The President's Hydrogen Fuel Initiative

Workshop on
Manufacturing R&D for the Hydrogen Economy
Washington, DC
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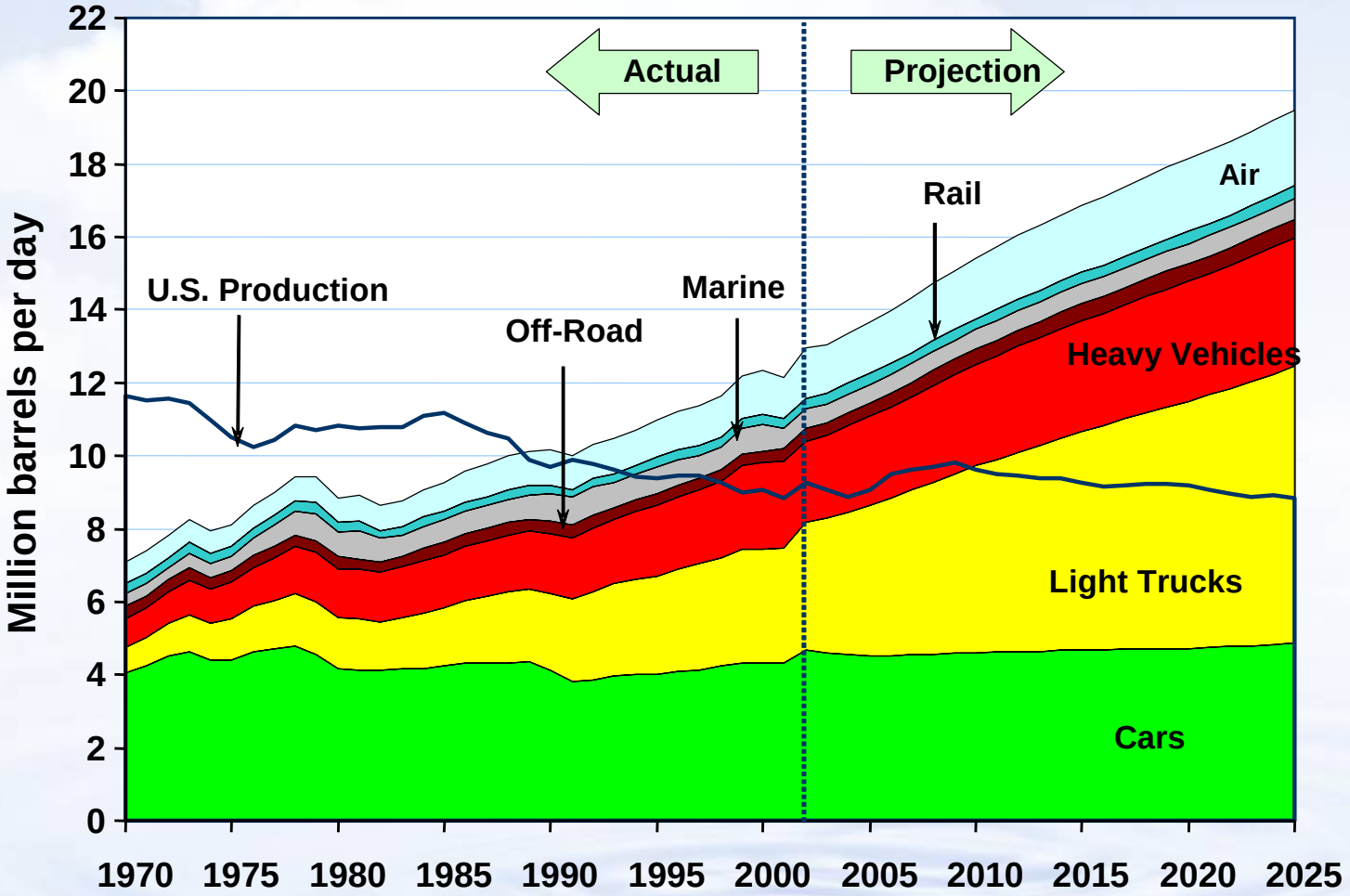
Planning

U.S. Energy Dependence is Driven By Transportation



- The U.S. imports 55% of its oil; expected to grow to 68% by 2025 under the status quo.
- Transportation accounts for 2/3 of the 20 million barrels of oil our nation uses each day.
- Gasoline hybrid electric vehicles will help in the near –mid term; a replacement for petroleum is needed for the long-term.

Hydrogen Provides a Solution

Producing hydrogen from domestic resources, including renewable, nuclear, and coal with carbon sequestration, can reduce dependence on petroleum, and yield virtually zero criteria and greenhouse gas emissions.

Coal

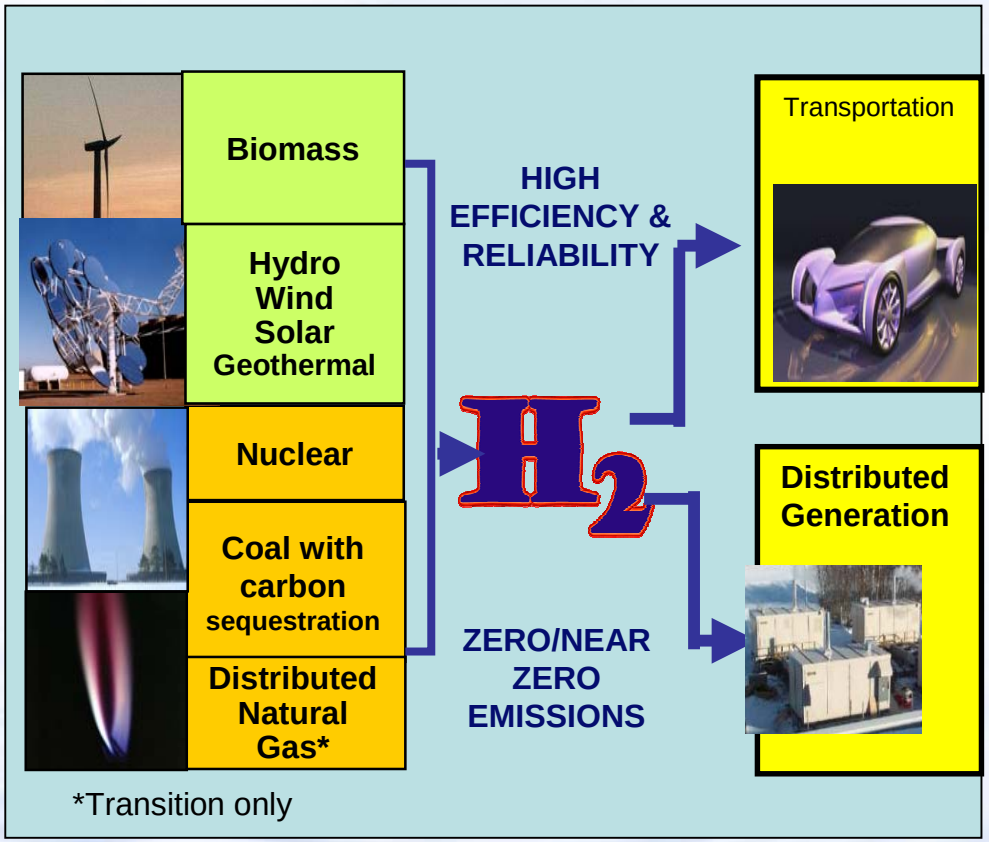
- Only with carbon capture & sequestration
- Gasification process produces hydrogen directly
- Electricity not produced as an intermediary

Distributed Natural Gas

- Transition strategy
- "Well-to-wheels" greenhouse gas emissions substantially less than gasoline hybrid-electric vehicle
- Not a long-term source for hydrogen (imports and demand in other sectors)

Nuclear/Renewable

- Electrolysis (one option)
- Electricity not necessarily produced as an intermediary, options being pursued include:
  - Gasification of biomass
  - Reforming of renewable liquids
  - Photoelectrochemical
  - Photobiological
  - Thermochemical (solar and nuclear)

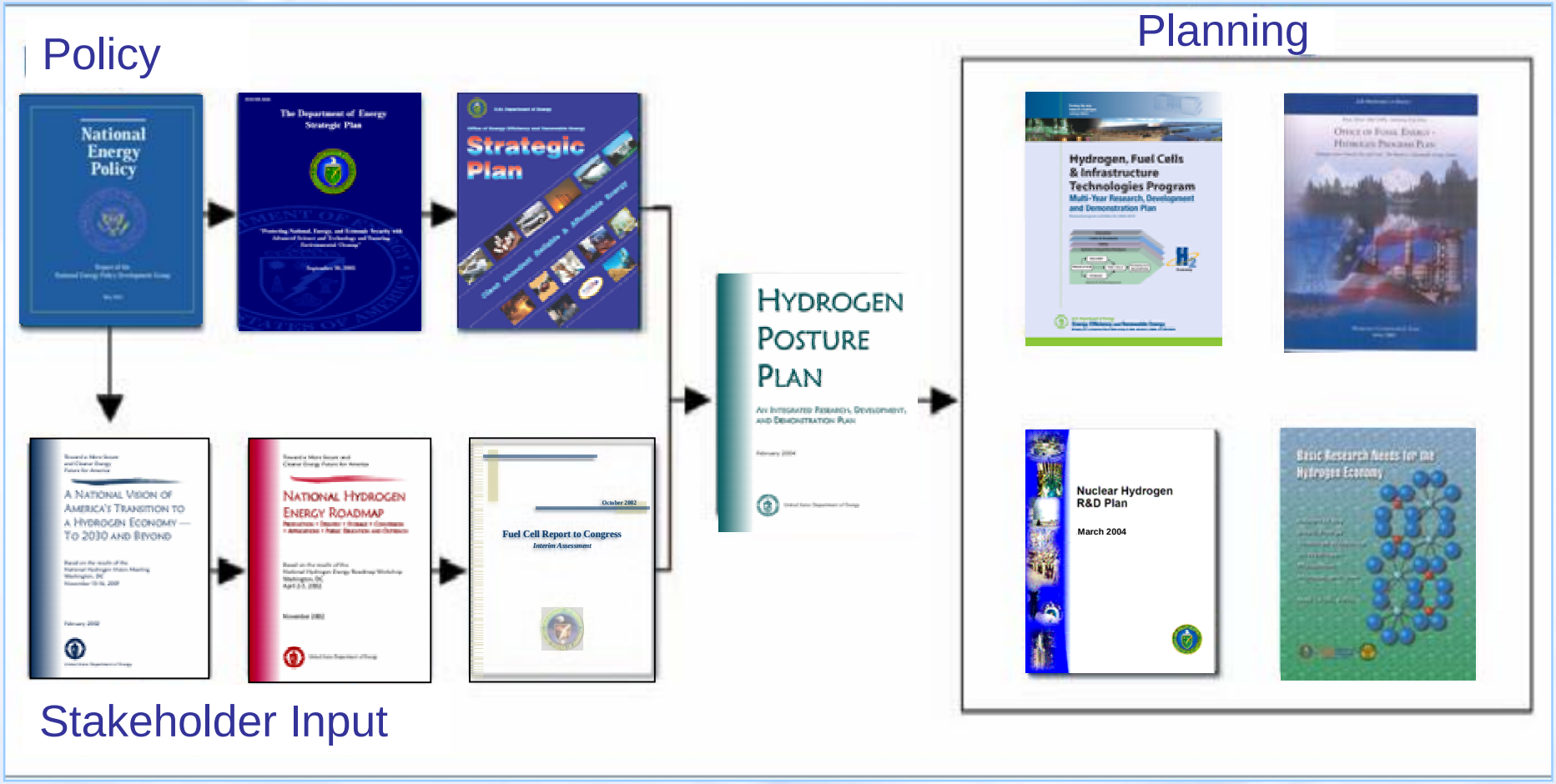


Hydrogen Infrastructure and Fuel Cell Technologies put on an Accelerated Schedule

- **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.**

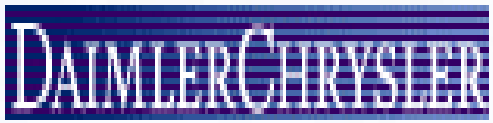
Fuel Cell Vehicles in the Showroom and Hydrogen at Fueling Stations by 2020

Policy and R,D&D Planning



FreedomCAR and Fuel Partnership Established

ChevronTexaco



Energy Company/DOE Technical Teams

- Production
- Delivery
- Fuel Pathway Integration

Auto/Energy/DOE Technical Teams

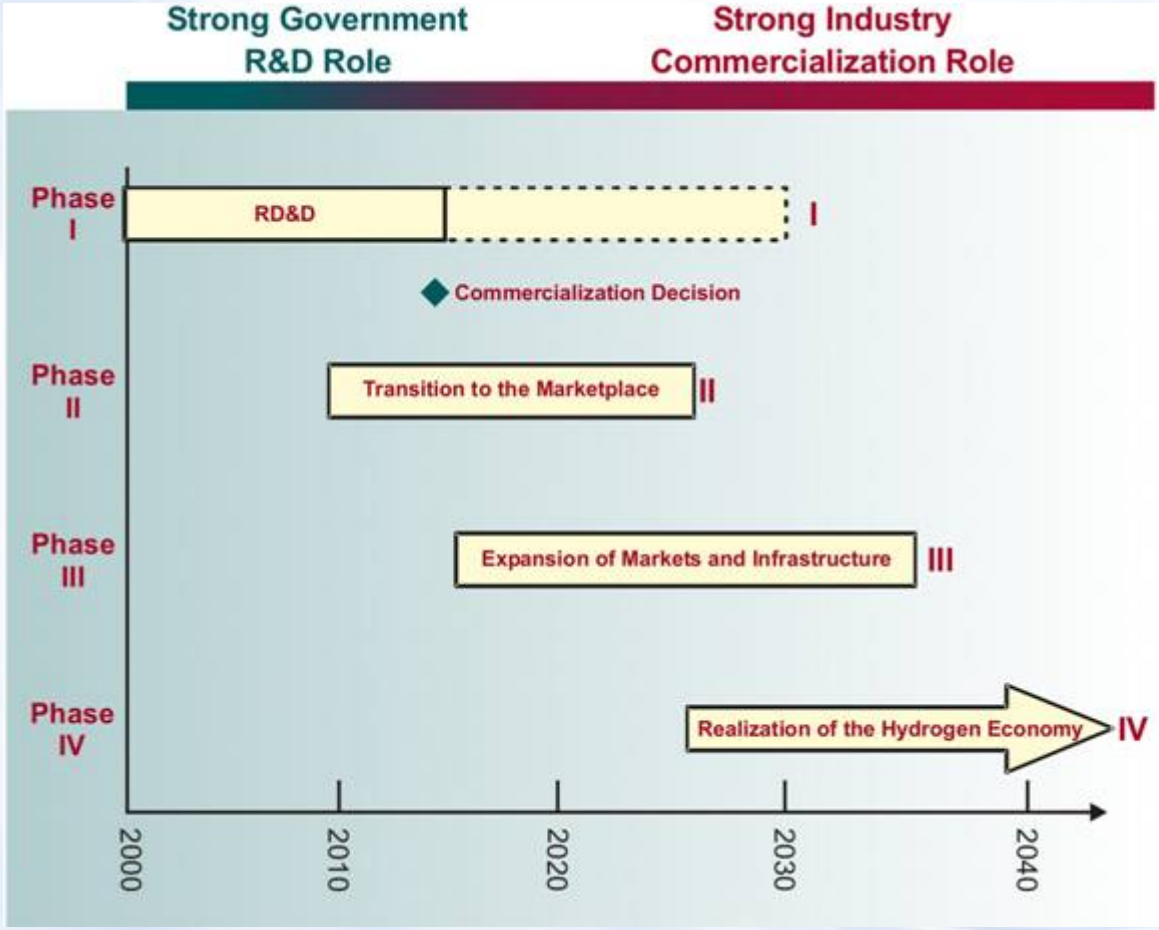
- Codes and Standards
- Storage

Auto/DOE Technical Teams

- **Fuel Cells**

Technology Roadmaps have been developed for each Technical Team.

Hydrogen Economy Timeline



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

Implementation

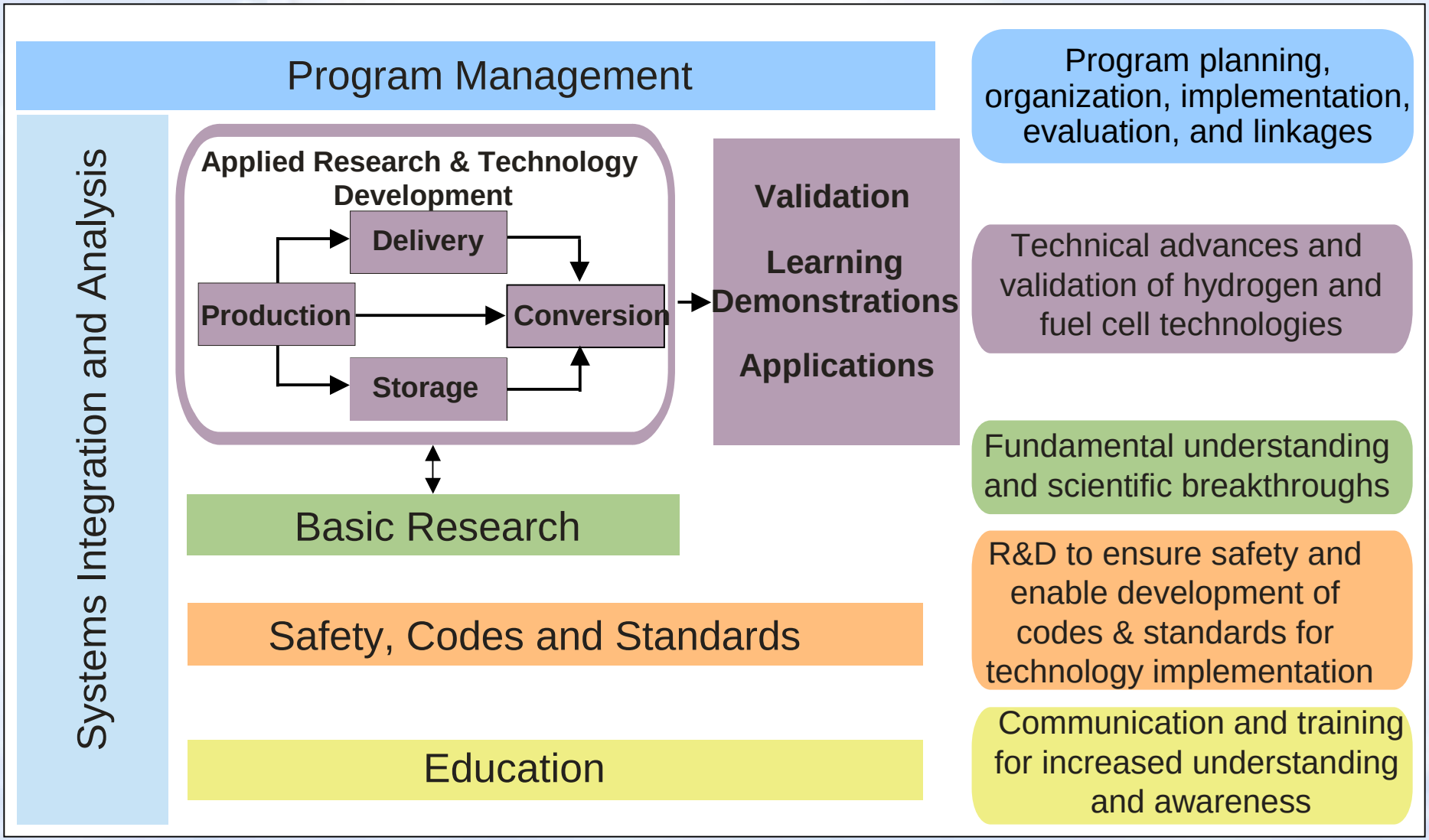
Key Hydrogen R&D Challenges Identified

Cost Reduction is a Primary R&D Driver

- **Hydrogen Production and Delivery**
  - Cost of hydrogen must be competitive with gasoline, without adverse environmental impacts
    - ➢ **$2.00-3.00/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.

Program Structured to Address Challenges



Projects in Place to Overcome Challenges

- Putting in place the projects that support the plans
- Initial solicitations are complete; yearly solicitations will continue

- **Initiated over $510M in new projects ($755M with private cost share) to overcome critical technology challenges. Includes:**
  - **Hydrogen Storage Centers of Excellence**
  - **New projects in hydrogen production**
  - **New fuel cell R&D projects**
  - **Learning demonstrations to evaluate technologies in real-world operating conditions, measure progress toward targets, and help focus R&D**
  - **Basic research addressing:**
    - **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**

Next: Manufacturing R&D

Manufacturing R & D for the Hydrogen Economy

Manufacturing challenges:

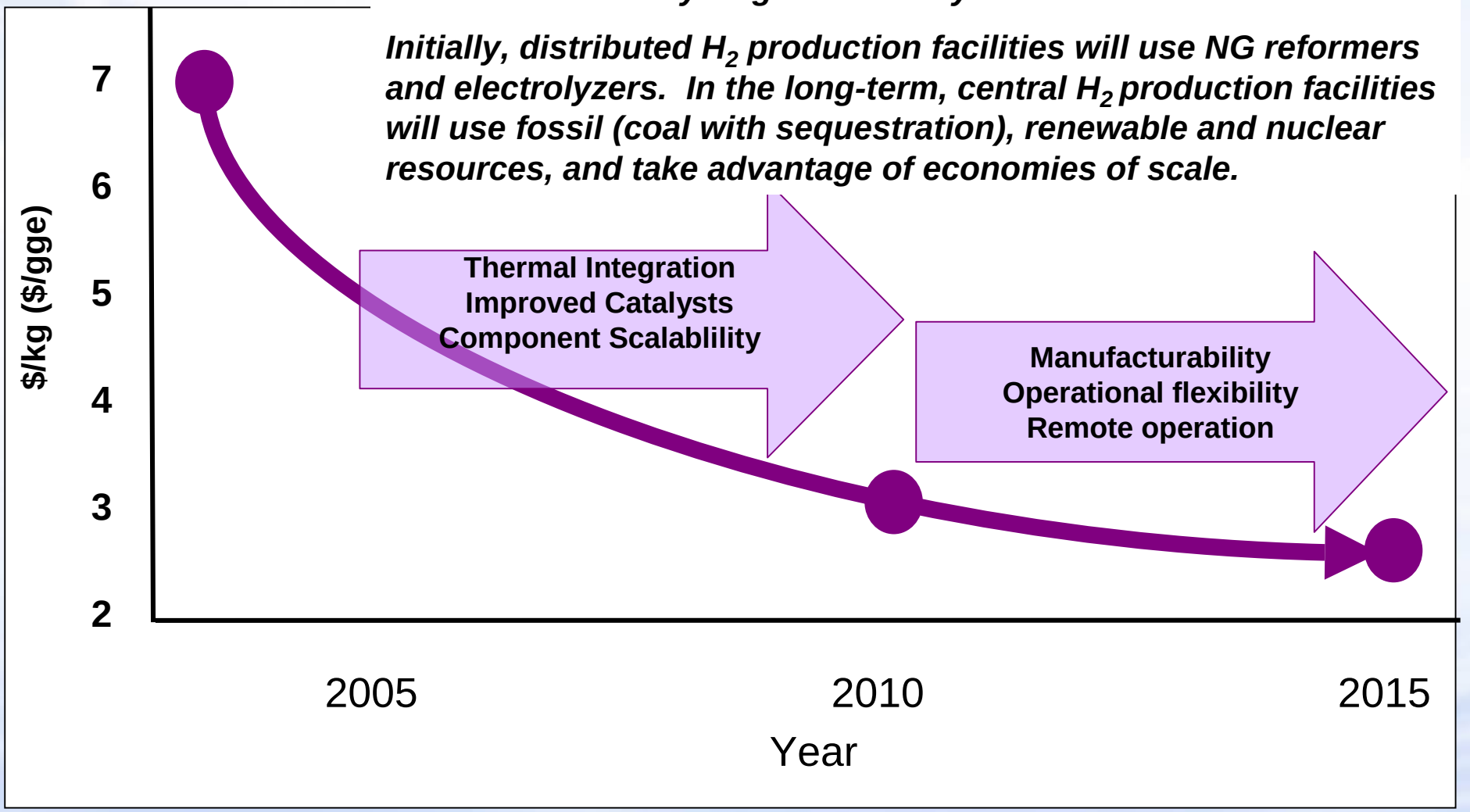
- Developing innovative, low-cost fabrication methods for new materials and applications
  - ➢ Adapting laboratory fabrication methods to low-cost, high-volume production
  - ➢ Establishing and refining cost-effective manufacturing techniques while hydrogen products are still evolving
- Meeting customer requirements for hydrogen systems
- Addressing the diversity and size of industries in both the manufacturing and energy sectors
- Developing a supplier network

Hydrogen Production

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

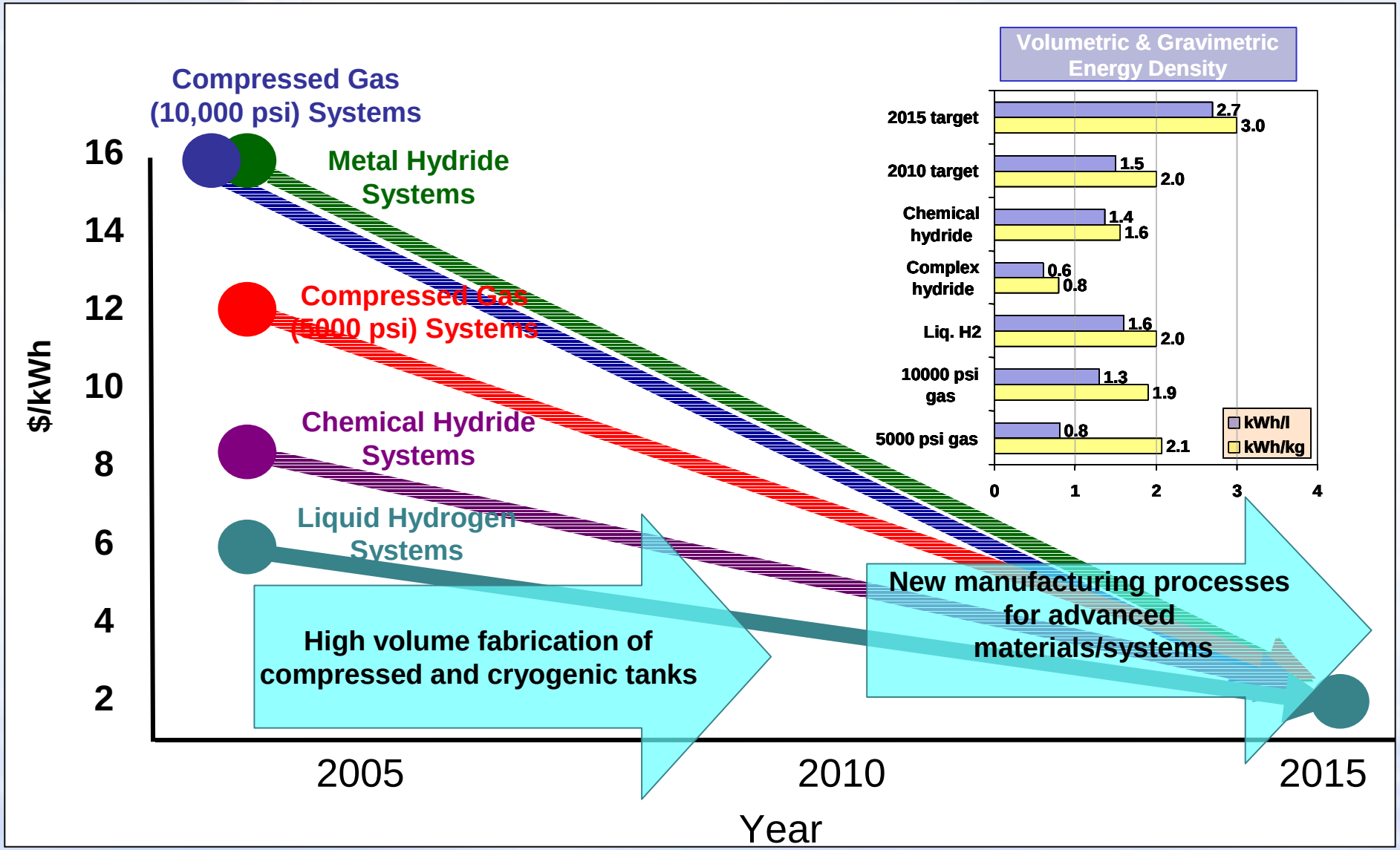
Transition to the Hydrogen Economy:

Initially, distributed H_2 production facilities will use NG reformers and electrolyzers. In the long-term, central H_2 production facilities will use fossil (coal with sequestration), renewable and nuclear resources, and take advantage of economies of scale.



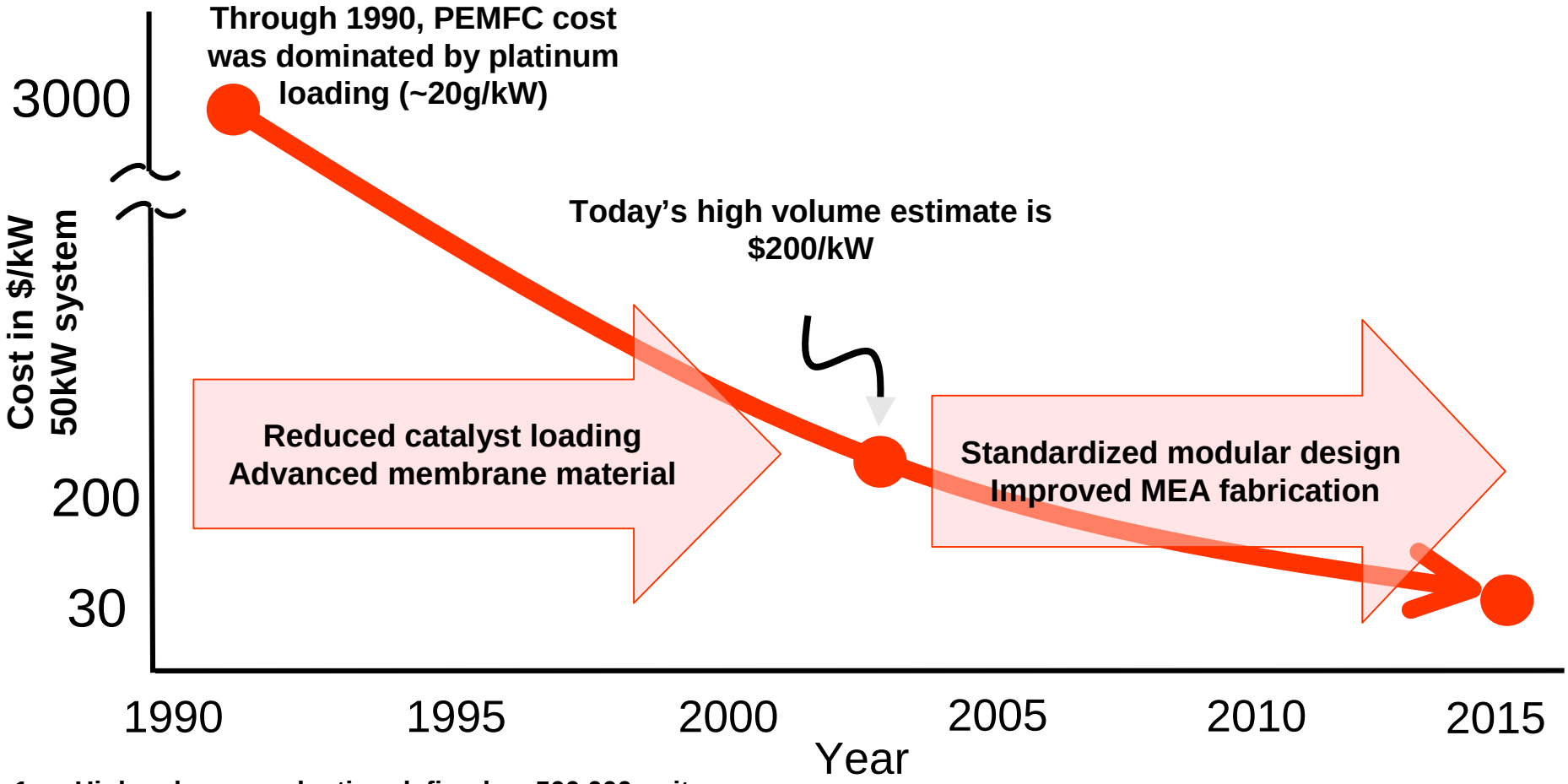
Hydrogen Storage

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



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. System = fuel cell stack and all balance of plant components.

Next Steps

- **Develop R&D Roadmap with stakeholders and experts in industry, academia, and government**
  - **Workshop in July 2005**
- **Define Core Manufacturing Technology Needs through a rigorous gap analysis**
- **Promote a coordinated, broad-based national R&D effort**
  - **Generic, pre-competitive core R&D on fabrication processes**
  - **Industry-led teams to develop manufacturing capability through cost-shared financial agreements**

Manufacturing R&D - Connected To Hydrogen Economy Timeline