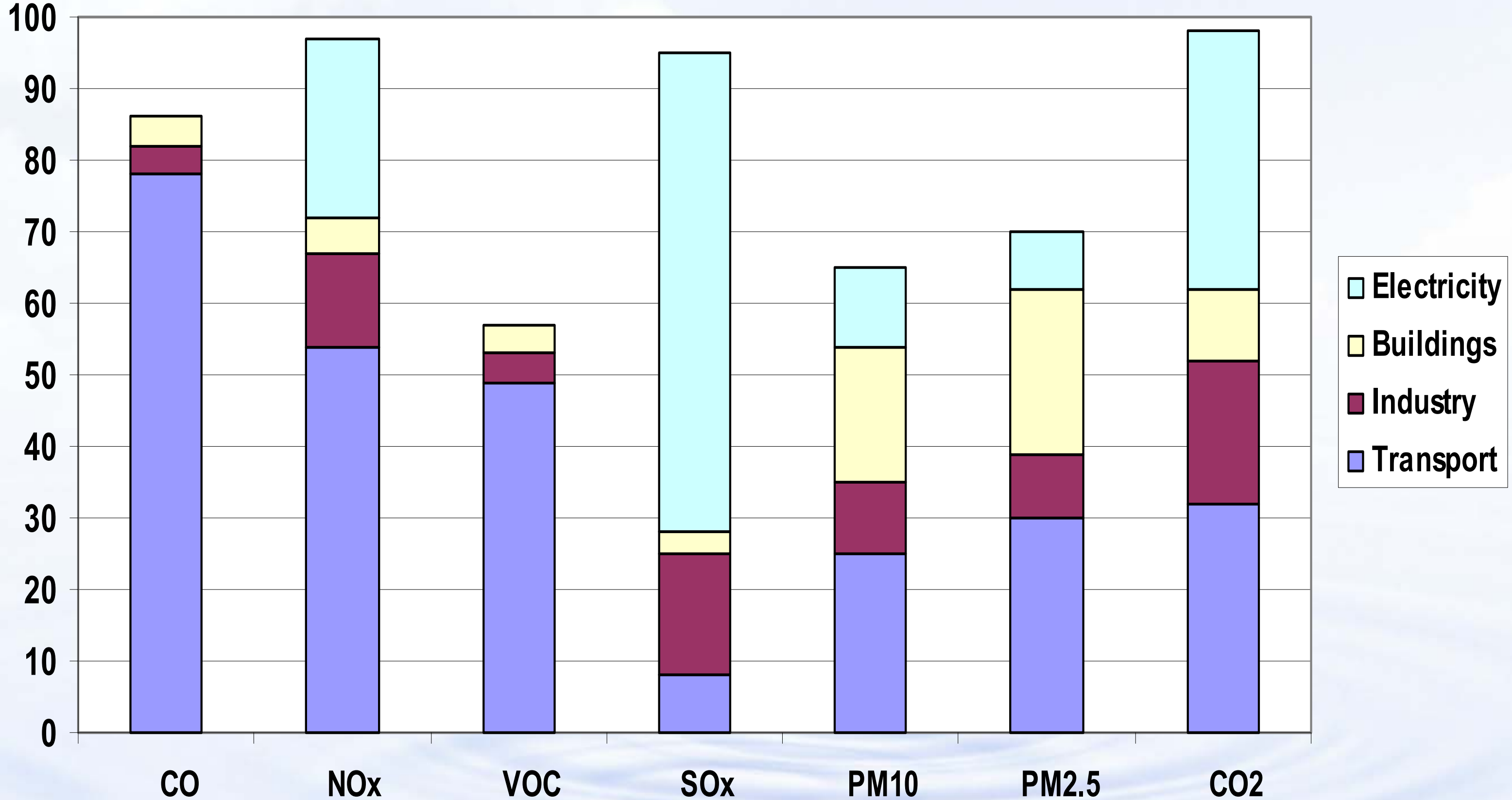


World Oil Reserves are Consolidating in OPEC Nations



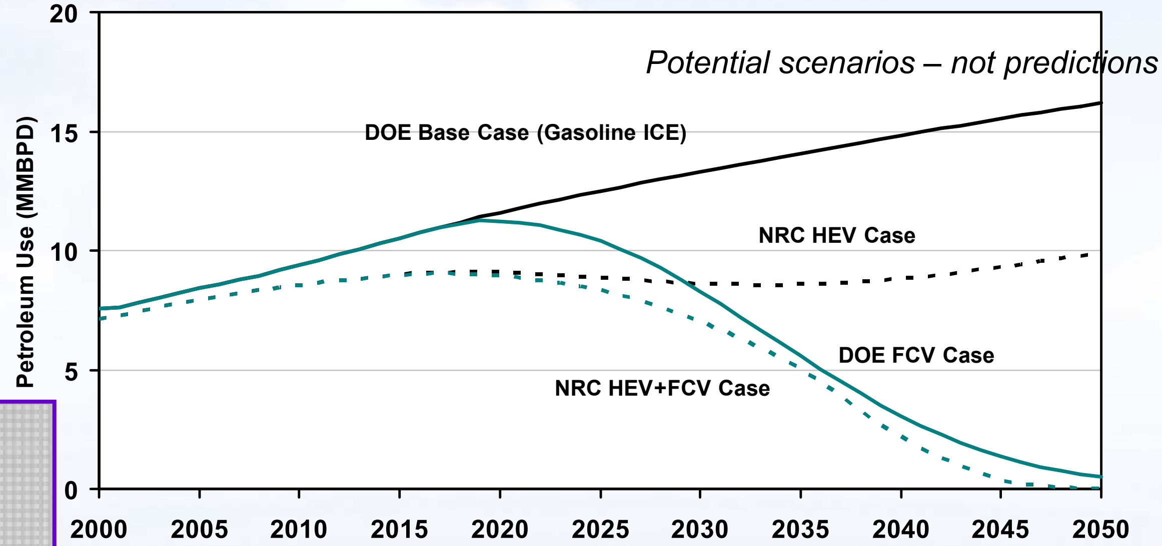
Source: DOE/EIA, International Petroleum Statistics Reports, April 1999; DOE/EIA 0520, International Energy Annual 1997, DOE/EIA0219(97), February 1999.

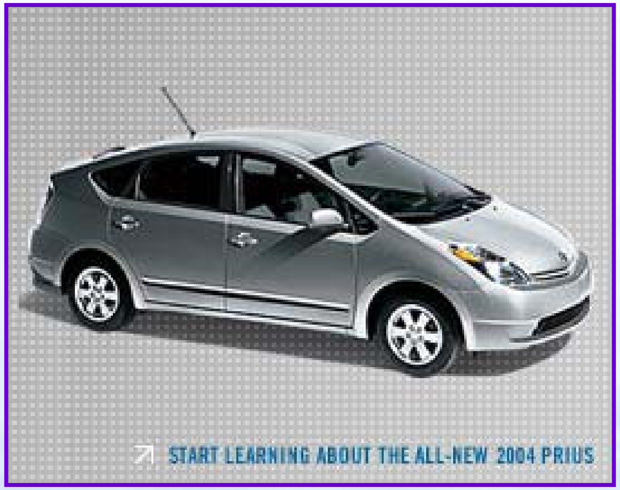
U.S. 1998 Energy-Linked Emissions as Percentage of Total Emissions



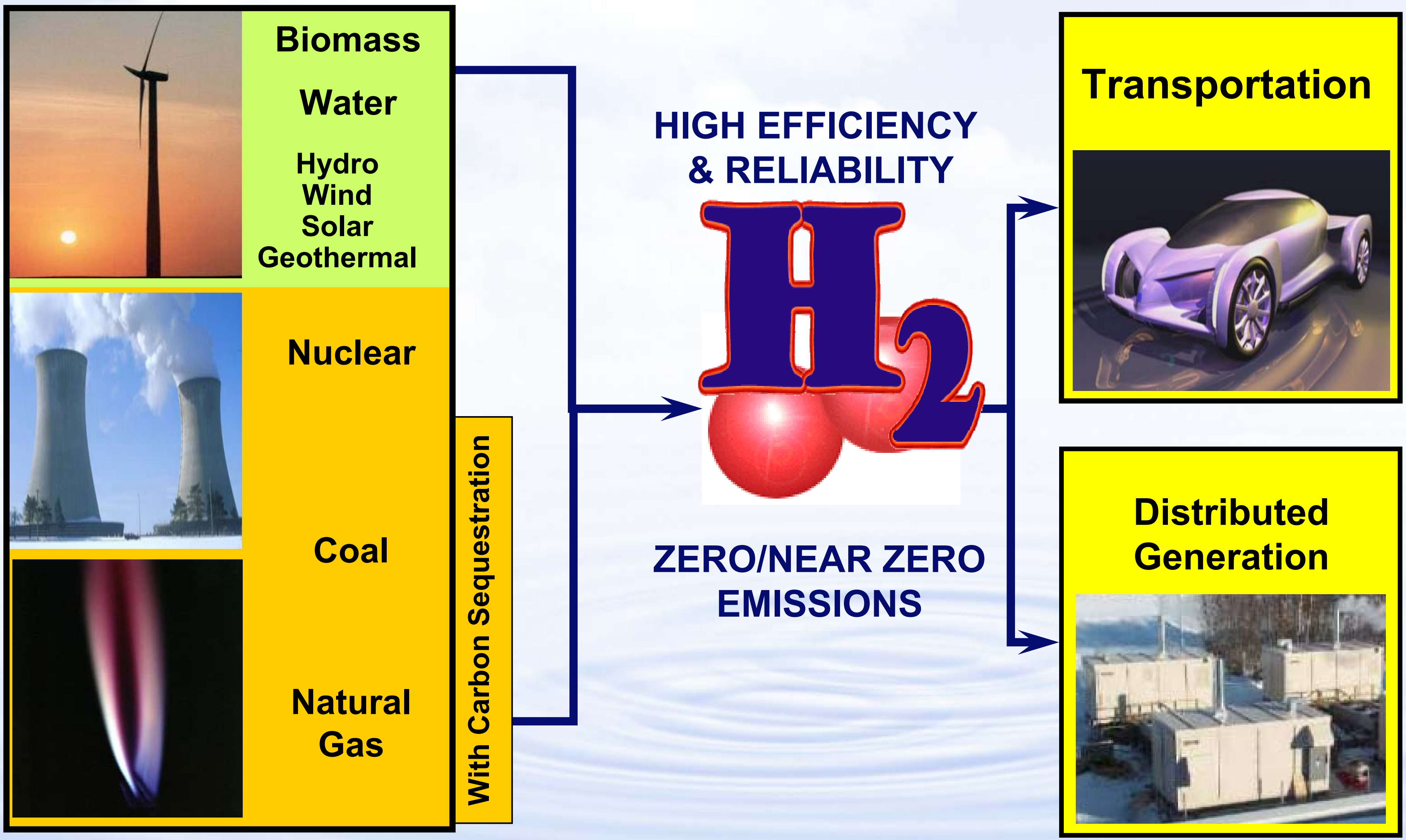
Hybrids are a Bridge

***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.*





Why Hydrogen? It's __abundant__, __clean__, __efficient__, and can be derived from diverse __domestic__ resources.



Tremendous Progress Made Since President Bush's State of the Union Address

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

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

- Program Management of Departmental Hydrogen Activities Integrated
  - **- OSTP-Led Interagency Coordination**
- Public/Private Partnerships Established
- NRC Evaluation of DOE Plans Aiding in Hydrogen Production Strategies
- Major Systems Integration/ Analysis Capability Being Implemented
- Significant Technology Progress

FreedomCAR and Fuel Partnership Established

New Energy Company/DOE Technical Teams
- Production
- Delivery
- Fuel Pathway Integration

New Joint Auto/Energy/DOE Technical Teams
- Codes and Standards
- Storage

International Partnership for the Hydrogen Economy

Russian Federation

USA

Canada

Iceland

Japan

South Korea

China

India

<u>IPHE Partners' Economy:</u>

- 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

<u>An IPHE Vision</u>:

"… 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

United Kingdom

France

Germany

Italy

Australia

Brazil

Norway

European Commission

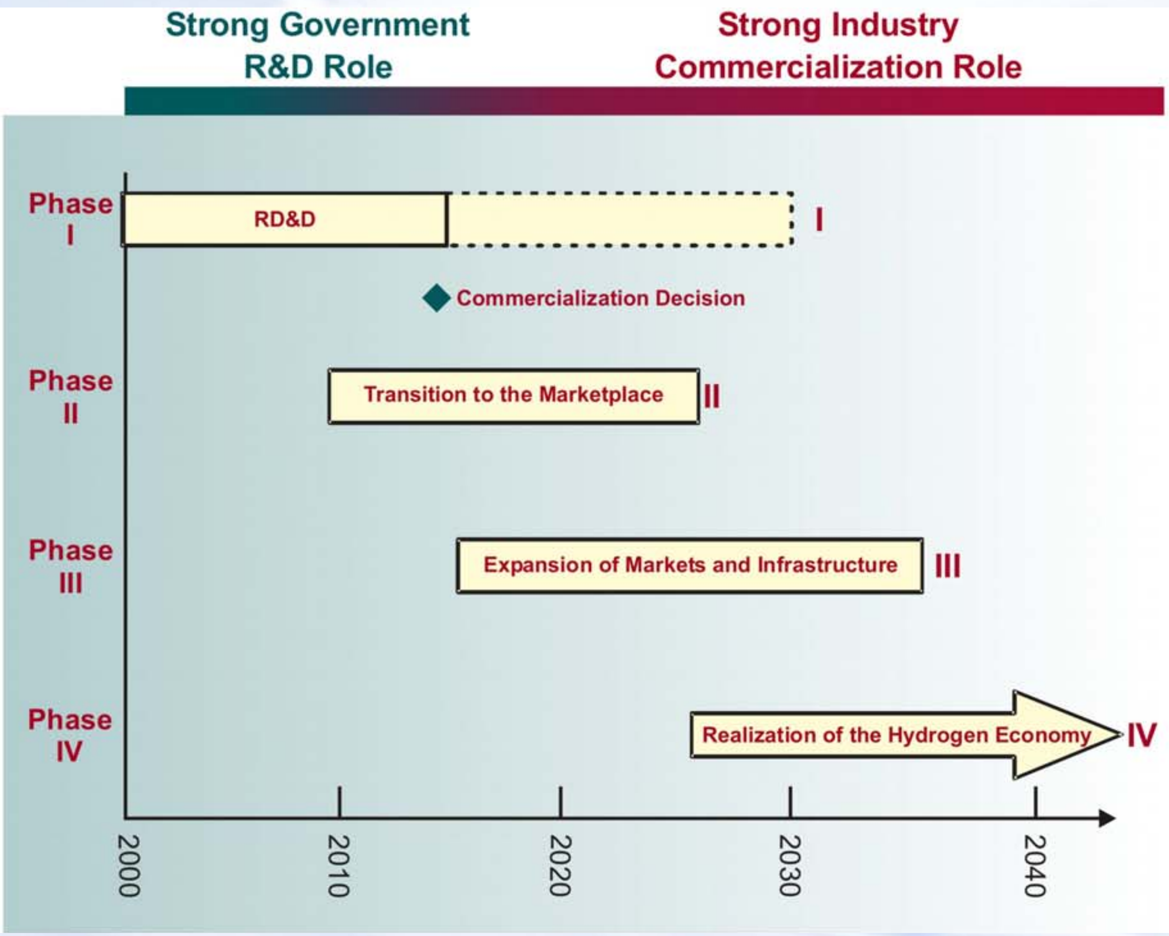
DOE Intra-Agency Collaboration

DOE Posture Plan

- EERE
- Fossil Energy
- Nuclear Energy
- Office of Science

- EERE
  - Hydrogen, Fuel Cells, Infrastructure Program
  - Vehicle Technologies Program
  - Solar Program
  - Wind Program
  - Biomass Program

Timeline for 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

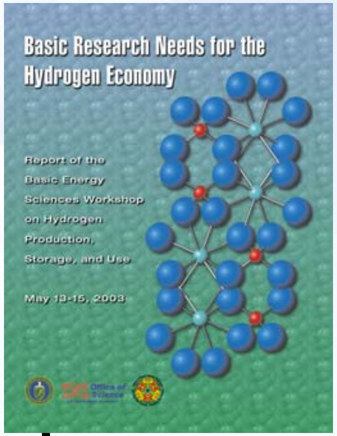
Positive commercialization decision in 2015 leads to beginning of mass-produced hydrogen fuel cell cars by 2020

Summary of U.S. Planning and Implementation

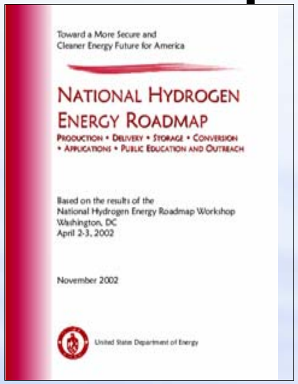
President's Hydrogen Fuel Initiative

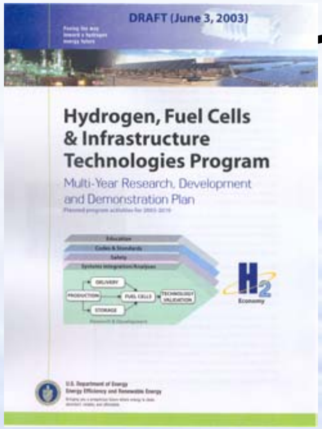
FreedomCAR

FutureGen

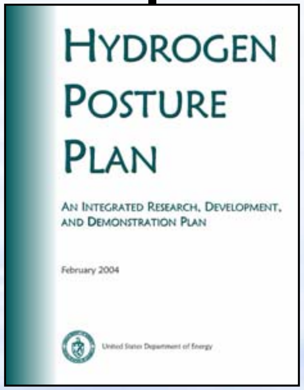


Jan'02 | Nov'02 | Jan'03 | Feb'03 | May'03 | Nov'03 | Feb'04





International Partnership for the Hydrogen Economy



Program Elements

- Hydrogen Production
- Hydrogen Delivery
- On-Board Vehicle Storage
- Fuel Cells
- Safety, Codes & Standards
- Systems Analysis
- Education

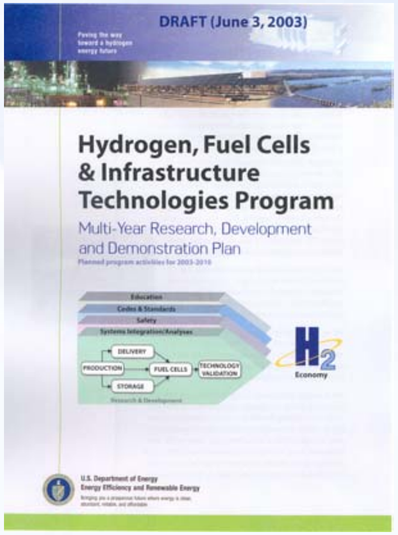
Barriers to a Hydrogen Economy

<u>Critical Path Technology Barriers:</u>

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

<u>Economic/Institutional Barriers:</u>

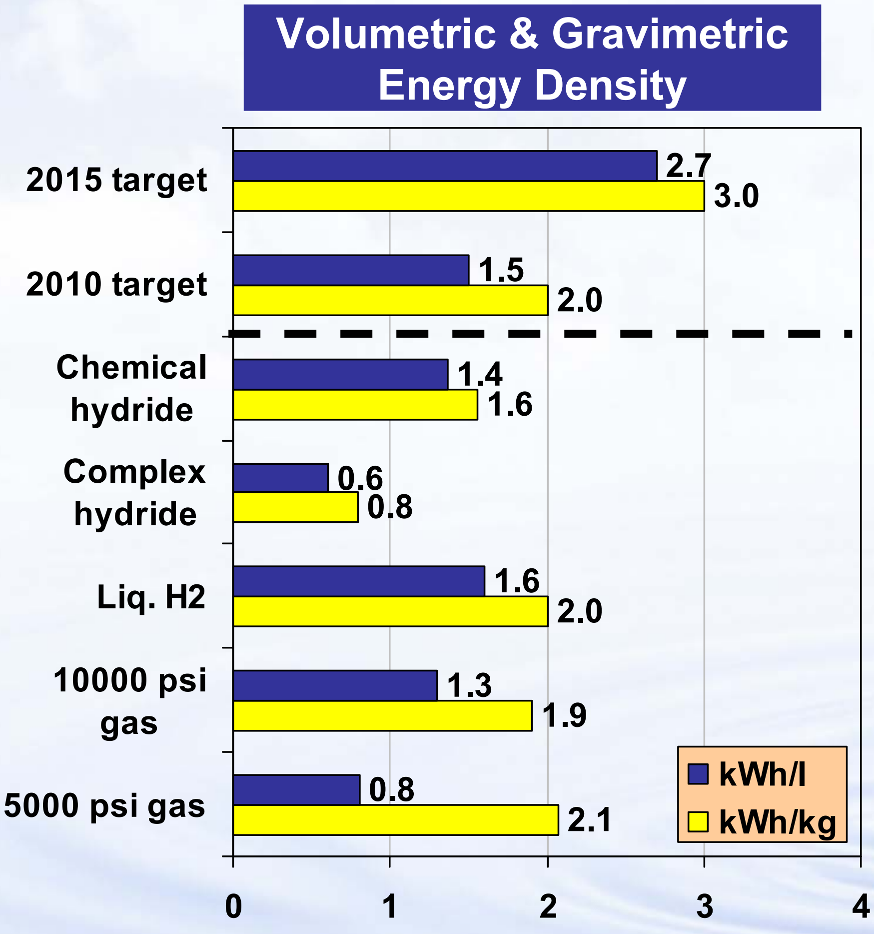
- Codes and Standards (Safety, and Global Competitiveness)
- Hydrogen Delivery (Investment for new Distribution Infrastructure)
- Education

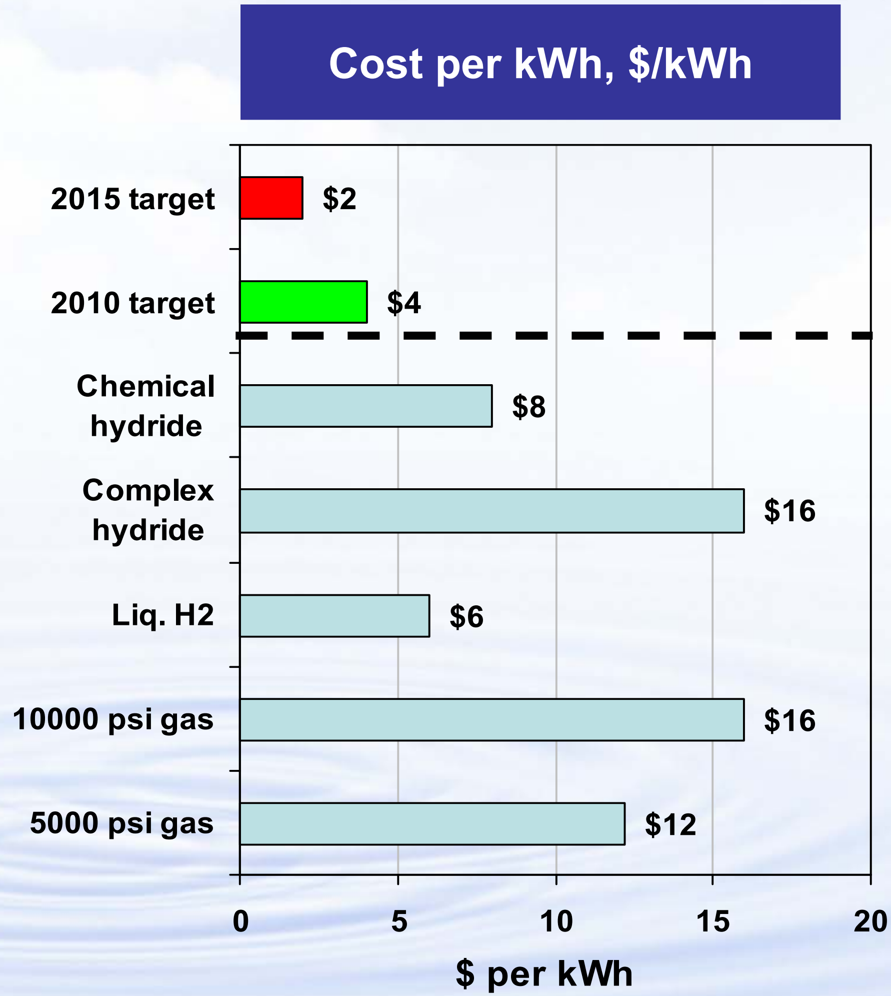


http://www.eere.energy.gov/hydrogenanfuelcells/mypp/

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

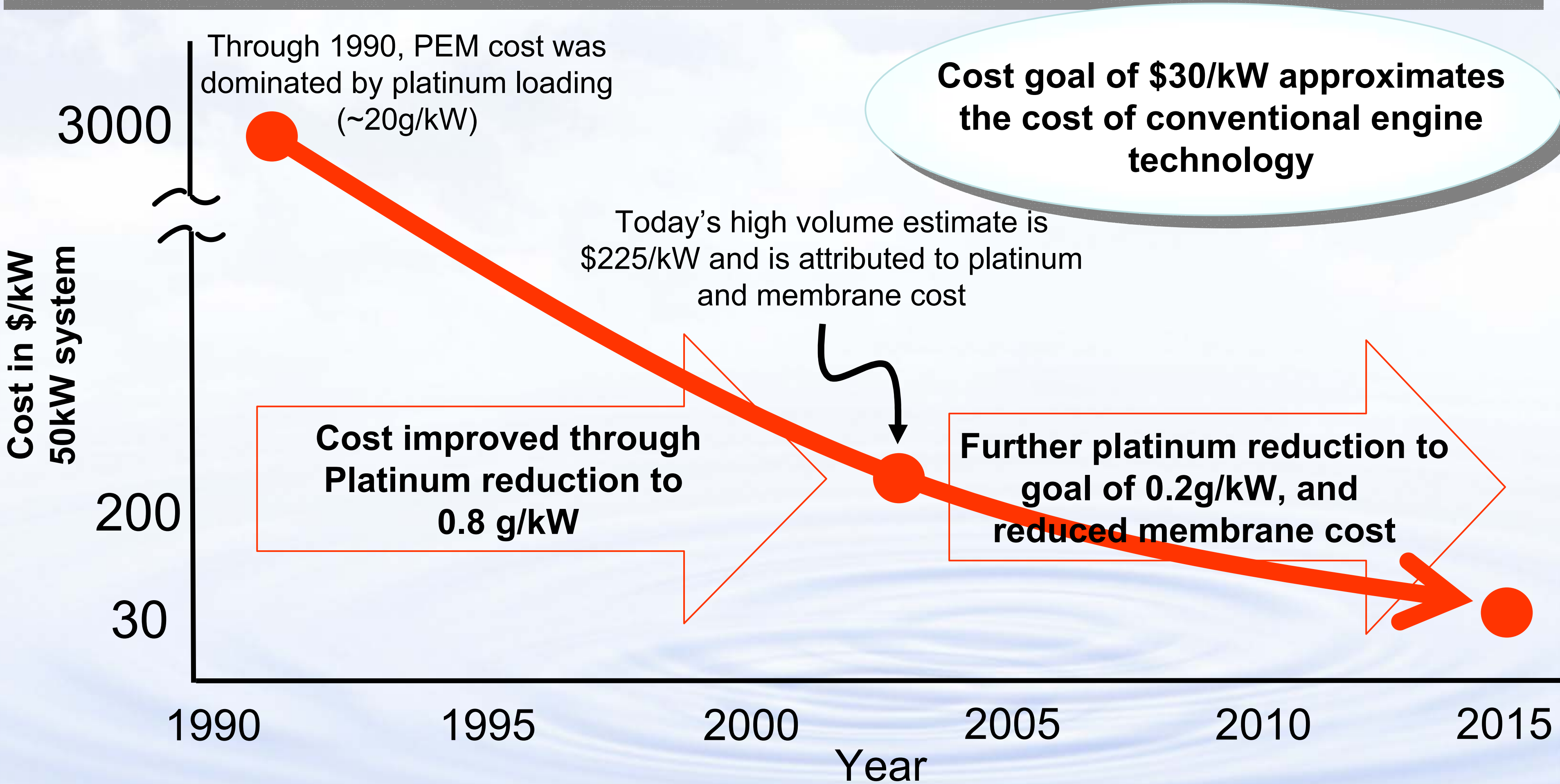
No current H_2 storage technology meets the targets





PEM Fuel Cell Cost: A 7X gap between today's high volume cost and the 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..

Hydrogen Production Technologies

- Distributed natural gas reforming
- Distributed bio-derived liquids reforming
- Electrolysis
- Reforming biomass producer gas from gasification/pyrolysis
- Biological hydrogen production
- Photoelectrochemical hydrogen production
- Coal gasification with sequestration(FE)
- Nuclear driven HT thermochemical cycles (NE)
- Solar driven HT thermochemical cycles

Analysis is Crucial to Success

- NRC Report: Strongly recommends an increased emphasis on analysis including systems integration analysis and all energy systems analysis
- The envisioned Hydrogen/Electric Economy and the Transition is complex, highly interactive, and has many dimensions
  - Technologies
  - Markets: transportation, power, all hydrogen markets, all energy markets, and interacts with chemicals, food and feed, etc. through feedstock use
  - Time frames: short term (2010-2030), mid term (2030-2050) and long term
  - Geography: local, regional, national, global
  - Costs and Benefits
  - Policy

Types of Analyses

- Resource Analysis
- Existing Infrastructure
- Technology Characterization (TEA & Enviro)
- Macro-System Models
- Integrated Baseline Analysis
- Market Analysis
- Infrastructure Transition Analysis
- Benefits Analysis

DOE Hydrogen Budget

(EWD & Interior Appropriations in thousands of dollars)

MAJOR LINE ITEMS	FY 04 Appropriations	FY 05 Request	Omnibus Appropriations
Production & Delivery R&D (EE)	$22,564	$25,325	
Storage R&D (EE)	$29,432	$30,000	
Safety, Codes & Standards, and Utilization (EE)	$5,904	$18,000	
Infrastructure Validation (EE)	$18,379	$15,000	
Education and Cross-cutting Analysis (EE)	$5,712	$7,000	
EERE Hydrogen Technology Subtotal– (EWD)	**$81,991*** **(Net: $41,991)**	**$95,325**	**$95,325**** **(Net: $58,635)**
NE Hydrogen Subtotal – (EWD)	$6,400	$9,000	$9,000
FE Hydrogen Subtotal – (Interior)	$4,900	$16,000	$17,000
SC – (EWD)	$0	$29,200	$29,200
Hydrogen Technology Total	**$93,791**	**$149,525**	**$150,525**

* **Includes $40M of Earmarked projects**

** **Includes $36.7M of earmarked projects. Eliminates education.**

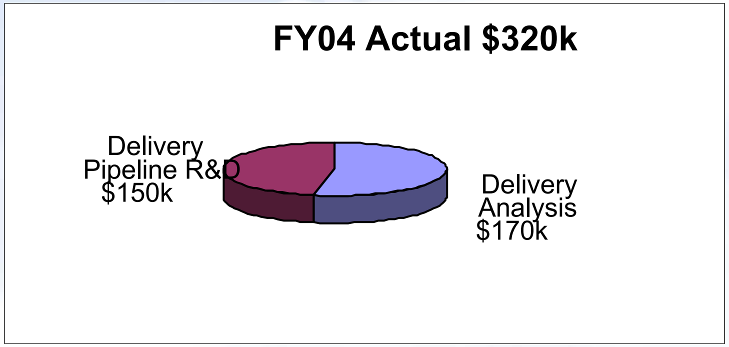
DOE Hydrogen Budget

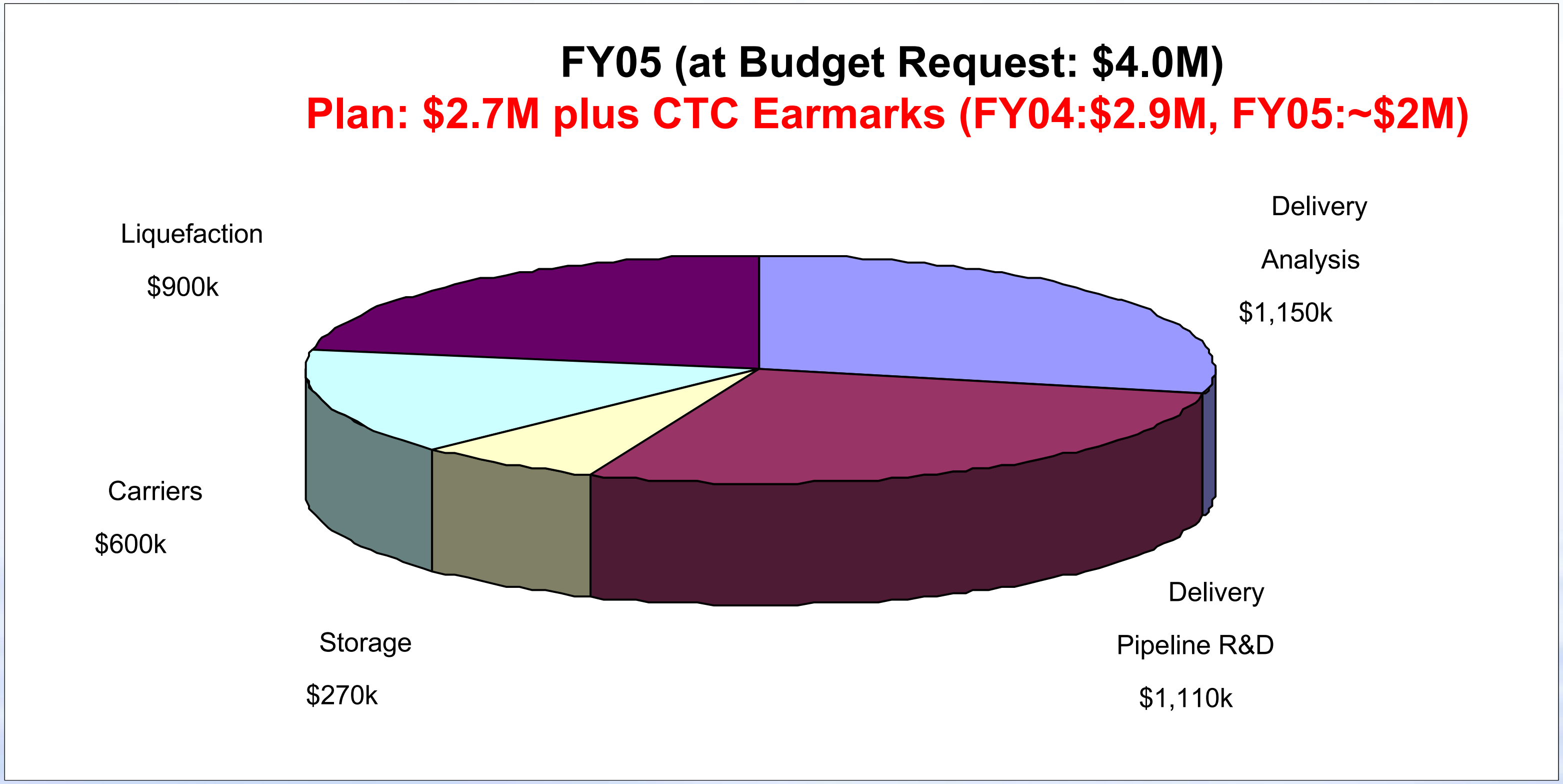
(EWD & Interior Appropriations in thousands of dollars)

MAJOR LINE ITEMS	FY 05 Request	FY05 Plan*
Production & Delivery R&D (EE) Production Delivery	$25,325 ($21,325) ($4,000)	$14,600 ($11,900) ($2,700)
Storage R&D (EE)	$30,000	$24,800
Safety, Codes & Standards, and Utilization (EE)	$18,000	$5,900
Infrastructure Validation (EE)	$15,000	$9,800
Cross-cutting Analysis (EE)	$7,000	$3,525
Earmarks		**$36,700**
EERE Hydrogen Technology Subtotal– (EWD)	**$95,325**	**$95,325**

*** Tentative Plan**

Delivery Budget





Back-Up Slides

HT Thermochemical Cycles

- Manganese Sulfate Cycle Example

$MnSO_4 \rightarrow MnO + SO_2(g) + .5O_2(g)$ 1150 C

$MnO + SO_2 + H_2O \rightarrow MnSO_4 + H_2(g)$ 120 C

HT Thermochemical Cycles

- Volatile Metal Cycle Example

$ZnO \rightarrow Zn + .5O_2$	~2100 K
$Zn + H_2O \rightarrow ZnO + H_2$	500 K

HT Thermochemical Cycles

- Sulfuric Acid Based Cycles
  - Hybrid Sulfur

$2H_2SO_4(g) \rightarrow 2SO_2(g) + 2H_2O(g) + O_2(g)$	950 C
$SO_2(g) + 2H_2O(g) \rightarrow H_2SO_4(l) + H_2(g)$ (elec)	77 C

  - Sulfur Iodide

$2H_2SO_4(g) \rightarrow 2SO_2(g) + 2H_2O(g) + O_2(g)$	850 C
$2HI \rightarrow I_2(g) + H_2(g)$	300 C
$I_2 + SO_2(a) + 2H_2O \rightarrow 2HI(a) + H_2SO_4(a)$	100 C