U.S. Department of Energy Fuel Cell Activities: Progress and Future Directions

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Total Energy USA

Houston, Texas

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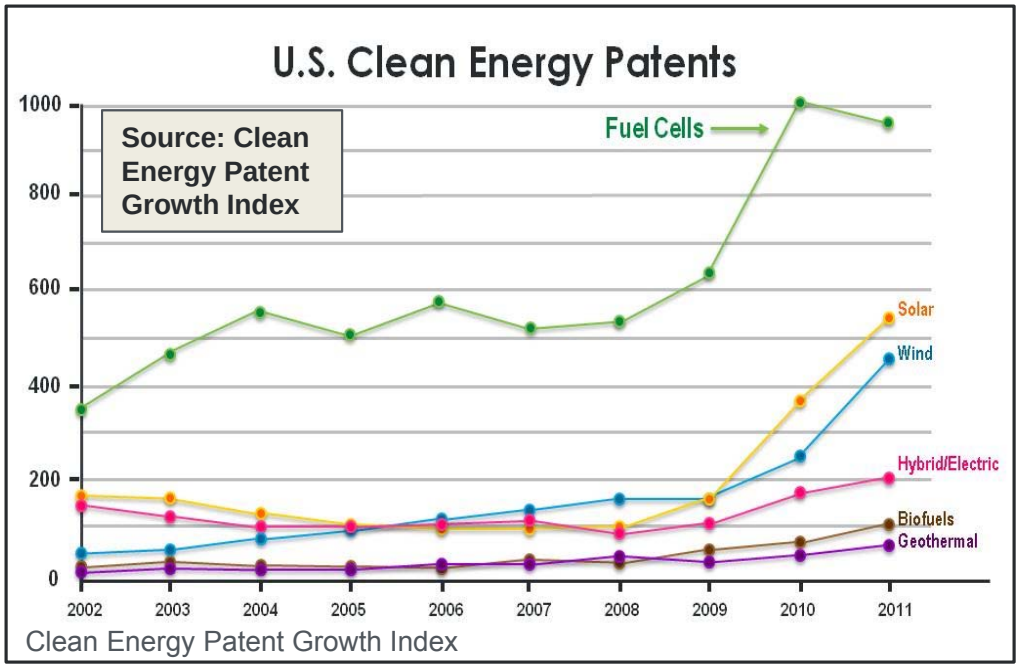
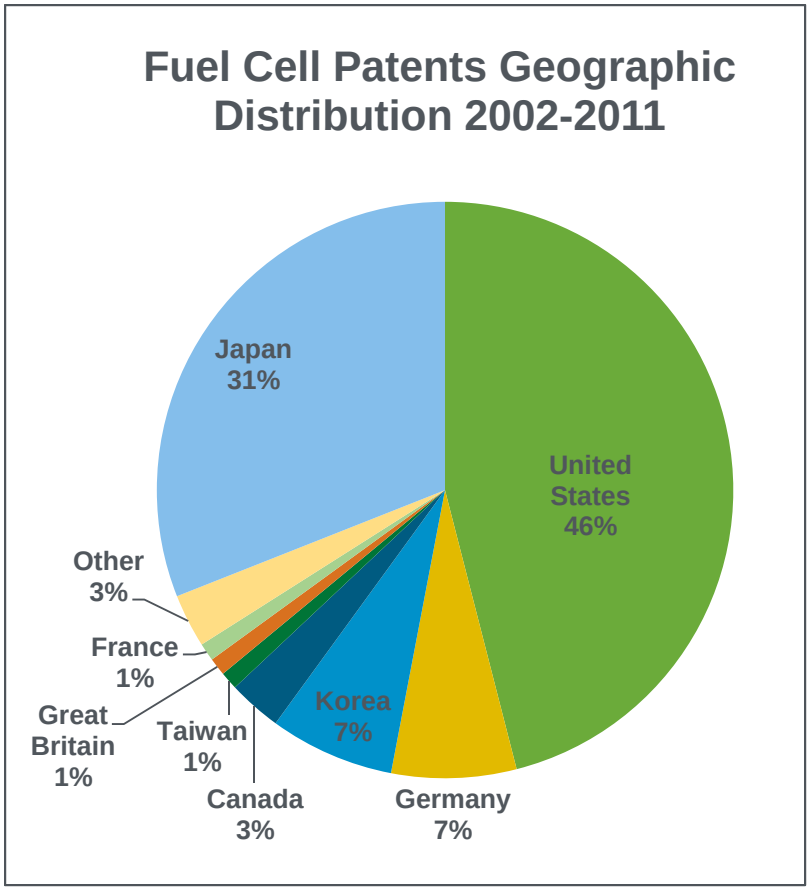
Overview
Fuel Cells – An Emerging Global Industry



Top 10 companies: GM, Honda, Samsung, Toyota, UTC Power, Nissan, Ballard, Plug Power, Panasonic, Delphi Technologies



Clean Energy Patent Growth Index[1] shows that fuel cell patents lead in the clean energy field with over 950 fuel cell patents issued in 2011.

- Nearly double the second place holder, solar, which has ~540 patents.

[1] 2010 Year in Review from http://cepgi.typepad.com/heslin_rothenberg_farley_/
[1] http://cepgi.typepad.com/files/cepgi-4th-quarter-2011-1.pdf

Worldwide Investment & Interest Are *Strong and Growing*

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Interest in fuel cells and hydrogen is global, with more than $1 billion in public investment in RD&D annually.

Examples of Global Players in addition to the U.S.

Japan: **$242 million in FY12, $400 million requested for FY13** (~$1.0 Billion in funding for FY08–FY12);

- Nearly 30,000 residential fuel cells deployed (40,000 by April 2013)
- Plans for 2 million FCEVs and 1000 H_2 stations by 2025 (100 stations by 2015)

Germany: >$1.2 Billion in funding ('07 – '16)

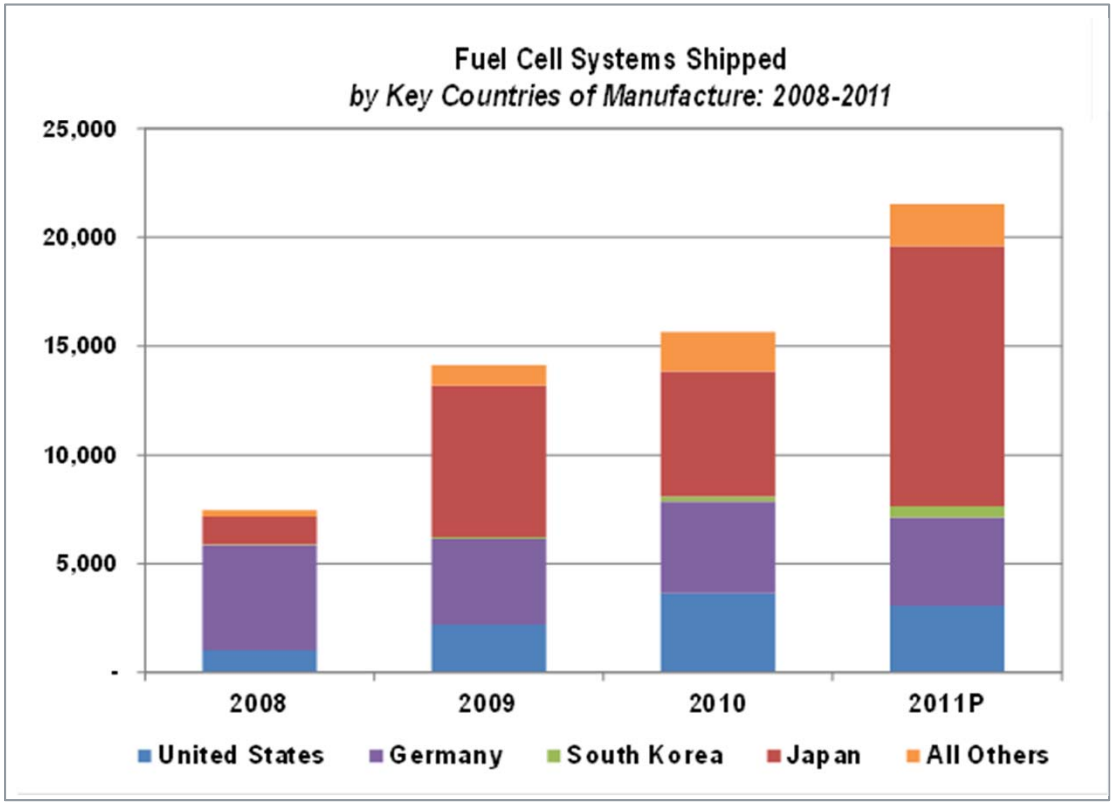
- plans for 1,000 hydrogen stations
- >22,000 small fuel cells shipped.

European Union: >$1.2 Billion in funding ('08–'13)

South Korea: ~$590 M ('04-'11); plans to produce 20% of world shipments and create 560,000 jobs in Korea

China: Thousands of small units deployed; 70 FCEVs, buses, 100 FC shuttles at World Expo and Olympics

Worldwide fuel cell markets continue to grow (>20,000 units shipped in 2011; >35% increase over 2010),



Sources: Pike Research, BTI, DOE Fuel Cells Market Report

Potential Early Markets to Reduce Cost

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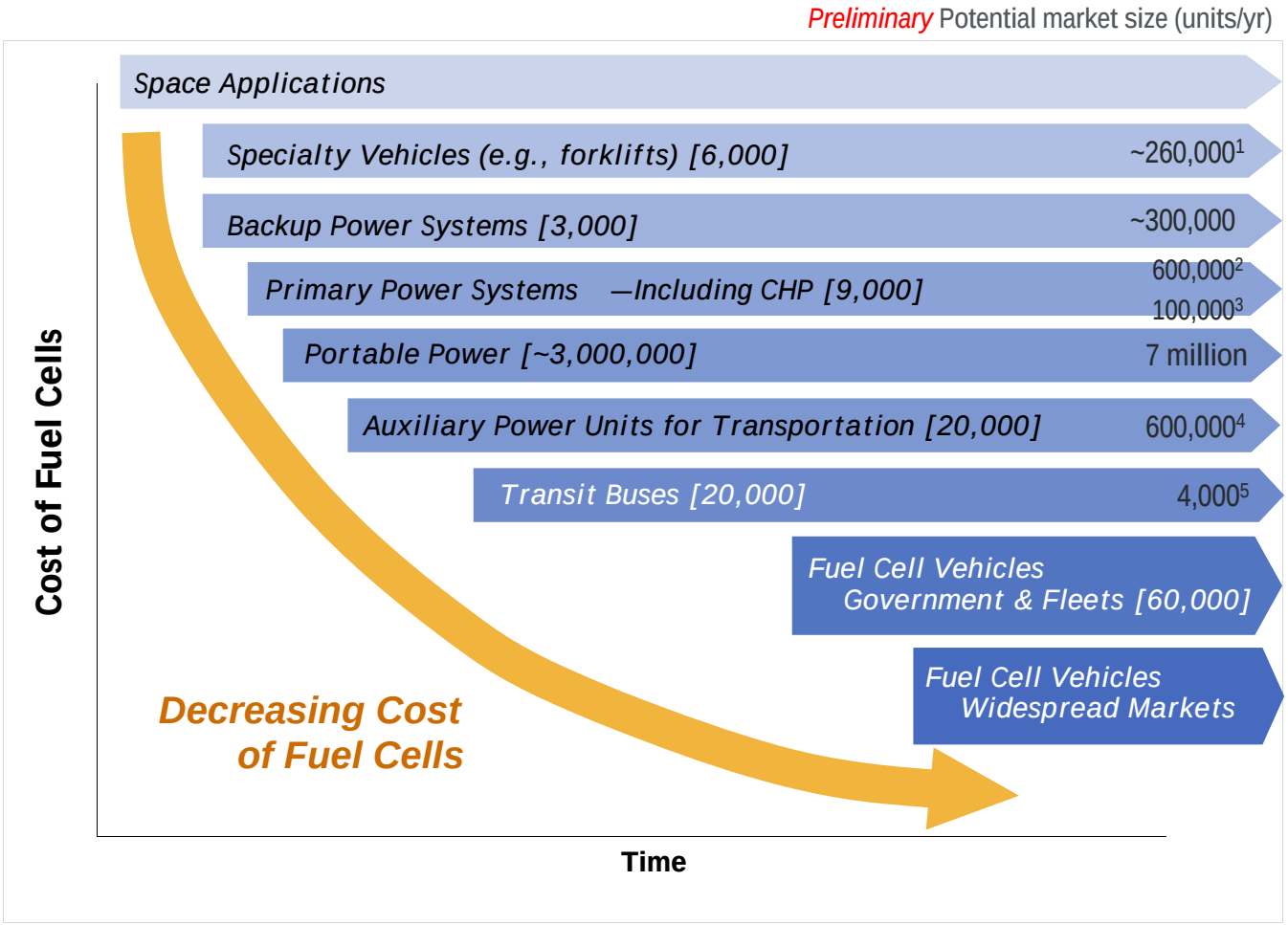
As the cost of fuel cells comes down (through technological improvements and economies of scale), they will become competitive in a growing number of markets.



The Market Potential

Independent analyses show global markets could mature over the next 10–20 years, producing revenues of:

- **$14 – $31 billion/year for stationary power**
- **$11 billion/year for portable power**
- **$18 – $97 billion/year for transportation**

References: [1]ITA 2010 Outlook, [2]MicroCHP, [3]Large scale CHP, [4]Industry estimate based on refrigerated truck and trailer APUs (total number), [5]http://hydrogen.energy.gov/pdfs/12012_fuel_cell_bus_targets.pdf

DOE Program Overview

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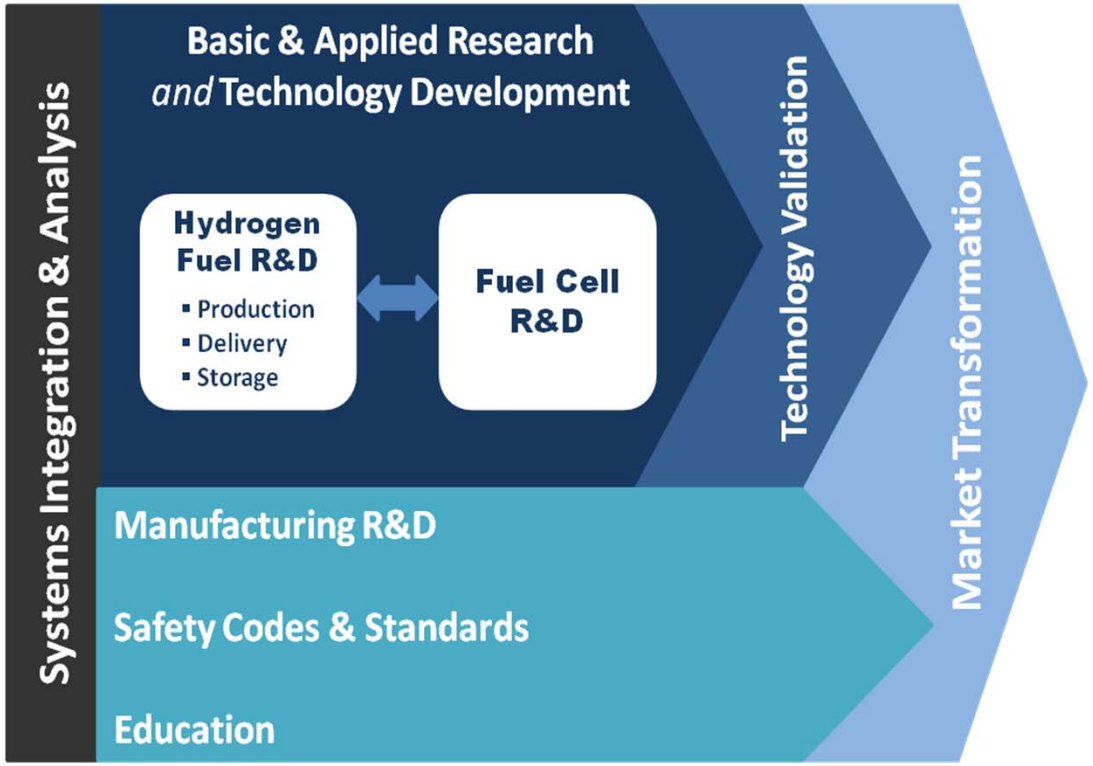
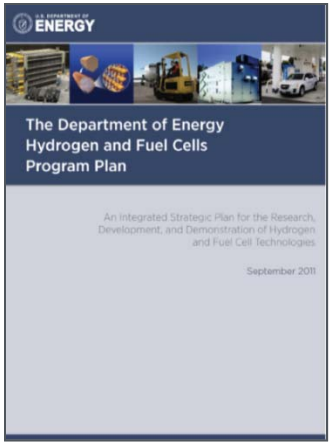
The Program is an integrated effort, structured to address all the key challenges and obstacles facing widespread commercialization.



WIDESPREAD COMMERCIALIZATION ACROSS ALL SECTORS

- Transportation
- Stationary Power
- Auxiliary Power
- Backup Power
- Portable Power



Released September 2011
Update to the Hydrogen Posture Plan (2006)
Includes Four DOE Offices
EERE, FE, NE and Science

Nearly 300 projects currently funded

at companies, national labs, and universities/institutes

Federal RD&D Role

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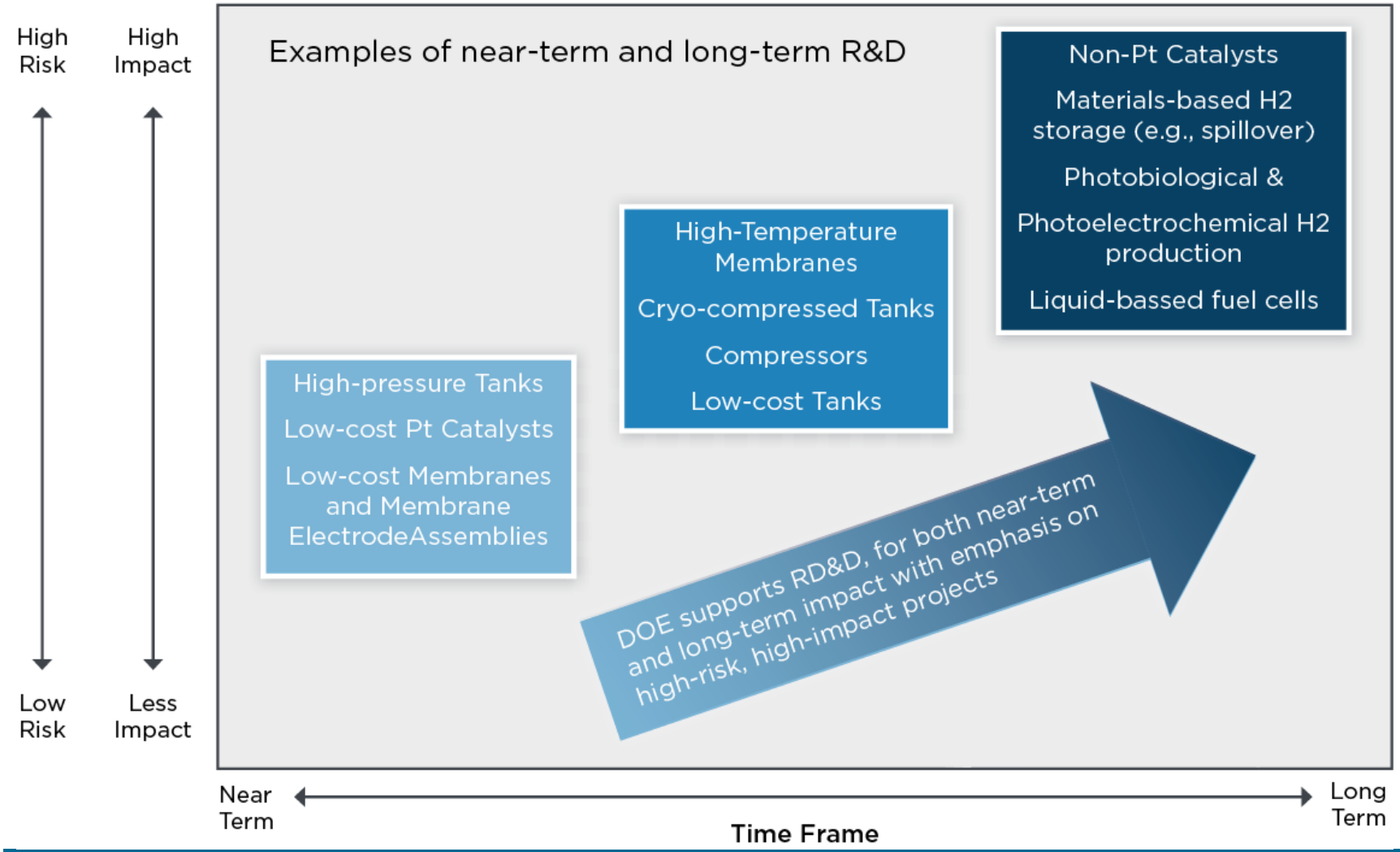
DOE's Focus is on **High-Risk, High-Impact R&D**



Summary: Program Impact

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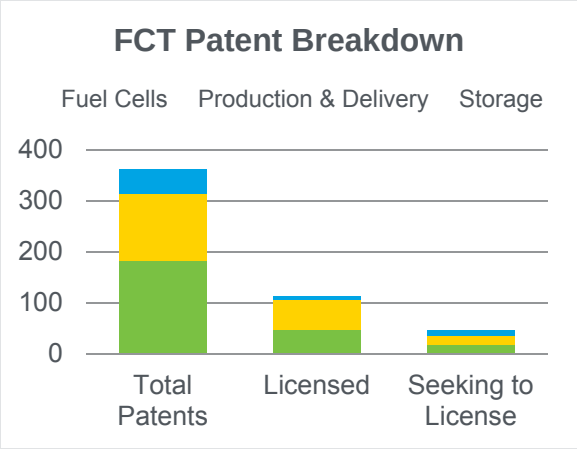
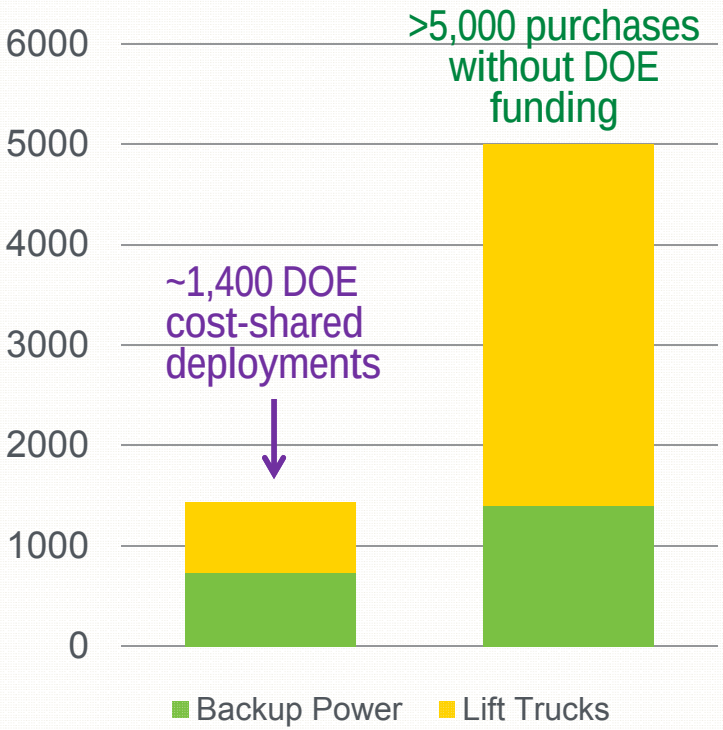
DOE FCT funding has led to 363 patents, 35 commercial technologies and 65 emerging technologies. Example of Impact: ~$70M in funding for specific projects was tracked – and found to have led to nearly $200M in industry investment and revenues.

DOE FCT funding has enabled:

- > 80% cost reduction in PEM fuel cells since 2002, > 35% since 2008
- Reduction in Pt by a factor of 5 since 2005
- > Double the durability since 2006
- > 80% cost reduction in electrolyzer stacks in the last decade



Leveraging DOE funds: Early market deployments of ~1,400 have led to >5,000 additional purchases by industry with *no* DOE funding.



*DOE cost-shared deployments led to **>3X** additional purchases.*

Recovery Act and Market Transformation – **Government as "catalyst" for market success of emerging technologies.**

Progress Example– Fuel Cells

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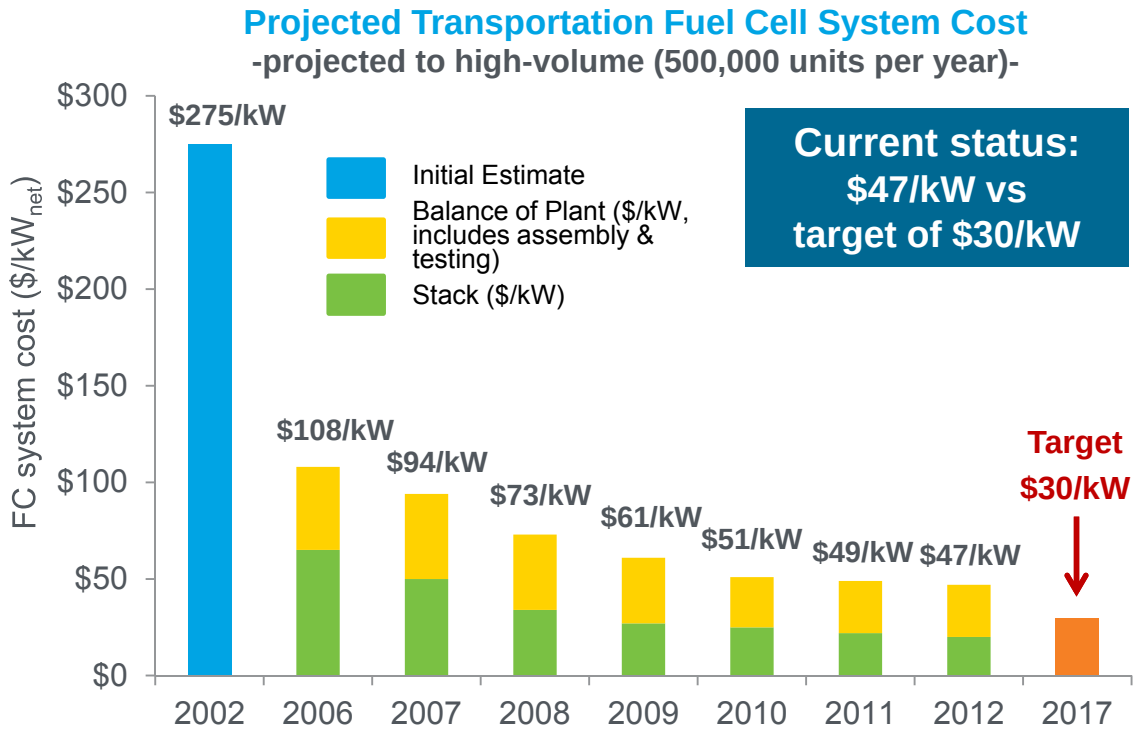
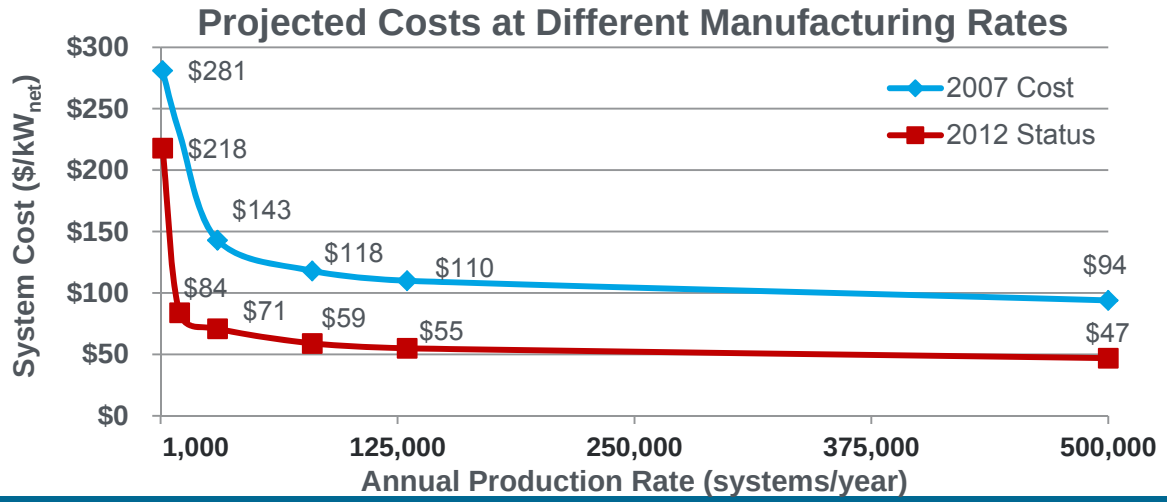
Projected high-volume cost of fuel cells has been reduced to $47/kW (2012)*

- ***More than 35% reduction since 2008***
- ***More than 80% reduction since 2002***





Based on projection to high-volume manufacturing (500,000 units/year). *The projected cost status is based on an analysis of state-of-the-art components that have been developed and demonstrated through the DOE Program at the laboratory scale. Additional efforts would be needed for integration of components into a complete automotive system that meets durability requirements in real-world conditions.*

Current Portfolio Addresses High-Impact Areas – PEM Example

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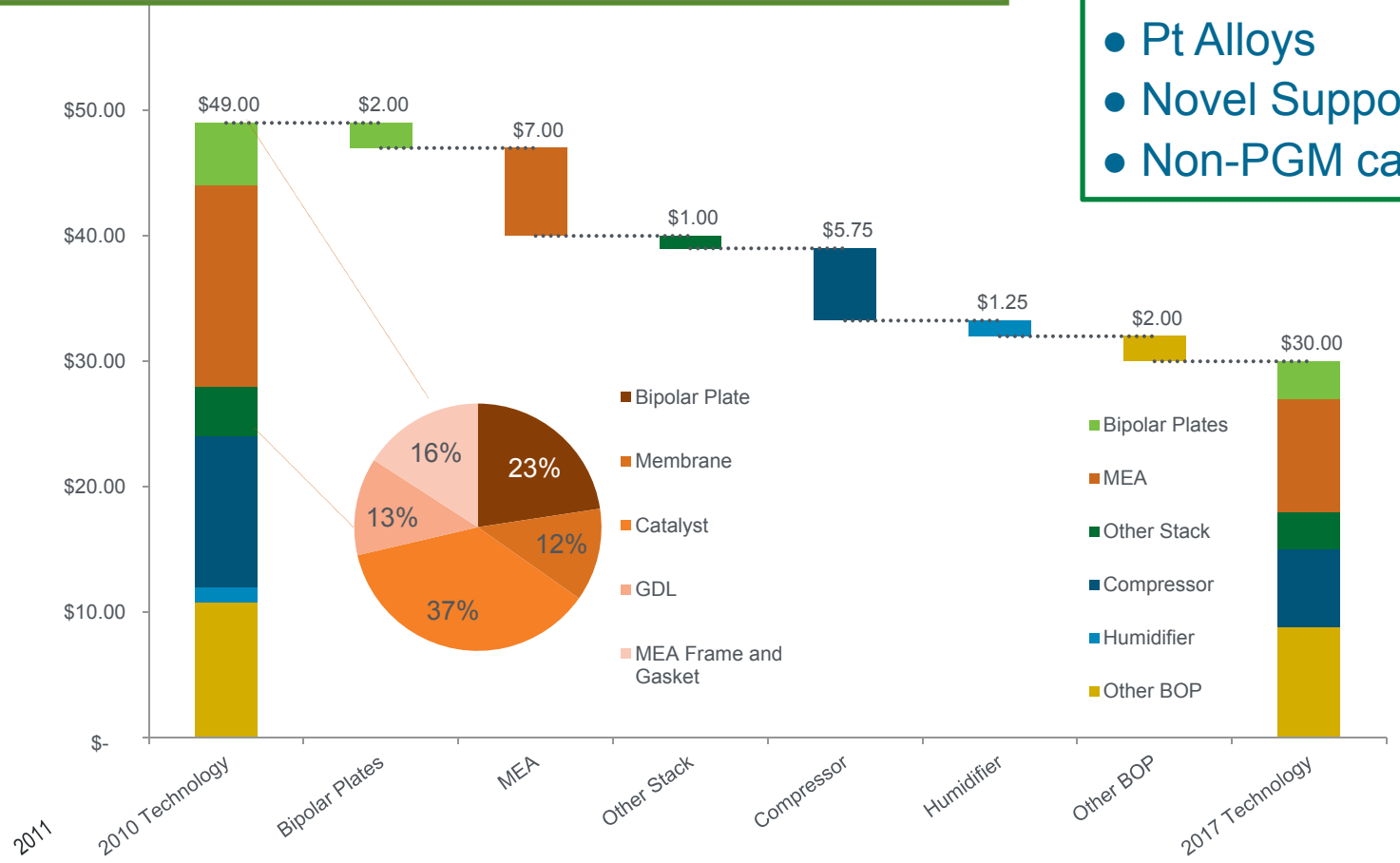
Strategic technical analysis guides focus areas and priorities for budget.
Need to reduce cost but also increase durability.

Strategies to Address Challenges – Catalyst Examples

- Lower PGM Content
- Pt Alloys
- Novel Support Structures
- Non-PGM catalysts



Targeted 80 kW PEM fuel cell system cost: $30/kW at 500,000 units/yr

Challenges and Strategy: Stationary Applications

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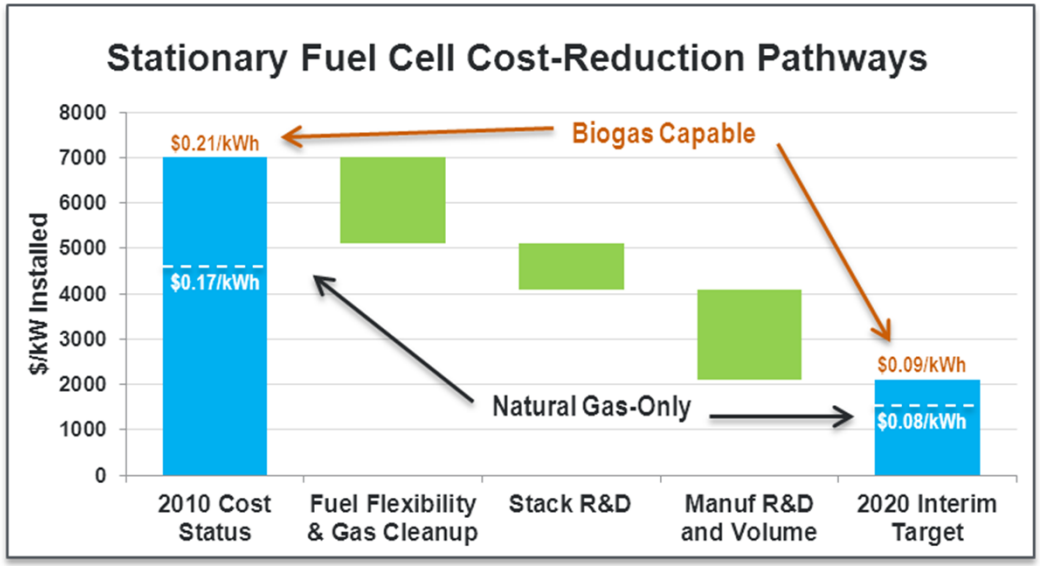
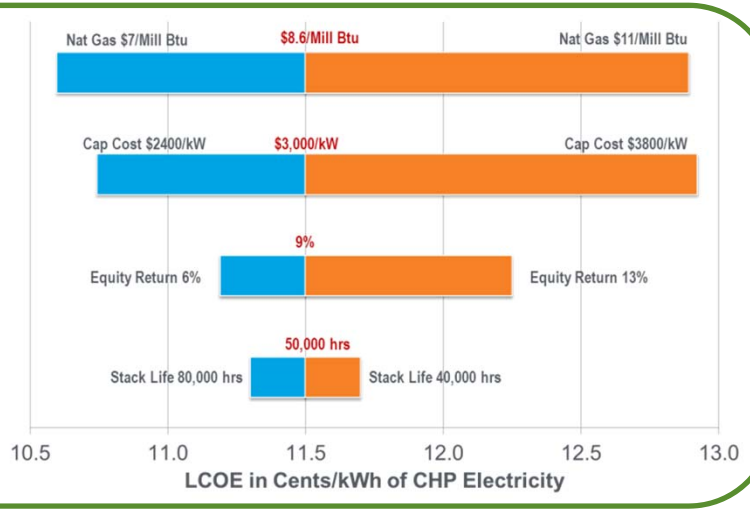
Further reduction in capital cost of medium scale distributed generation/CHP (100 kW – 3 MW) need to be pursued to facilitate widespread commercialization



- Further reduction of fuel cell system cost required to expedite commercialization
- Natural gas availability and fuel cell performance (efficiency) gains will enhance the technology's market attractiveness
- Development of a cost-effective process for removing fuel contaminants would allow for fuel flexibility
- Also applicable for tri-gen (H_2 production)

Sensitivity analysis around 2015 targets assesses impact of fuel cell system cost and durability on commercialization prospects

Technical Parameters (2015)	
Electric Efficiency (LHV)	45.0%
Combined Effic.(LHV)	87.5%
Size, MWe	1
Operating Life, years	20
Equipment, $/kWe	2,300
Engineering& Installation, $/kWe	700
Fixed O&M, $/MWh	13
Variable O&M, $/MWh	8.0



Opportunities for Distributed Generation (DG) and Efficient use of Natural Gas- and Biogas?

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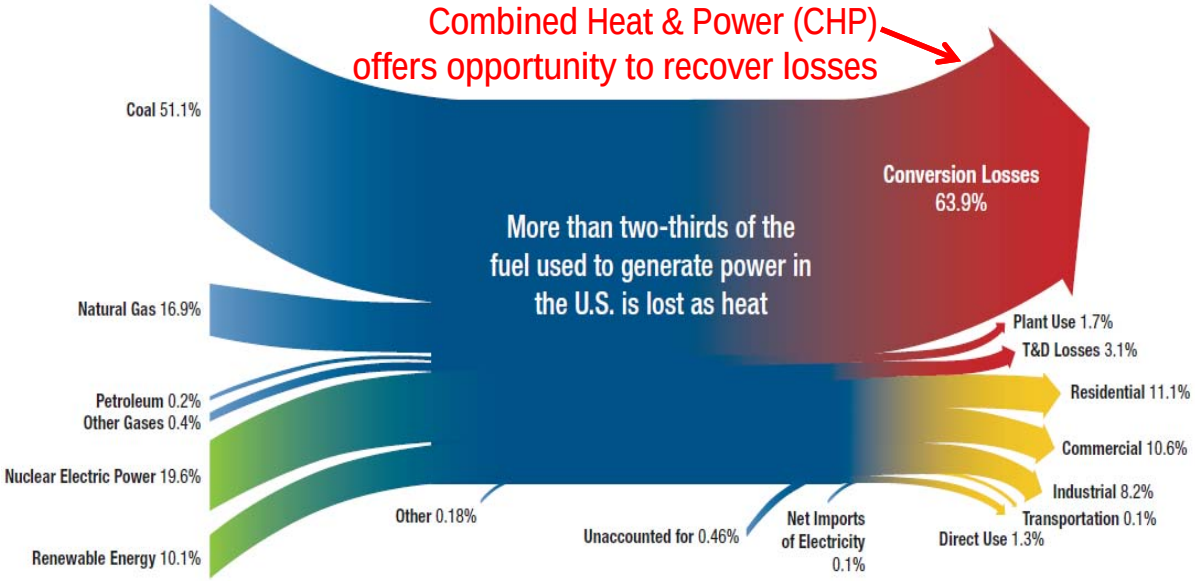
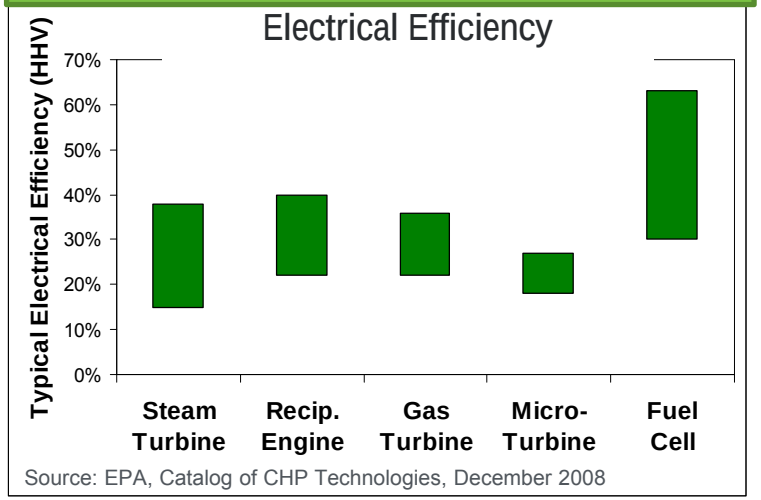


Source: http://www.chpcenterse.org/pdfs/ORNL_CHP_Report_Dec_2008.pdf

Range of electrical efficiencies for DG technologies



Source: EPA, Catalog of CHP Technologies, December 2008

Examples of fuel cell deployments using natural gas

Supermarkets *one of several in the food industry interested*

Critical Loads- e.g. banks, hospitals, data centers

New World Trade Center (Freedom Tower) will use ***12 fuel cells totaling 4.8MW***

Durability - Input Solicited

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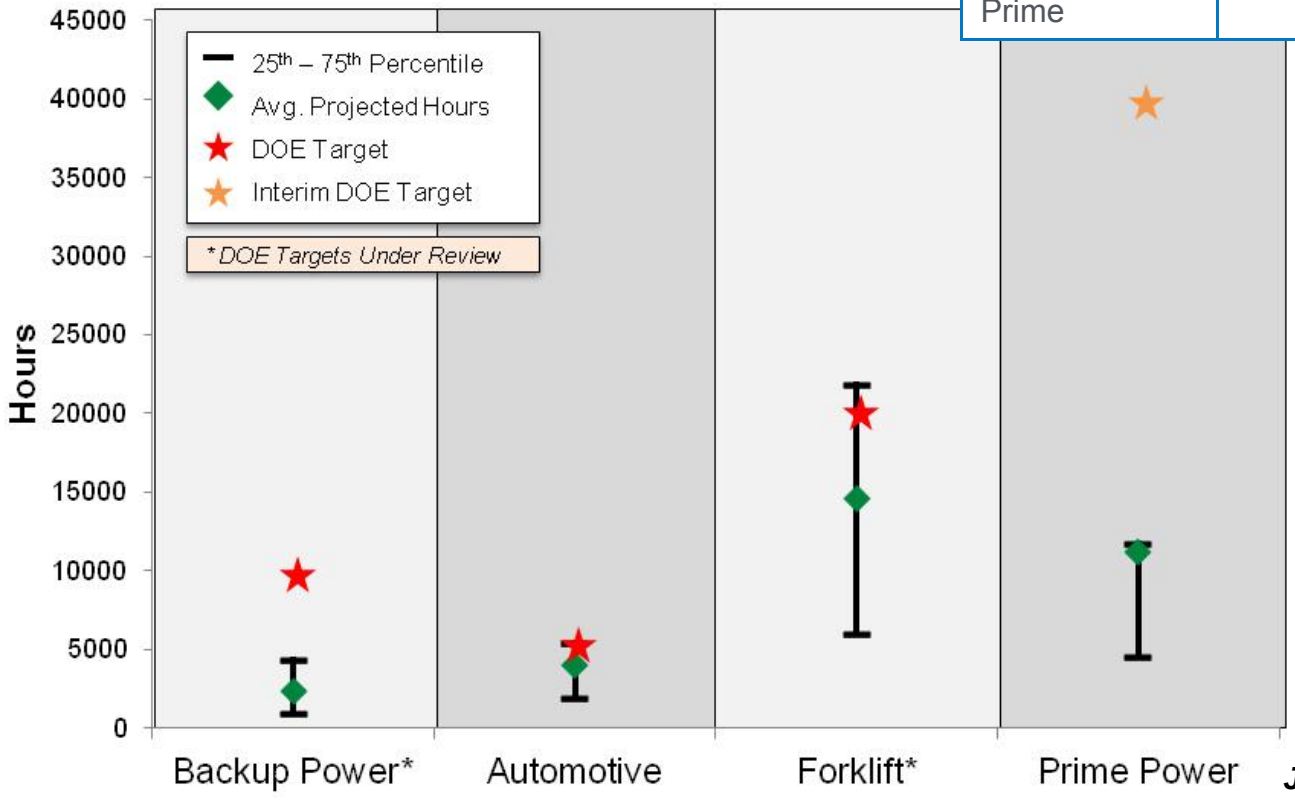
Aggregated results provide a benchmark in time of state-of-the-art fuel cell durability

DOE/NREL is aggregating and analyzing durability results by application that protect proprietary data, providing a benchmark in time of state-of-the-art fuel cell durability. Results include 82 data sets from 10 fuel cell developers.

Application	Avg Projected Time to 10% Voltage Drop	Avg Operation Hours
Backup power	2,400	1,100
Automotive	4,000	2,700
Forklift	14,600	4,400
Prime	11,200	7,000



PEM & SOFC data from lab tested, full active area short stacks and systems with full stacks. Data generated from constant load, transient load, and accelerated testing.

Please send inquires to Fuelcelldatacenter@ee.doe.gov

J. Kurtz, et al., NREL

Future Directions

Continue and strengthen critical R&D

- **Hydrogen, fuel cells, manufacturing, safety, codes and standards, etc.**

Conduct strategic, selective demonstrations of innovative technologies

Continue to conduct key analysis to guide RD&D and path forward, determine infrastructure needs and opportunities to address them

Leverage activities to maximize impact

- **U.S. and global partnerships**

Continue and strengthen communication and outreach

Thank You

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New energy data initiative to share the latest energy information and data. Please visit:

http://en.openei.org/wiki/Gateway:Hydrogen

hydrogenandfuelcells.energy.gov