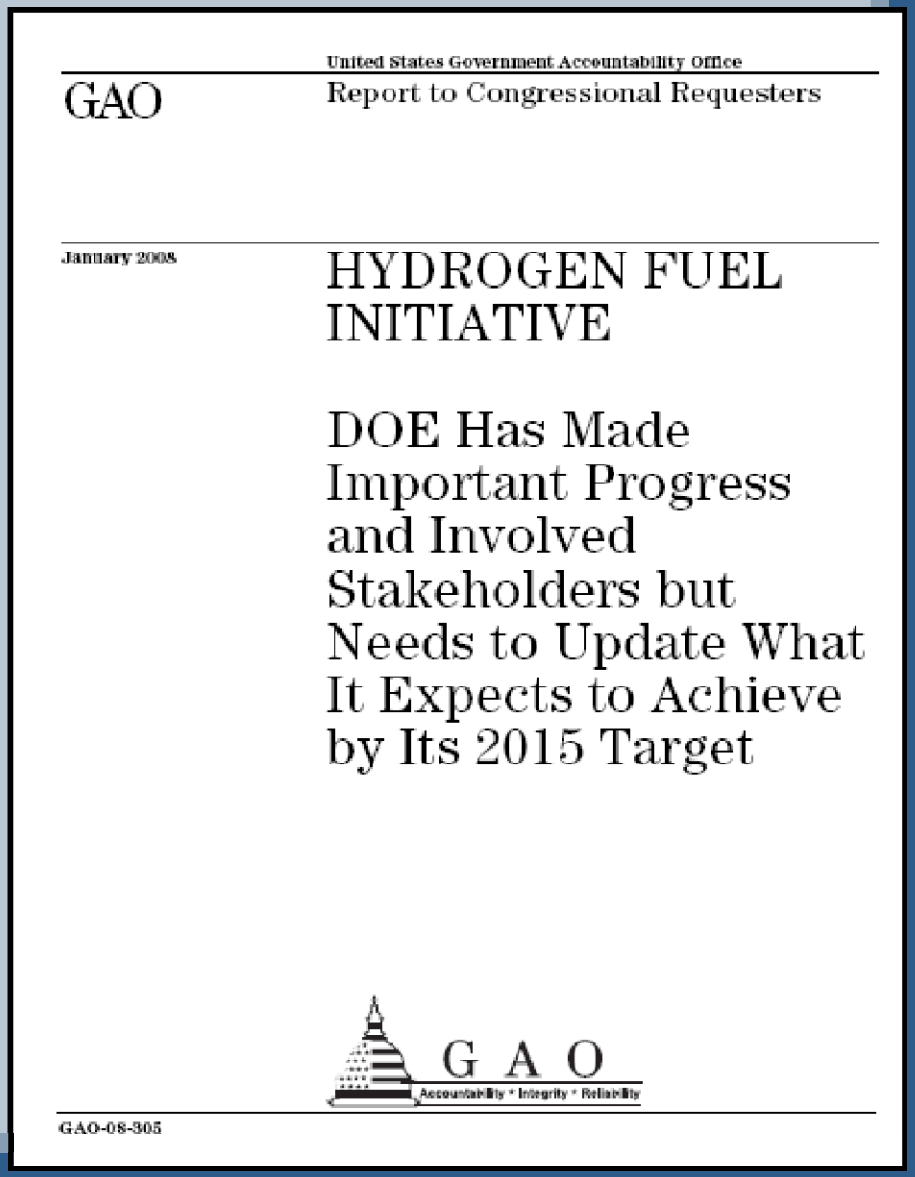


United States Government Accountability Office

GAO

Report to Congressional Requesters

January 2008

HYDROGEN FUEL INITIATIVE

DOE Has Made Important Progress and Involved Stakeholders but Needs to Update What It Expects to Achieve by Its 2015 Target

GAO

Accountability * Integrity * Reliability

GAO-08-305

Hydrogen Program Response to GAO Comment on Targets

HTAC Meeting
February 18, 2009

JoAnn Milliken
Program Manager
DOE Hydrogen Program

OUTLINE

- Overview of GAO Review
- Findings
  - Program Management & Progress
  - Remaining Challenges & Gaps
- GAO Main Recommendation: Clarity on 2015 Technology Readiness
- Current Targets
- Reevaluation of Targets

Overview of GAO Review

U.S. DEPARTMENT OF ENERGY

Examined extent to which DOE:

- ☑ Made progress in meeting targets
- ☑ Worked with industry to set and meet targets
- ☑ Worked with other federal agencies to develop and demonstrate targets

Process:

- ❖ Reviewed documents
- ❖ Interviewed DOE program managers, national laboratory scientists, industry executives, independent experts, and federal/state government officials
- ❖ Assessed DOE's process for soliciting industry input
- ❖ Attended technical meetings
- ❖ Toured industry facilities
- ❖ Attended 1st meeting of the Interagency Task Force (August 2007)

FINDINGS
Program Management & Progress

U.S. DEPARTMENT OF ENERGY

- DOE has made important progress in all R&D areas (fundamental and applied science):
  - Reduced cost of producing hydrogen from natural gas
  - Developed model to identify/optimize major elements of a H_2 delivery infrastructure
  - Increased storage capacity of H_2 by 50%
  - Reduced cost and improved durability of fuel cells
- DOE has generally managed its R&D resources well
- Managers at other federal agencies are generally satisfied with effort to coordinate activities among agencies
- DOE has involved experts at earliest planning stages and has continually focused on highest R&D priorities

FINDINGS
Remaining Challenges & Gaps

U.S. DEPARTMENT OF ENERGY

- Challenges requiring significant scientific advances lie ahead
  - Storing enough H_2 onboard to achieve >300 mi driving range
  - Reducing cost of delivering H_2 to consumers
  - Further reducing cost and improving durability of fuel cells
- Technical challenges and budget constraints has led DOE to push back some of its interim target dates
- DOE has not identified R&D funding needed to achieve its 2015 targets ***(Note: DOE does not publish out year budget profiles.)***
- Emphasis on fuel cell for vehicles has left little funding for stationary/portable applications which potentially could be commercialized before vehicles

GAO MAIN RECCOMMENDATION
Clarity on 2015 Technology Readiness

U.S. DEPARTMENT OF ENERGY

GAO Finding…

"DOE has not updated its 2006 Hydrogen Posture Plan to reflect what it reasonably expects to achieve by technology readiness date of 2015."

DOE Response…

- Working toward cost and performance targets to enable technologies to be competitive in the market and industry to make commercialization decisions
- Identified critical path R&D/targets for automotive applications
- Also identified R&D activities/targets to further develop and sustain hydrogen infrastructure beyond 2015, as well as for fuel cells in stationary and portable applications
- Targets are currently being reevaluated and updated to reflect changes over the past several years

CURRENT TARGETS
Critical Path Technologies – H_2 Production

U.S. DEPARTMENT OF ENERGY

Hydrogen Production - Cost

- Target (2015): $2 - 3/gge *(delivered, untaxed)*
  - ***Achieved: $3/gge ($H_2$ from distributed natural gas)***
  - ***Status: $4.5/gge – 5.0/gge (distributed renewable H_2)***
  - ***Status: $5/gge - $9/gge (central H_2)****

* Includes $3/gge for delivery.

CURRENT TARGETS
Critical Path Technologies - H_2 Storage

U.S. DEPARTMENT OF ENERGY

*H_2 Storage – System Gravimetric Capacity**

- Target (2010): 6%
- Target (2015): 9%

*H_2 Storage – System Volumetric Capacity**

- Target (2010): 1.5 kWh/L (45 g/L)
- Target (2015): 2.7 kWh/L (81 g/L)

H_2 Storage System - Cost

- Target (2010): $4/kWh
- Target (2015): $2/kWh

H_2 Storage – 350 bar compressed H_2 - Status

- **Gravimetric Capacity:** 2.8% – 3.8%
- **Volumetric Capacity:** 17 – 18 g/L
- **Cost:** $17/kWh

H_2 Storage – 700 bar compressed H_2 - Status

- **Gravimetric Capacity:** 2.5% –4.4%
- **Volumetric Capacity:** 18 – 25 g/L
- **Cost:** $27/kWh

H_2 Storage – Liquid H_2 - Status

- **Gravimetric Capacity:** 5.1% – 6.5%
- **Volumetric Capacity:** 22 – 36 g/L
- **Cost:** $8/kWh *for system*

H_2 Storage – Materials (adsorbent) - Status

- **Gravimetric Capacity:** 3%
- **Volumetric Capacity:** 14 – 19 g/L
- **Cost:** $15.6/kWh

CURRENT TARGETS
Critical Path Technologies – Fuel Cells (Auto)

U.S. DEPARTMENT OF ENERGY

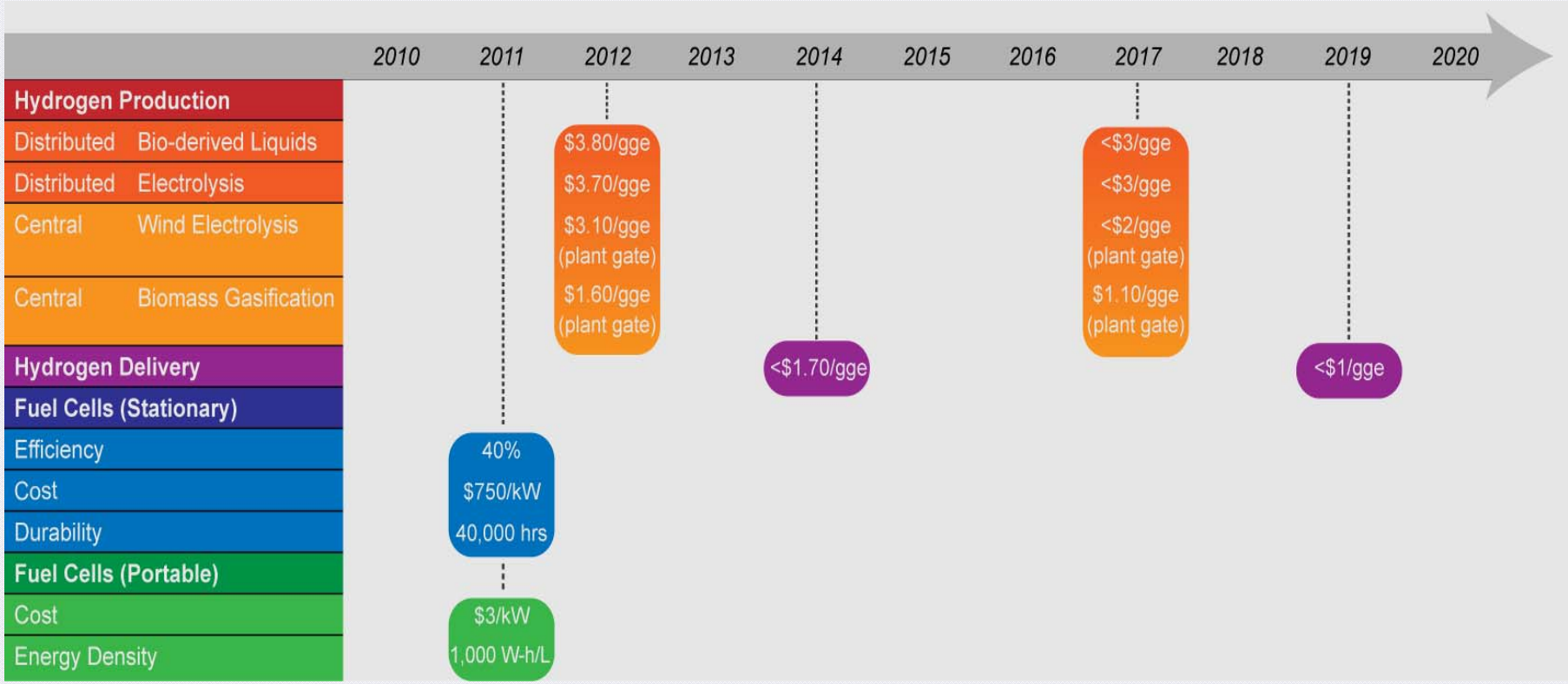
Fuel Cells (Auto) - Cost

- Target (2010): $45/kW
- Target (2015): $30/kW
  - ***Status (2008): $73/kW***

Fuel Cells (Auto) - Durability

- Target (2010 & 2015): 5,000 hrs
  - ***Status (2008):***
    1,900 hrs (projected)
    1,700 hrs (observed)

CURRENT TARGETS
Other Targets



The Program is Reevaluating Targets

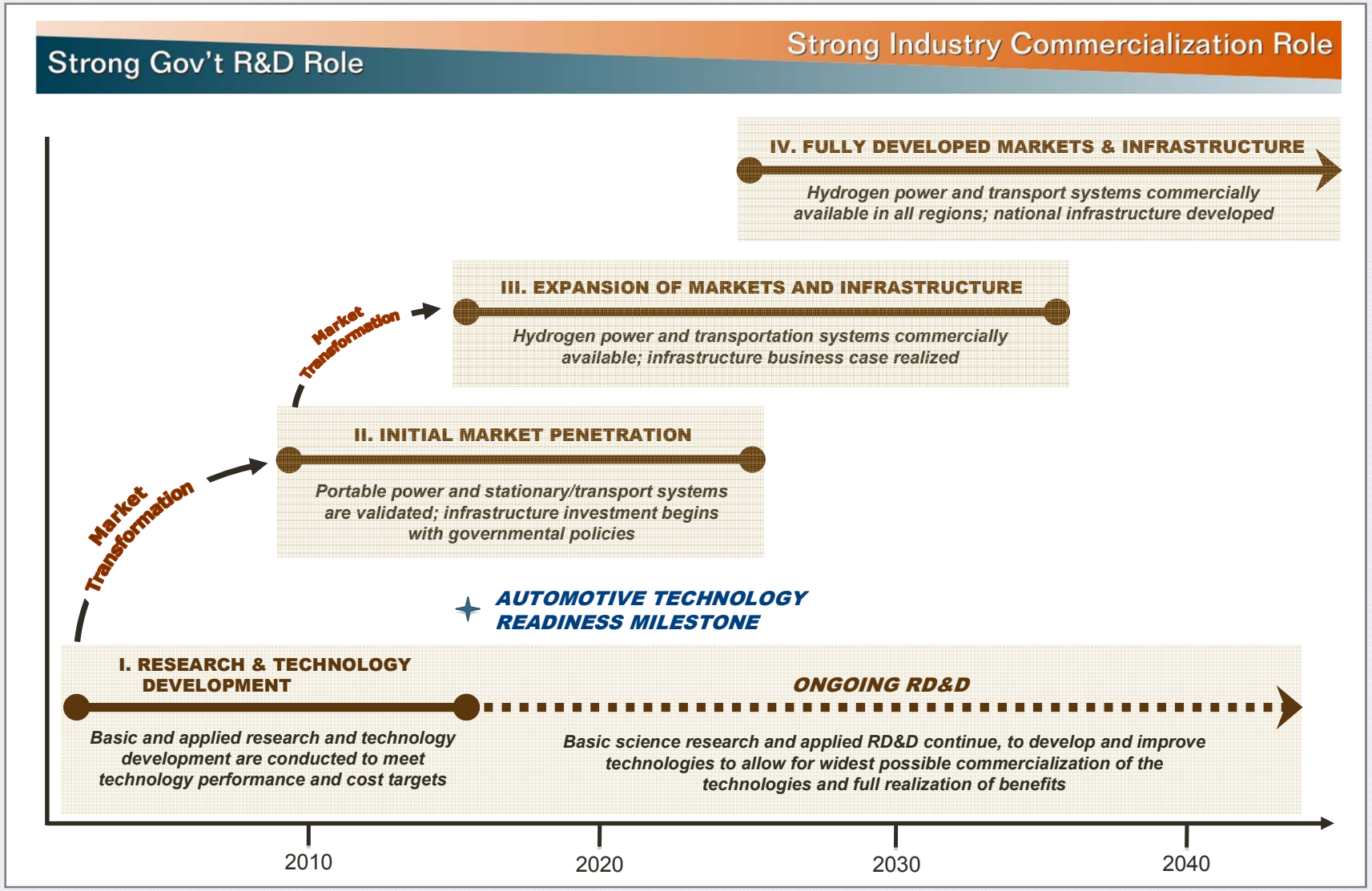
- Milestones exist to reevaluate targets (e.g., H_2 storage targets evaluated every 5 years) to assure validity of assumptions
- Significant changes have occurred in past 5 years
  - Access to “real-world” data
  - Changes in cost of gasoline
  - Changes to vehicle architecture assumptions
  - Learning
    - Competing technologies
    - System requirements
    - Market requirements

BACK-UP SLIDES

Evolution of Technologies & Markets

U.S. DEPARTMENT OF ENERGY

RD&D continues beyond technology readiness milestone.



Challenges & Barriers

- *The Program has identified the critical path barriers and the targets that need to be met for fuel cell vehicle (FCV) technology readiness in 2015.*
- *Targets for stationary and portable power fuel cells have also been developed.*

Technology Barriers

Hydrogen Cost

Target: $2 – 3 /gge

H_2 Storage Capacity & Cost

Greater than 300-mile range, without compromising safety or performance

Fuel Cell Cost & Durability

Targets:

Vehicles: $30 per kW, 5000-hr durability

Stationary Systems: $750/kW, 40,000-hr durability

Technology Validation:

Technologies must be demonstrated under real-world conditions

Economic & Institutional Barriers

Safety, Codes & Standards Development

H_2 Supply & Delivery Infrastructure

Domestic Manufacturing & Supplier Base

Public Awareness & Acceptance

Critical Path Barriers for FCVs

Market Transformation

Assisting the growth of early markets will help to overcome many barriers, including achieving significant cost reductions through economies of scale.

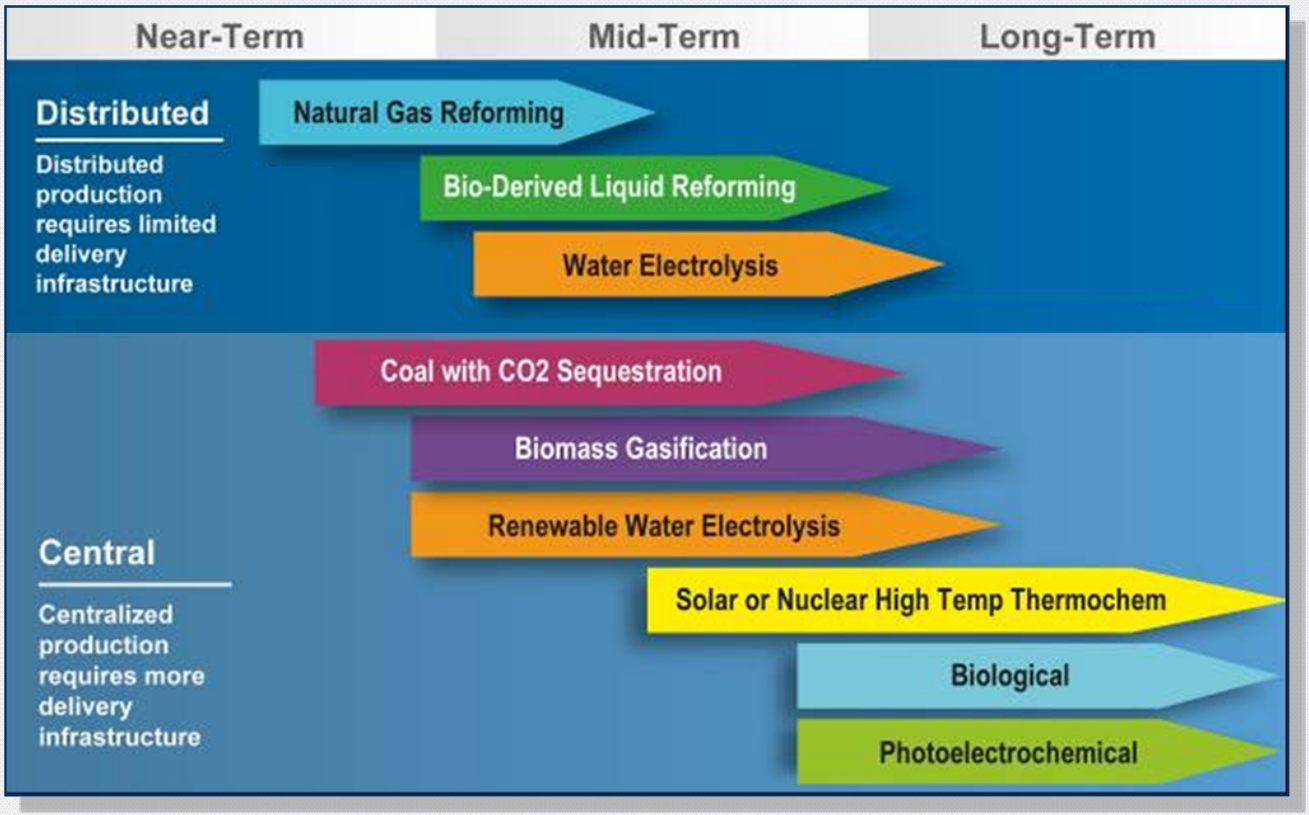
Hydrogen Production & Delivery R&D

U.S. DEPARTMENT OF ENERGY

The Program is working to develop clean, diverse, pathways for the supply of hydrogen from domestic resources, including fossil, nuclear, and renewable sources.

Key Production Objective:
Reduce the cost of delivered hydrogen (untaxed) to $2.00 – $3.00/gge (gallon gasoline equivalent).

Key Delivery Objective:
Reduce total hydrogen delivery cost to < $1.00/gge.



Current costs:

$3/gge to ~$5/gge

Current costs:

~$5/gge to ~$9/gge

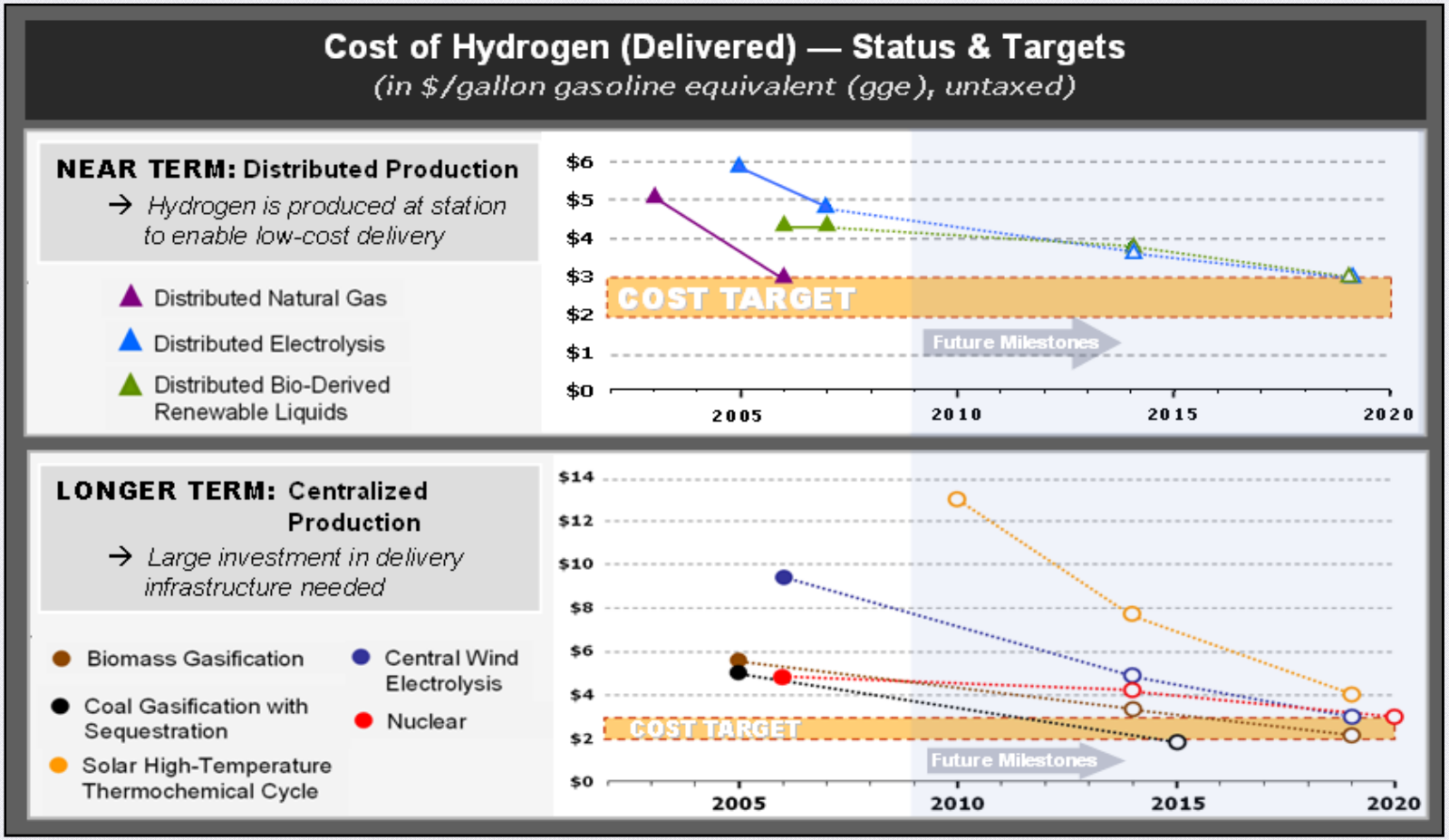
(includes $3/gge for delivery)

Hydrogen Production & Delivery R&D

U.S. DEPARTMENT OF ENERGY

KEY OBJECTIVE: Reduce the cost of hydrogen to $2 – $3/gge, delivered

The Program has established milestones for R&D efforts in all production pathways; cost of distributed production pathways has been reduced.



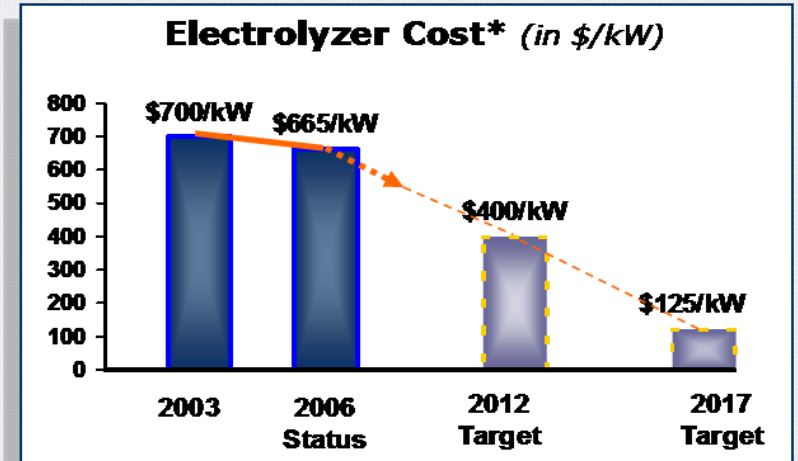
FY 09 Request: $0 **FY 09 Senate Mark: $22.0 million**

Hydrogen Production R&D

U.S. DEPARTMENT OF ENERGY

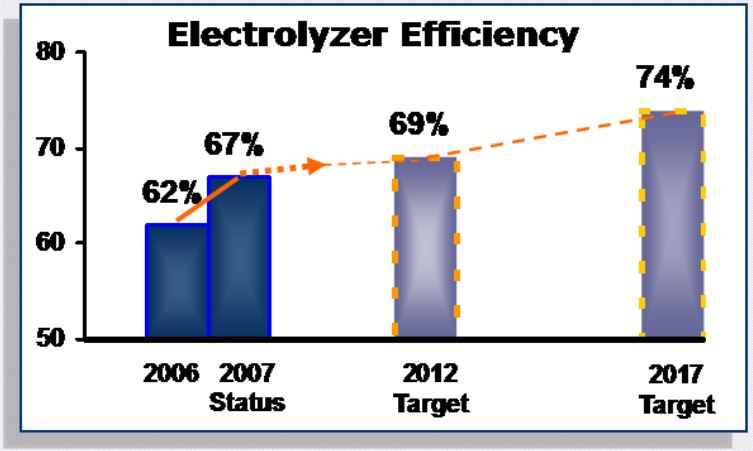
The Program has made progress in renewable hydrogen production, including advances in electrolyzers and biological production.

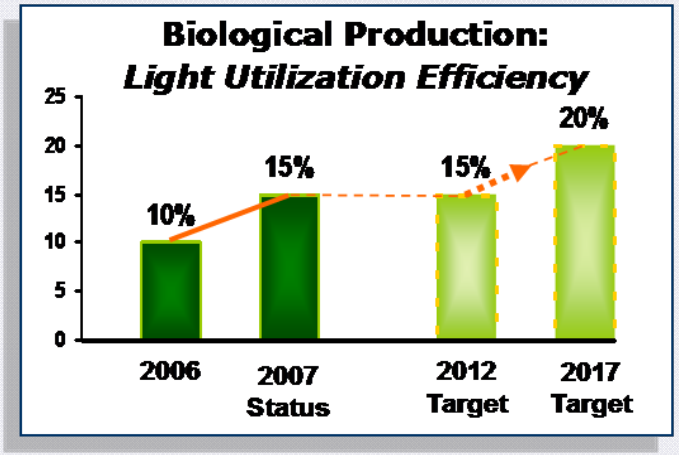
The capital cost of electrolyzers is being reduced



Progress is being made in biological production

The energy efficiency of electrolyzers is being improved





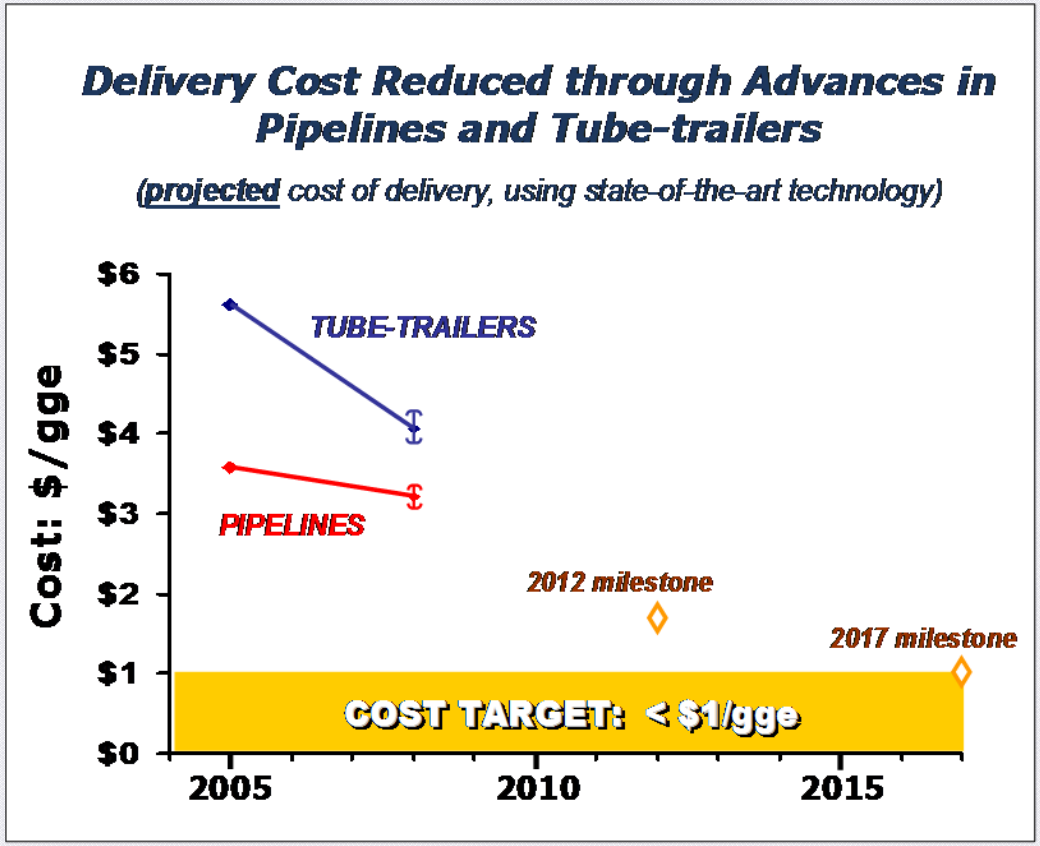
Hydrogen Delivery R&D

U.S. DEPARTMENT OF ENERGY

KEY OBJECTIVE: Reduce the total cost of delivering hydrogen to < $1.00/gge.

CHALLENGES

- High capital cost of pipelines, compression, liquefaction, off-board storage
- Improving energy efficiency of compression & liquefaction
- Embrittlement of pipelines
- Developing low-cost, efficient hydrogenation/dehydrogenation for liquid carriers
- Maintaining stringent quality requirements for H_2 used in PEM fuel cells

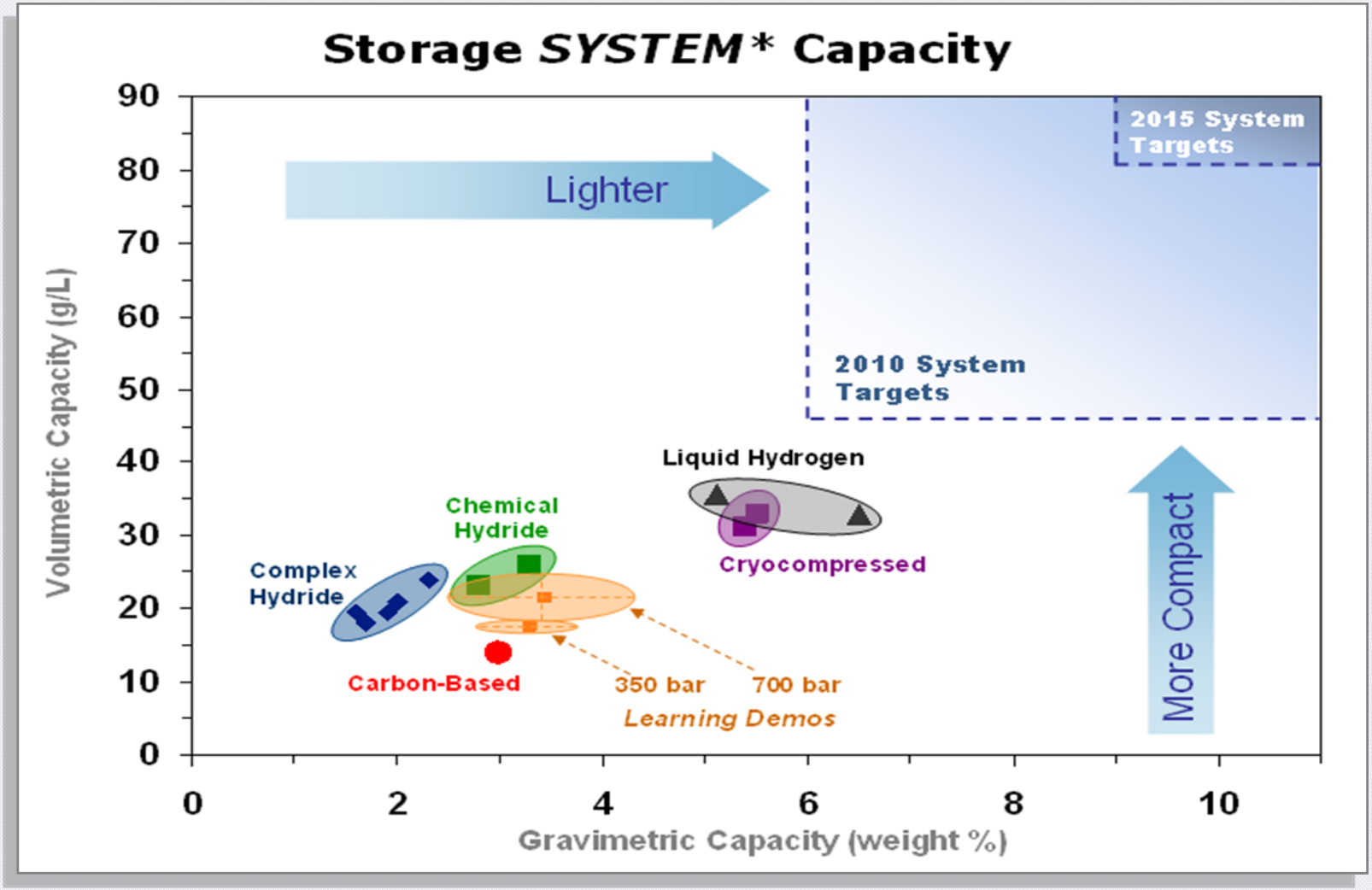


Hydrogen Storage R&D

U.S. DEPARTMENT OF ENERGY

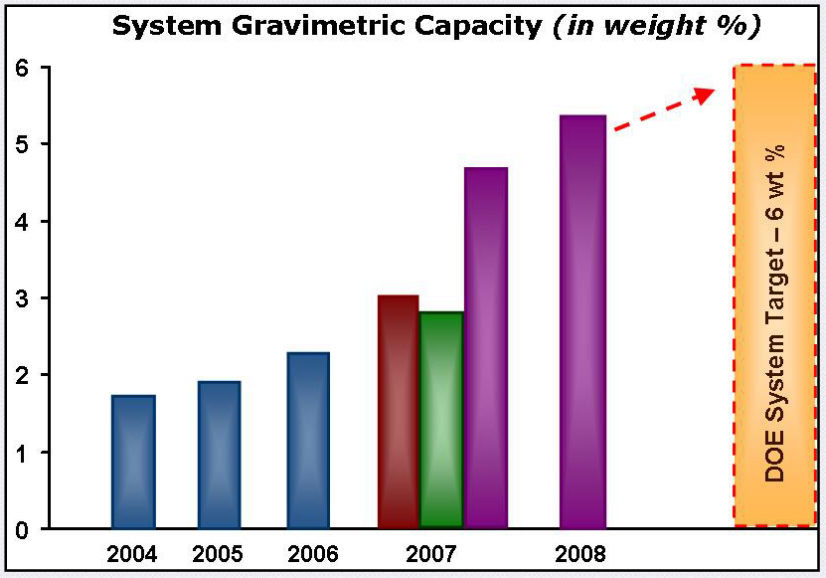
KEY OBJECTIVE: *> 300-mile driving range in all vehicle platforms, without compromising passenger/cargo space, performance, or cost*

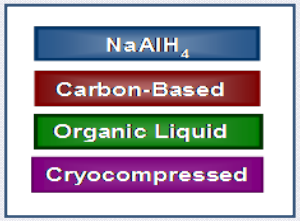
→ *No current technology meets storage system weight and volume targets.*



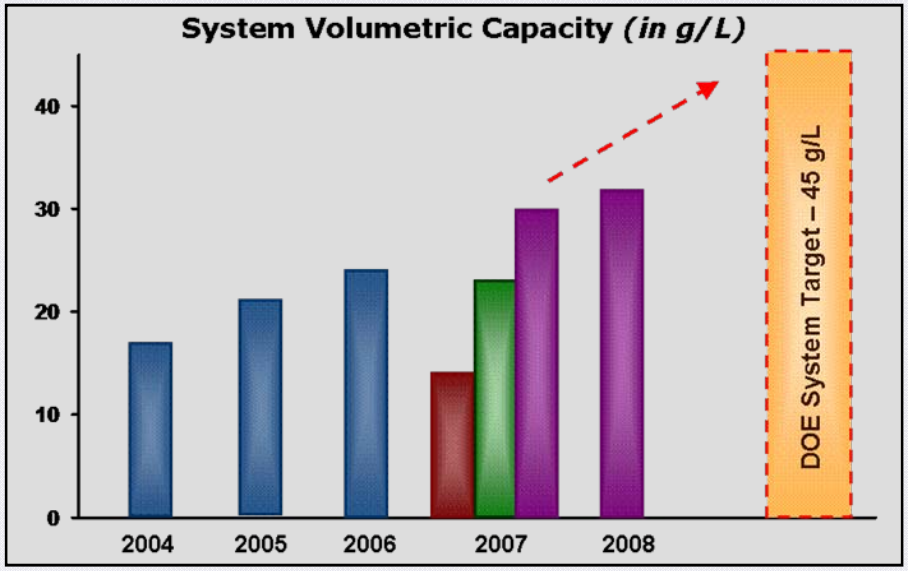
** System capacity estimates include materials, tanks, and balance of plant*

Hydrogen Storage System Progress





- Preliminary designs developed and improvements made
- But no technology meets targets
- Need to focus on volumetric capacities



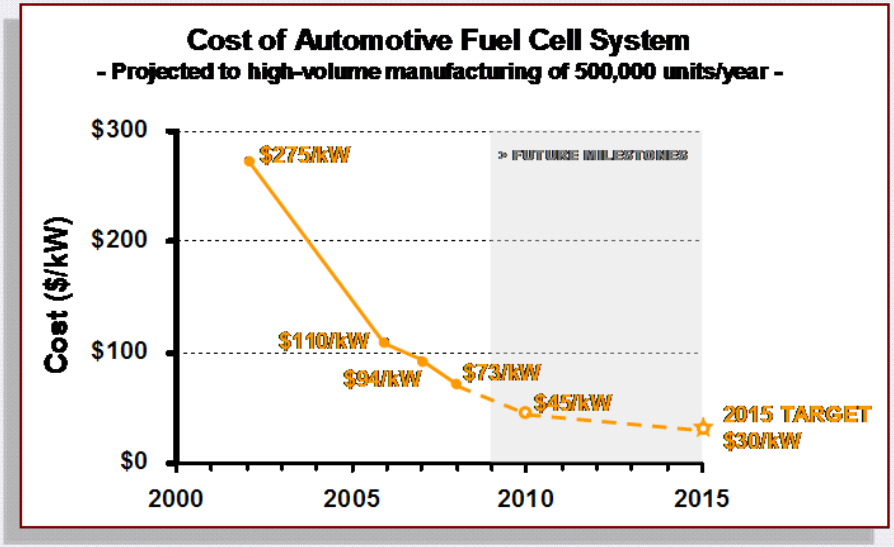
- Projected system capacities based on modeling and material data.
- Subscale prototype developed for $NaAlH_4$
- Full scale prototype developed for cryo-compressed tank

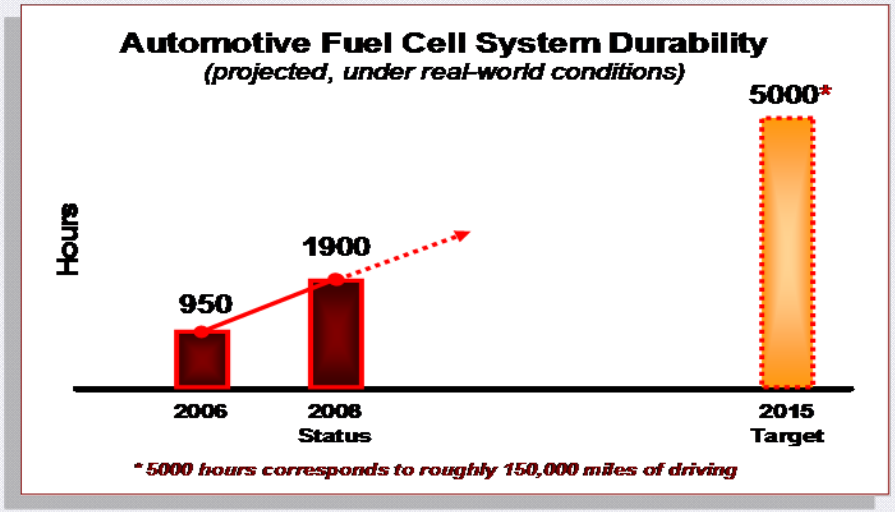
Fuel Cell R&D
Transportation

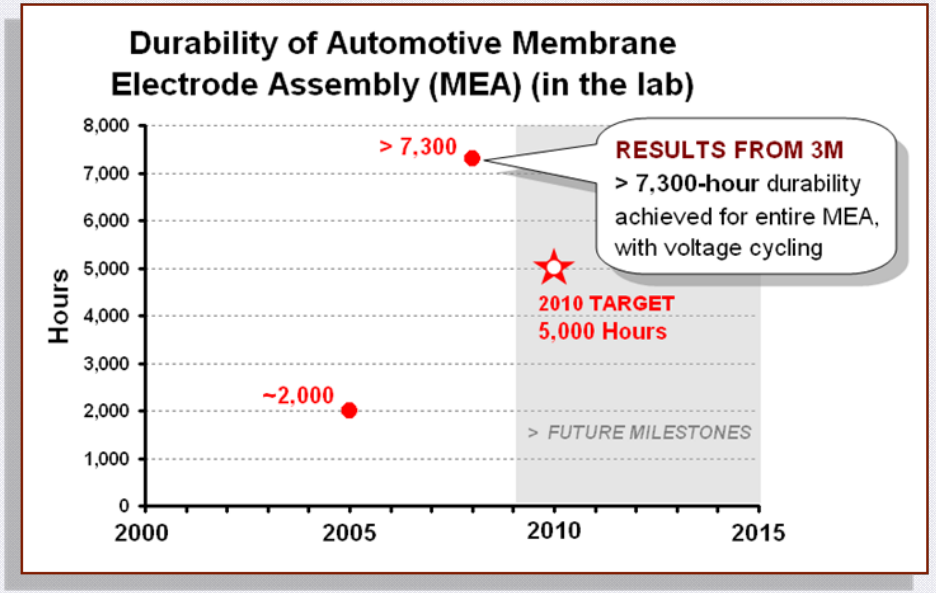
U.S. DEPARTMENT OF ENERGY

KEY OBJECTIVES: *Reduce cost of automotive fuel cell systems to $30/kW and improve durability to 5,000 hours (~150,000 miles).*

→ ***Significant progress is being made in reducing cost & improving durability.***







Progress toward key targets is achieved through improvements in critical components.

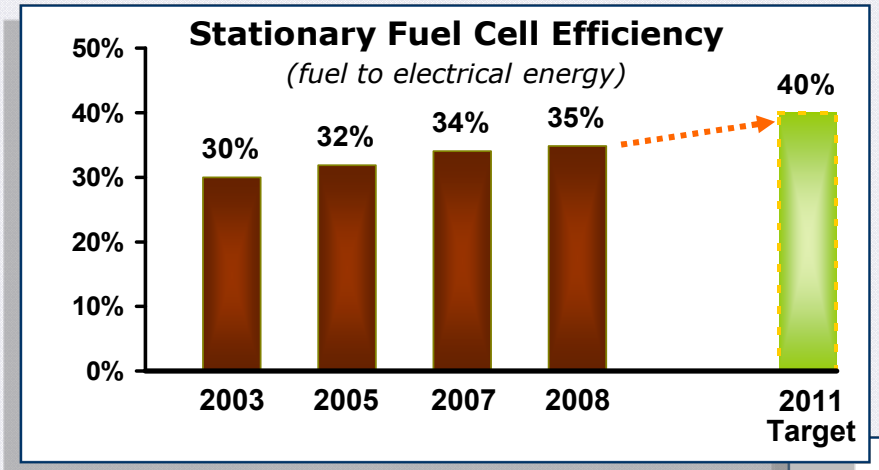
Fuel Cell R&D

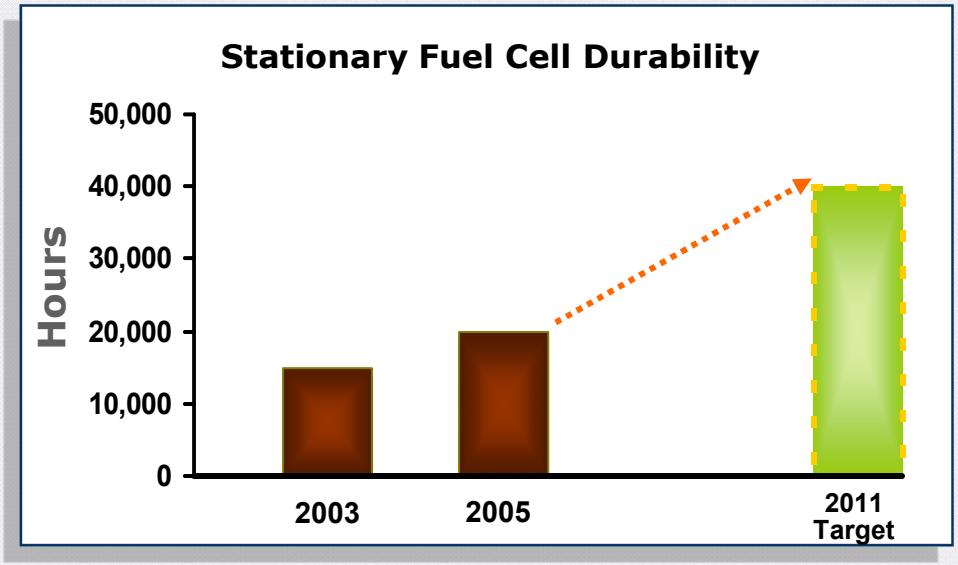
Stationary & Portable Power

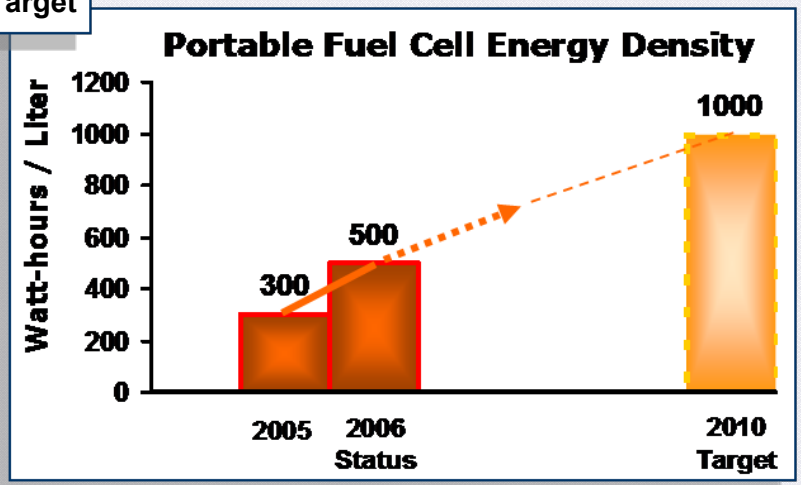
U.S. DEPARTMENT OF ENERGY

KEY OBJECTIVES:

- *Stationary Fuel Cell Systems—reduce cost to $750/kW and increase durability to 40,000 hours.*
- *Portable Fuel Cells—reduce cost to $3/W and increase energy density to 1,000 Watt-hours/Liter.*







Technology Validation

Technologies must be validated in integrated systems, under real-world conditions.

DOE Vehicle/Infrastructure Demonstration

(four teams in 50/50 cost-shared projects)

Verified performance in 122 fuel cell vehicles and 16 hydrogen stations:

- ***EFFICIENCY: 53 – 58%*** *(>2x higher than gasoline internal combustion engines)*
- ***RANGE: ~196 – 254 miles***
- ***FUEL CELL SYSTEM DURABILITY:***
  - ***1,900 hours, projected (~57,000 miles)***
  - ***1,700 hours, observed (~51,000 miles)***

Additional projects include:

- **Demonstrating integration of renewable power and hydrogen production**
- **Data collection and analysis with other agencies**
  - *DOT's Fuel Cell Bus Program*
  - *DOD's fuel cell forklifts*