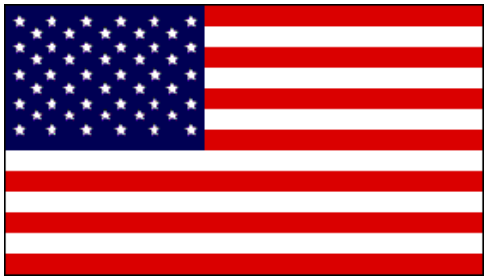
US Hydrogen Program

Country Statement for the IPHE Steering Committee
January 26-28, 2005
Paris, FRANCE

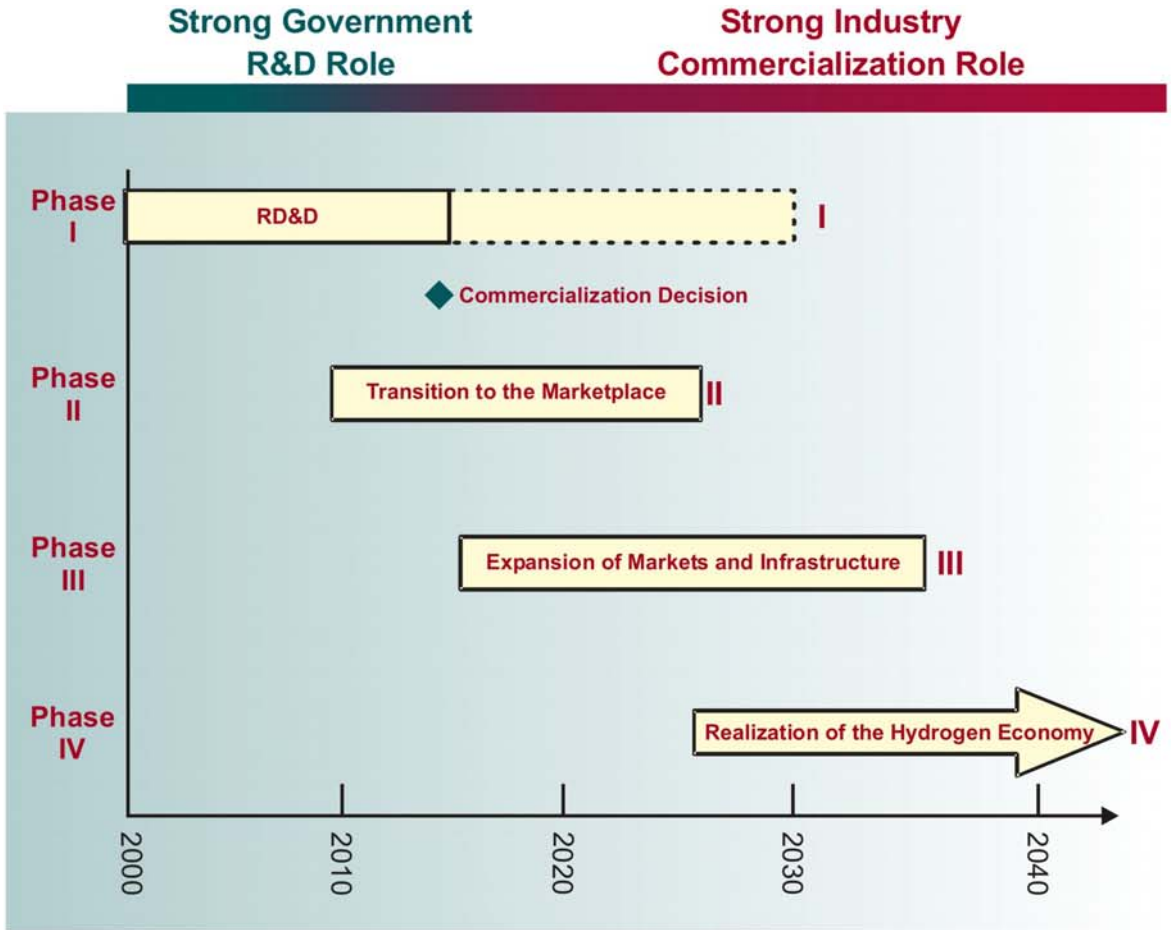


United States of America

Outline

- Program Strategy and Timeline
- New Awards and Activities
- Recent Progress
- Information Sources

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

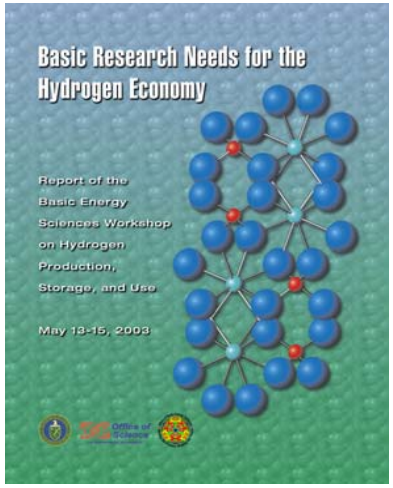
H_2 power and transport systems commercially available in all regions; national infrastructure

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

Barriers to a Hydrogen Economy

Critical Path Technology Barriers:

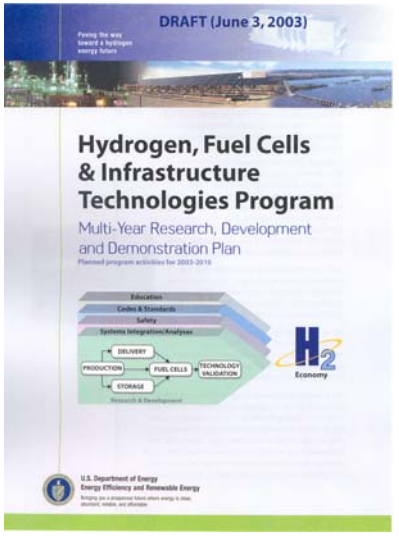
- Hydrogen Storage
  - >300 mile range
- Hydrogen Production Cost
  - $1.50-2.00 per gge
- Fuel Cell Cost
  - < $50 per kW



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

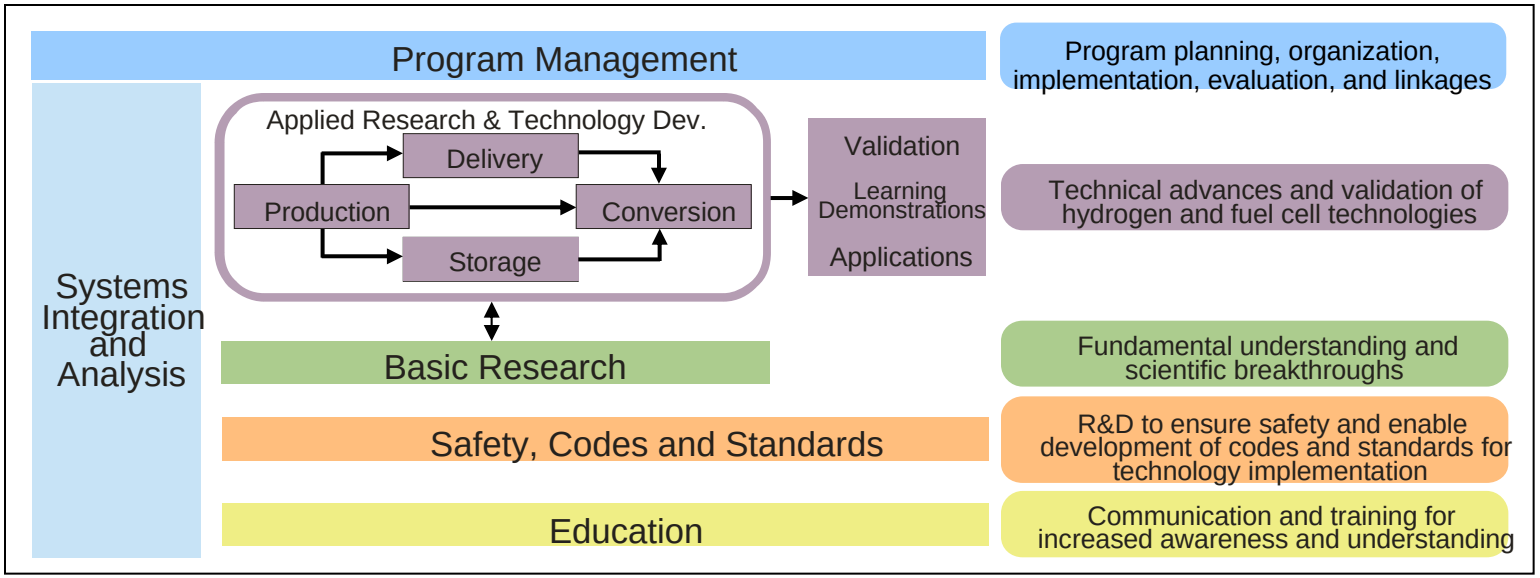
Economic/Institutional Barriers:

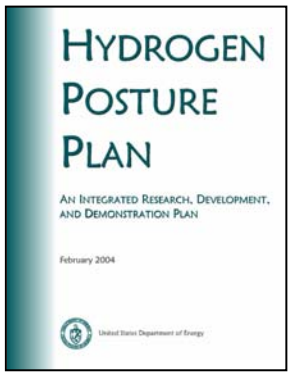
- Codes and Standards
  - Safety and Global Competitiveness
- Hydrogen Delivery
  - Investment for new Distribution Infrastructure
- Education



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

Hydrogen Program Elements





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

Recent Hydrogen Production Awards

Focused on using energy from diverse, domestic sources

Distributed Reforming: Natural Gas & Renewables

- Smaller, efficient reactors with durable catalysts
  - ✓Autothermal reforming catalysts & efficient systems
  - ✓Efficient steam methane reforming
  - ✓Bio-fuel reforming with coke resistant catalysts
  - ✓Reformers with non-precious metal catalysts

Photolytic

- Durable materials for photo-electrochemical devices that split water using sunlight
- Research microorganisms that split water using sunlight

Electrolysis

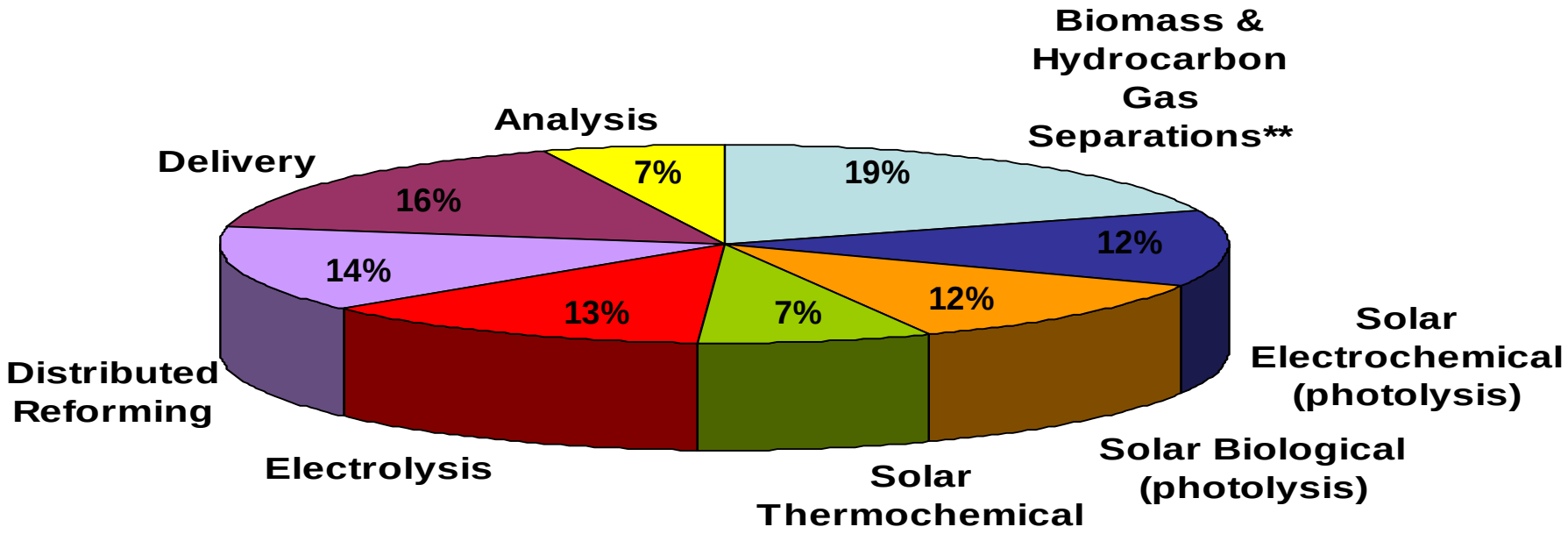
- Low cost and efficient materials & system designs
  - ✓New membrane and electrode materials for alkaline electrolysis
  - ✓High temperature solid oxide electrolysis systems
  - ✓New membrane and electrode materials for high pressure electrolysis
  - ✓Wind electrolysis power electronics development

Solar High Temperature (HT) Thermochemical Cycling

- Research water splitting using heat (600-2500C) from solar concentrators and compounds that recycle all chemical constituents during processing

Hydrogen Technology* Award Funding

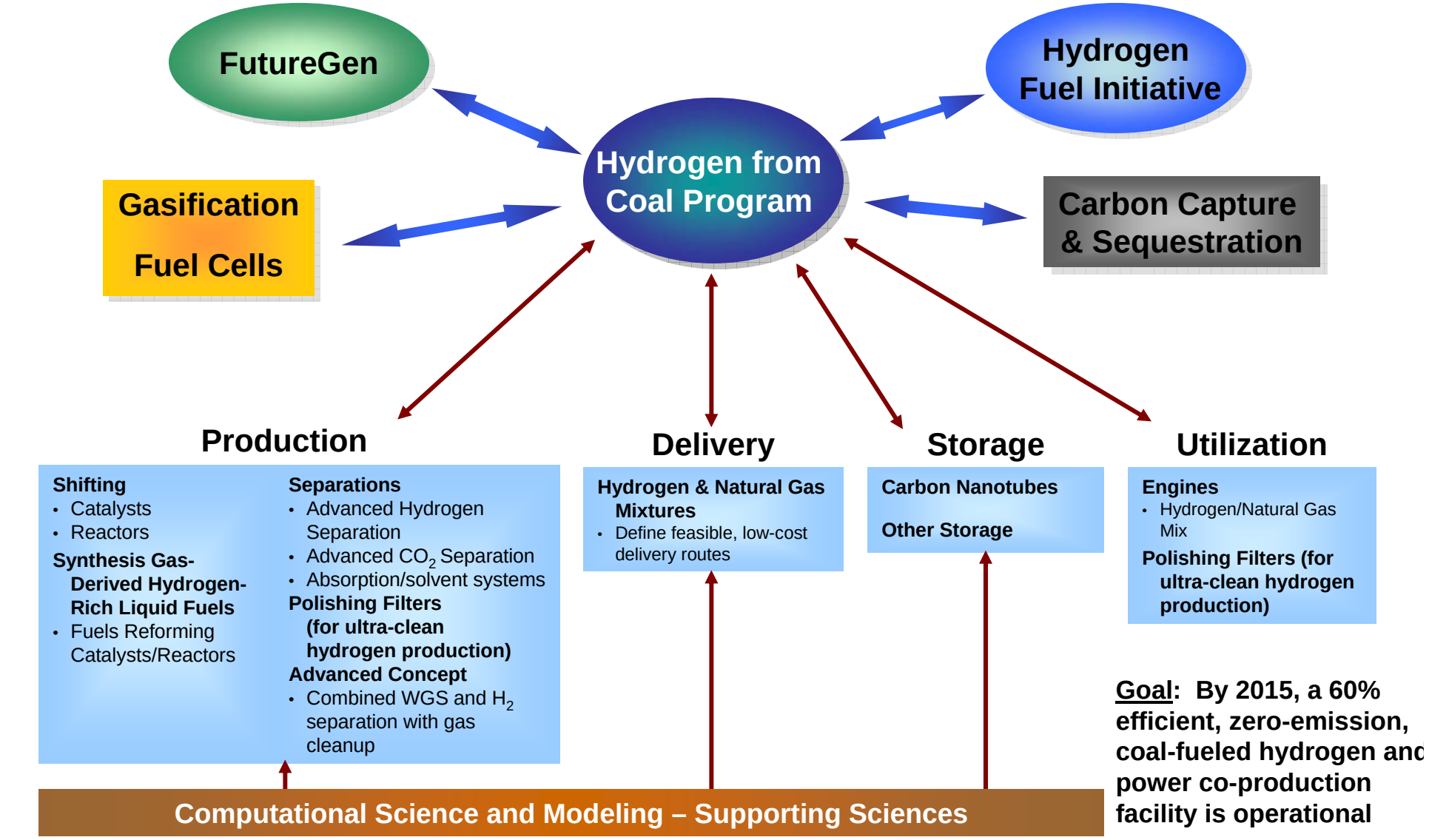
Total with Cost Share = $102 Million over 3 to 4 years
(Federal Share = $77 Million)



* Hydrogen Technology: Production, Delivery, and Analysis

** Hydrocarbon separation research co-funded with the Office of Fossil Energy

Coal-Based Hydrogen



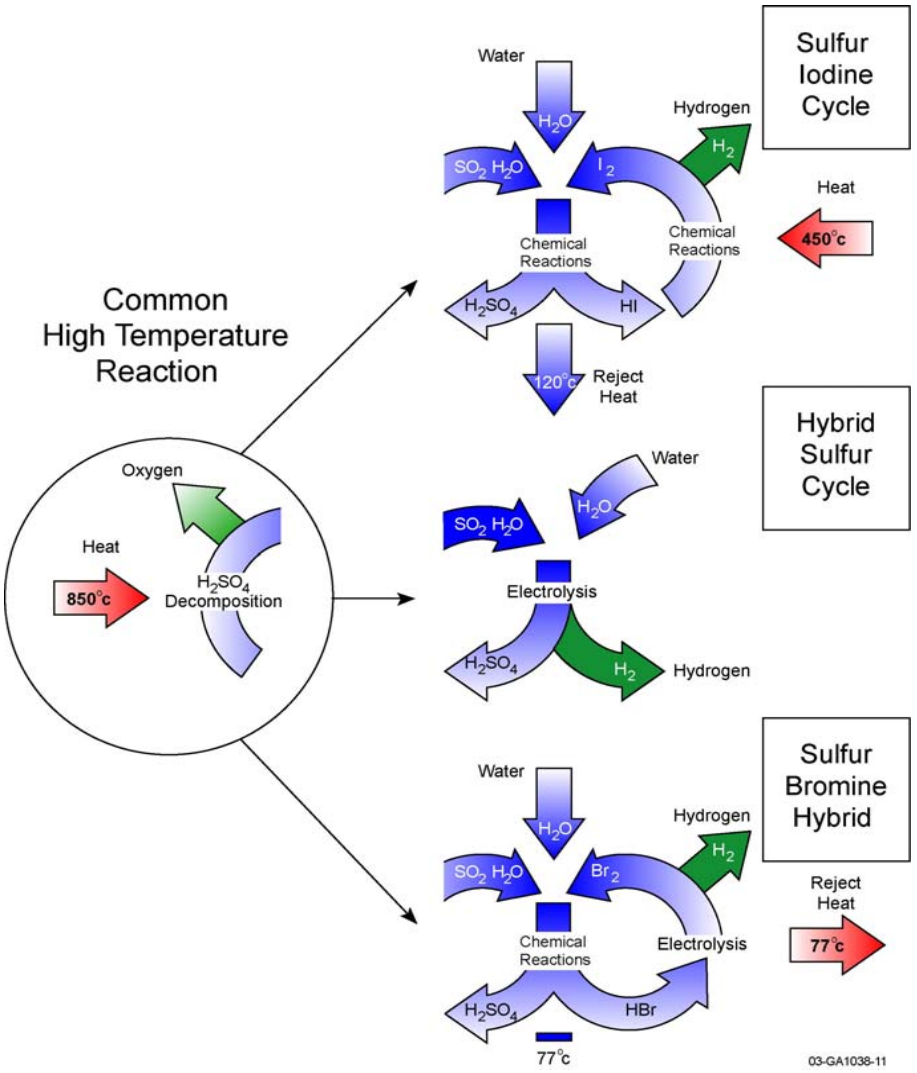
Goal: **By 2015, a 60% efficient, zero-emission, coal-fueled hydrogen and power co-production facility is operational**

Nuclear-based Hydrogen Production

Objective: By 2017, operate the nuclear hydrogen production plant using nuclear heat from the NGNP to produce hydrogen at a cost competitive with other alternative transportation fuels.

Technologies:

- Electrolysis
- Thermochemical Cycles
- Hybrid Cycles



BES Solicitation for Basic Research for Hydrogen Fuel Initiative

- Approximately $21.5M in new funding will be awarded in FY05
- Two solicitations (one for universities and one for FFRDCs) were issued in April 2004
- 668 qualified preproposals were received by July 15, 2004 in the following five categories.
  - *Novel Materials for Hydrogen Storage*
  - *Membranes for Separation, Purification, and Ion Transport*
  - *Design of Catalysts at the Nanoscale*
  - *Solar Hydrogen Production*
  - *Bio-Inspired Materials and Processes*

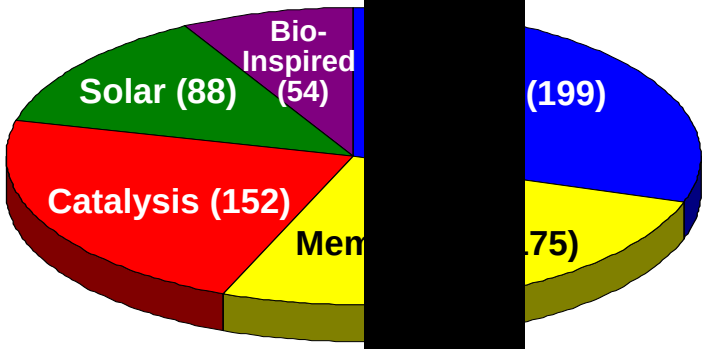
- 227 full proposals were received by January 4, 2005.

Jan. 4, 2005 roposals due

Feb – Apr 2005 peer review

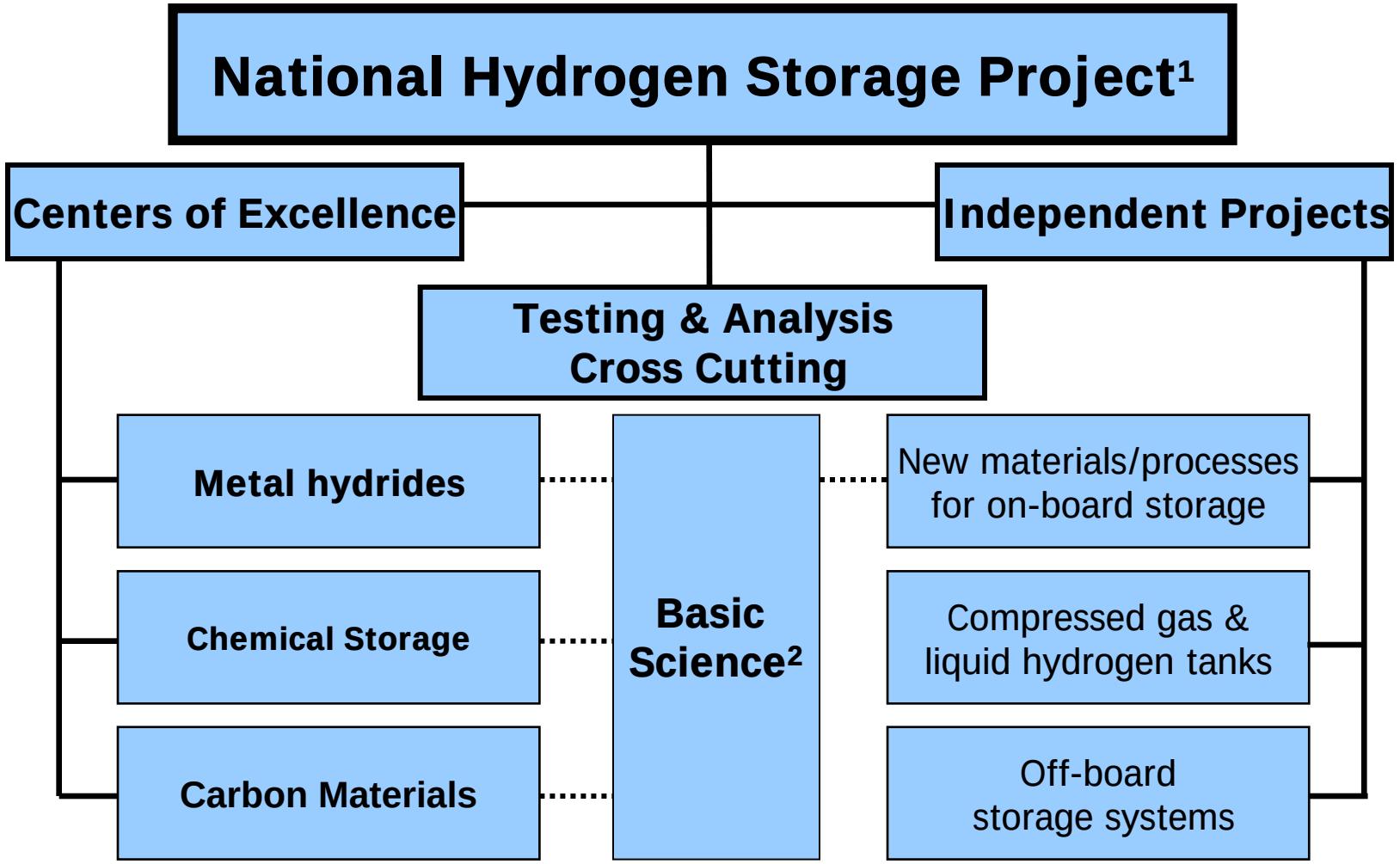
Apr – May 2005 essment of selection of

June – July 2005 made



Prepropos ed

Launched Hydrogen Storage Centers of Excellence



1. Coordinated by DOE Energy Efficiency and Renewable Energy, Office of Hydrogen, Fuel Cells and Infrastructure Technologies
2. Basic science for hydrogen storage conducted through DOE Office of Science, Basic Energy Sciences

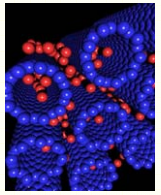
Hydrogen Storage: Stresses solid-state solutions for greater than 300-mile range.

Metal hydrides: Can "re-fill" H_2 at the fuel station, directly onto car.

- Light element-hydrogen compounds
- Solid-state materials, high-capacity

- 6 National Labs; 7 universities; 5 companies
  - ✓United Technologies, UOP, Intematix, HRL
  - ✓Stanford, CalTech, Univ. Illinois, Univ. Hawaii
  - ✓Sandia NL, Savannah River, NIST, JPL

Carbon Materials: Can store & release H_2 near ambient temperature.



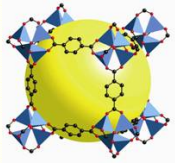
- Nanostructured carbon & metal hybrids
- Conducting polymers & metal-organic frameworks
- 4 National Labs; 10 universities; 1 company
  - ✓Air Products
  - ✓Univ. Michigan, Rice, Univ. Penn, Univ NC
  - ✓NREL, Oak Ridge, NIST

Chemical hydrogen: Re-fill off the vehicle & integrate with refueling station

- Light-element-hydrogen compounds
- High capacity, bind H with high energy

- 2 National Labs; 7 universities; 5 companies
  - ✓Air Products, Millennium Cell, Rohm & Haas
  - ✓RTI, Penn St, Univ Alabama, UCLA,
  - ✓Los Alamos, Pacific Northwest

New materials: "Out of Box" ideas for hydrogen storage

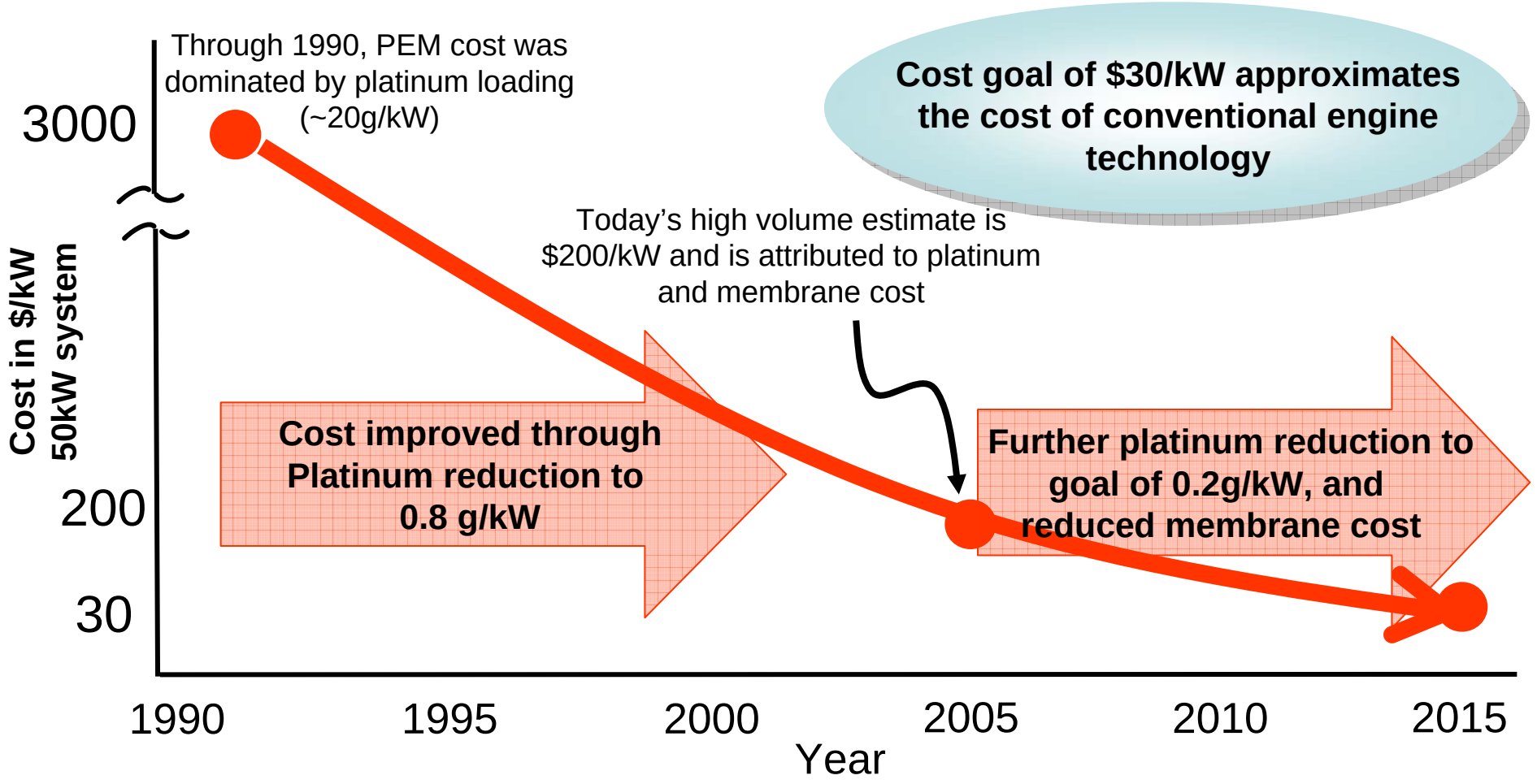


- Nanoporous materials & polymers
- Clathrates
- Metal perhydrides
- Glass microspheres

- 9 universities; 1 company
  - ✓ UC-Berkeley, UConn, Univ Missouri, Univ Michigan, Alfred, UC-Santa Barbara
  - ✓ TOFTEC / Univ. of Florida

PEM Fuel Cell Cost Reduced

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 $200/kW



1. High volume production defined as 500,000 units per year

Distributed Natural Gas-Based Hydrogen Production

- 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

Vehicle and Infrastructure "Learning" Demonstration

- $190 M with 50-50 cost share, for total of $380 M, over 6 years
- Will help DOE focus its research and development efforts
- Provide insight into vehicle and infrastructure interface issues
- Will help address codes, standards and safety issues
- Major auto and energy companies involved in 5 partnerships

Department of Transportation

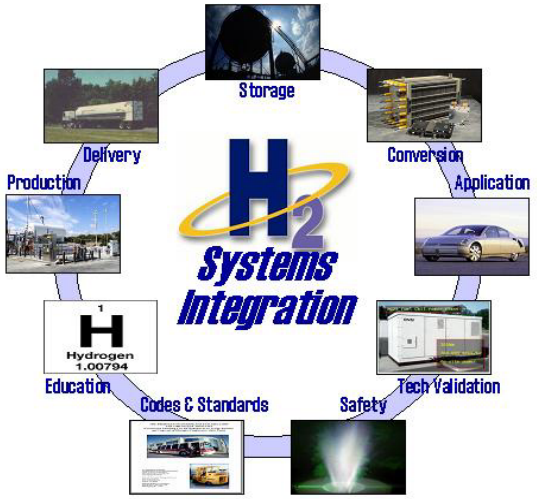
- **Safety:** Regulations that help ensure the safe design and operation of hydrogen vehicles and infrastructure
- **Global Connectivity:** Hydrogen Fuel initiatives involve Global Partnerships and international companies that span continents and borders. DOT's efforts are helping to make hydrogen a cornerstone of sustainable growth.
- **Environmental Stewardship:** Fuel-cell buses and heavy-duty vehicles will reduce transportation's impact on the environment

DOT Hydrogen Codes, Standards and Regulatory Activities

- National Highway Traffic Safety Administration (NHTSA): Vehicle safety R&D and regulatory role
  - Develop Federal motor Vehicle Safety Standards
  - Component level testing: safety systems, leak detection, fire exposure, and road hazards
  - On-board refueling system/fueling station interface
  - Full vehicle: recycling, fleet data, crash testing
  - International Codes and Standards: Lead U.S. delegation under UN process
- DOT Pipeline and Hazardous Materials Safety Administration
  - Regulation of the transportation safety and security of hazardous materials in commerce
- RSPA - the Research and Special Programs Administration
  - Evaluation, hazard analysis and risk management of hydrogen delivery

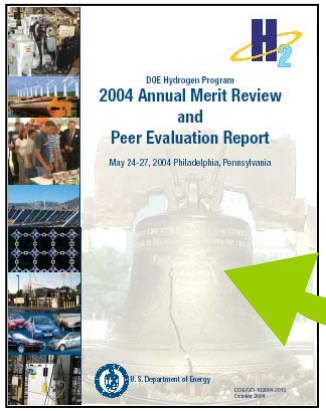
Established Systems Analysis & Integration

"The effective management of the Department of Energy hydrogen program will be far more challenging than any activity previously undertaken on the civilian energy side of the DOE." – National Academy of Sciences, February 2004

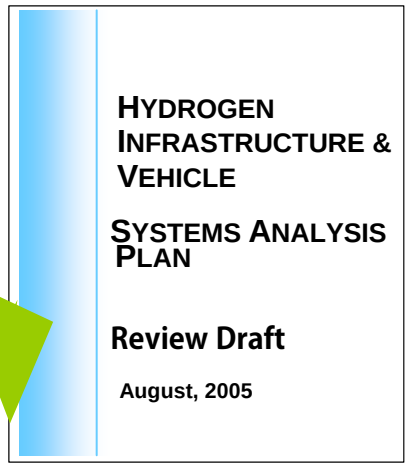


Established an independent Systems Integration and Analyses activity at NREL:

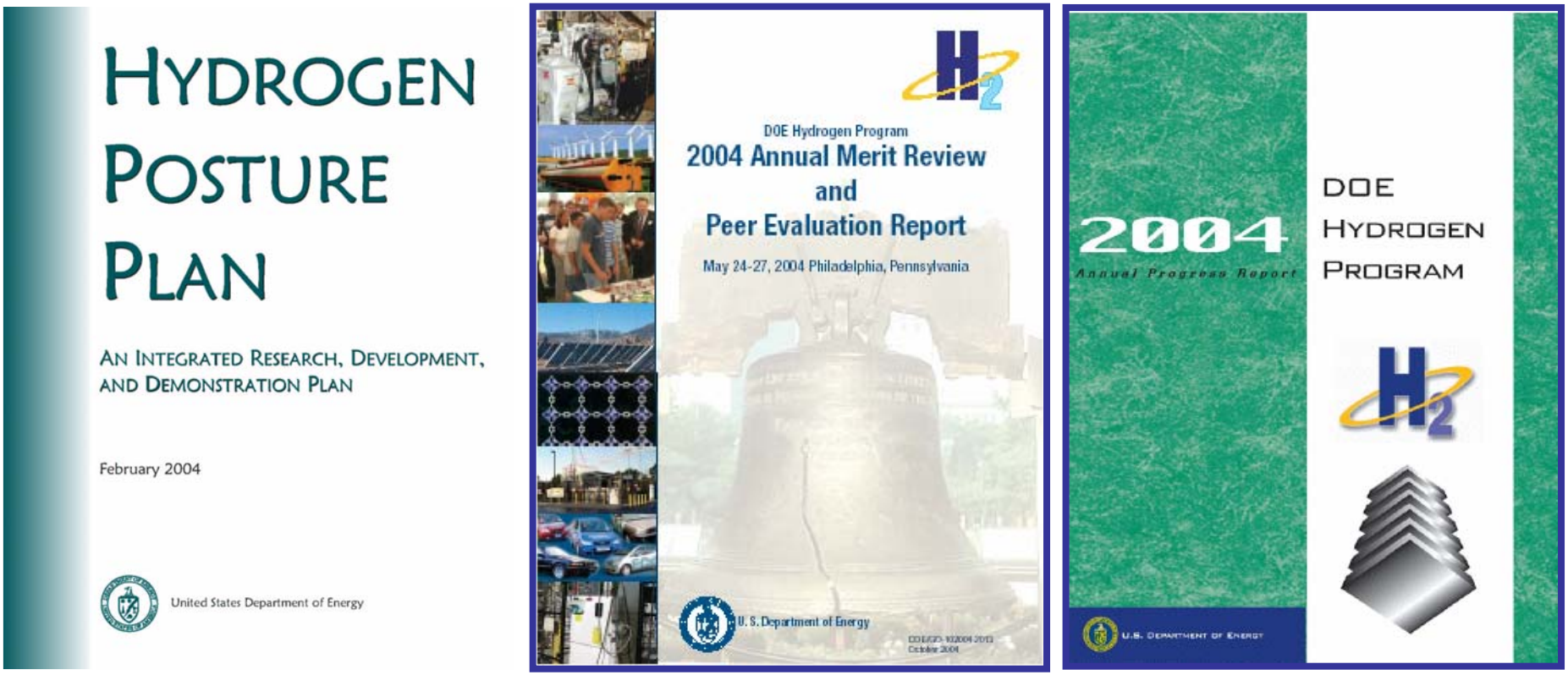
- **Established initial program Integrated Baseline**
  - **Combines Technical and Programmatic baselines into a common tool for planning, execution monitoring, and decision-making support**
- **Introducing Configuration/Change Control and Risk Management processes to the Program**
  - **Best practices from Federal Agencies/Industry, modified for R&D**



- **Independent Technical Reviews**
  - **Example: On-Board Fuel Processing Go/No-Go decision support in Jun 04**
- **Program Peer Review**
  - **Evaluates every project funded**



For More Information



http://www.rspa.dot.gov/dra/hydrogen/index.html

http://www.eere.energy.gov/hydrogenandfuelcells/

http://www.ne.doe.gov/hydrogen/hydrogenov.html

http://www.fossil.energy.gov/programs/fuels/index.html

http://www.sc.doe.gov/bes/bes.html

Interagency Coordination

- 9 US federal agencies
- Activities include:
  - A Hydrogen R&D "Taxonomy" of past, present, and possible future federal R&D
  - A searchable website with news and information on the progress of the President's Hydrogen Fuel Initiative

COMING SOON! www.hydrogen.gov