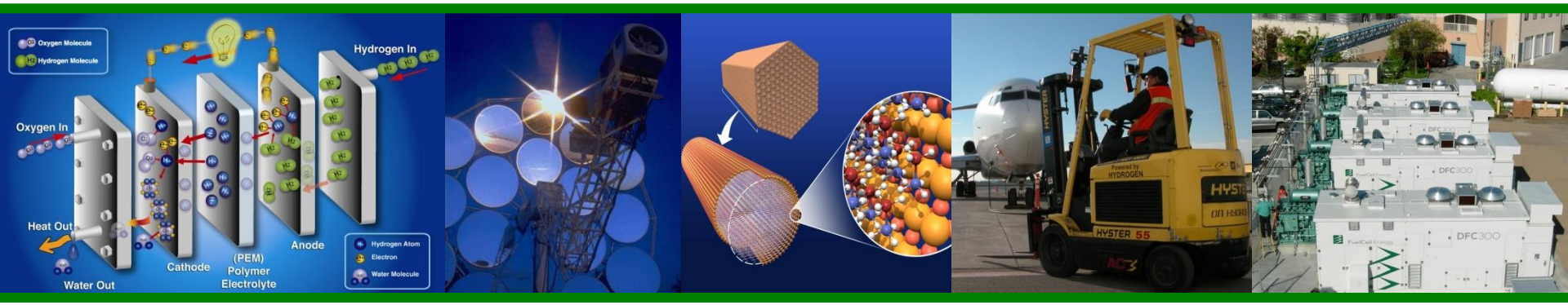
International Partnership for Hydrogen and Fuel Cells in the Economy



U.S. Country Update

IPHE Steering Committee Meeting

Sunita Satyapal

Director

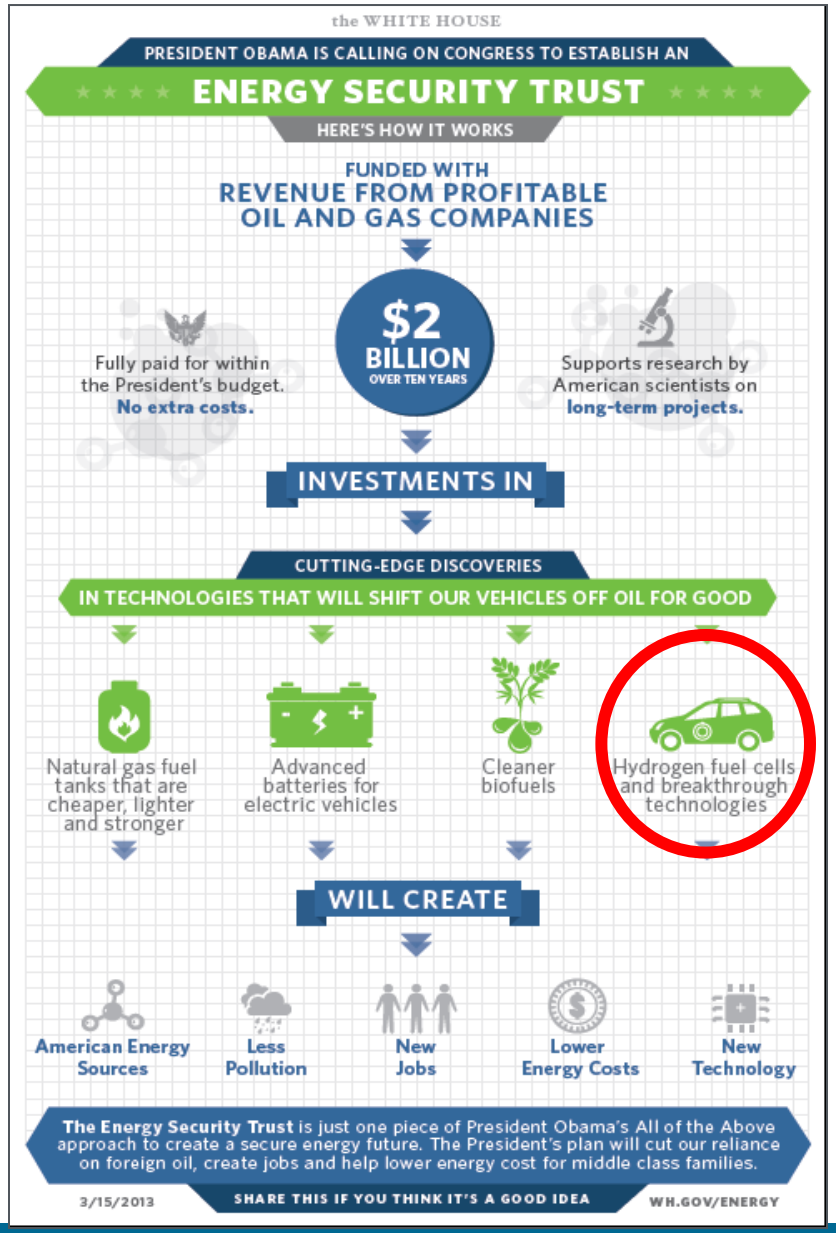
Hydrogen and Fuel Cells Program

U.S. Department of Energy

May 23, 2013

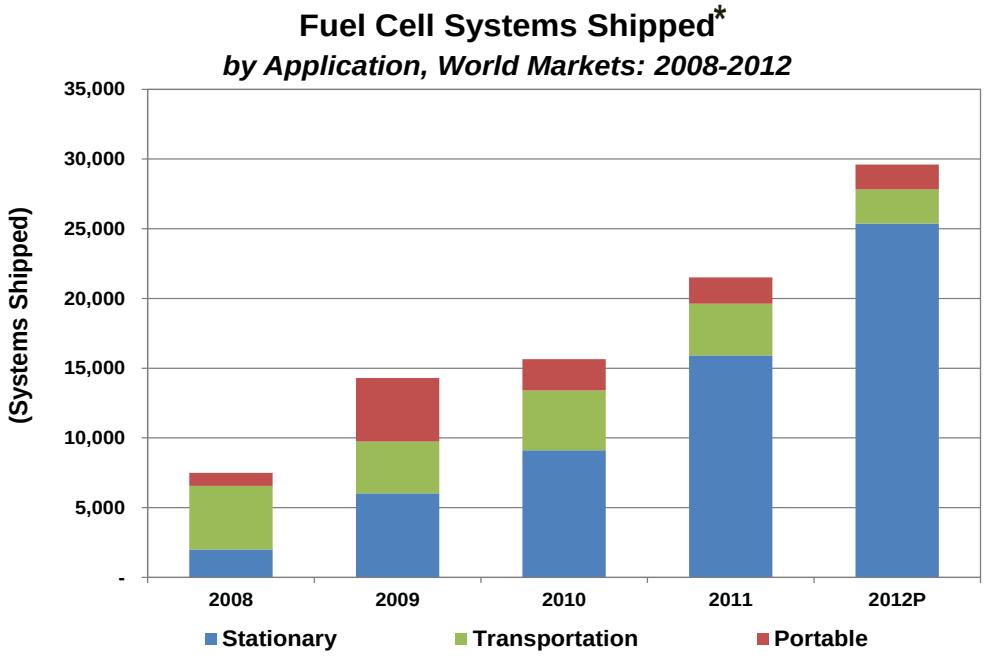
London, England

Fuel Cells are part of All-of-the-Above Energy Strategy



The President's proposal will support research into a range of cost-effective technologies – like advanced vehicles that run on electricity, homegrown biofuels, **fuel cells**, and domestically produced natural gas.

Fuel Cell Market Overview



Market Growth (2011 – 2012)

Fuel cell markets continue to grow:

- **> 45% increase in global MWs shipped**
- **> 35% increase in systems shipped**

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**

Several automakers have announced commercial FCEVs in the 2015-2017 timeframe.

***Sources: FuelCells2000, Navigant Research, Fuel Cell Today, ANL**

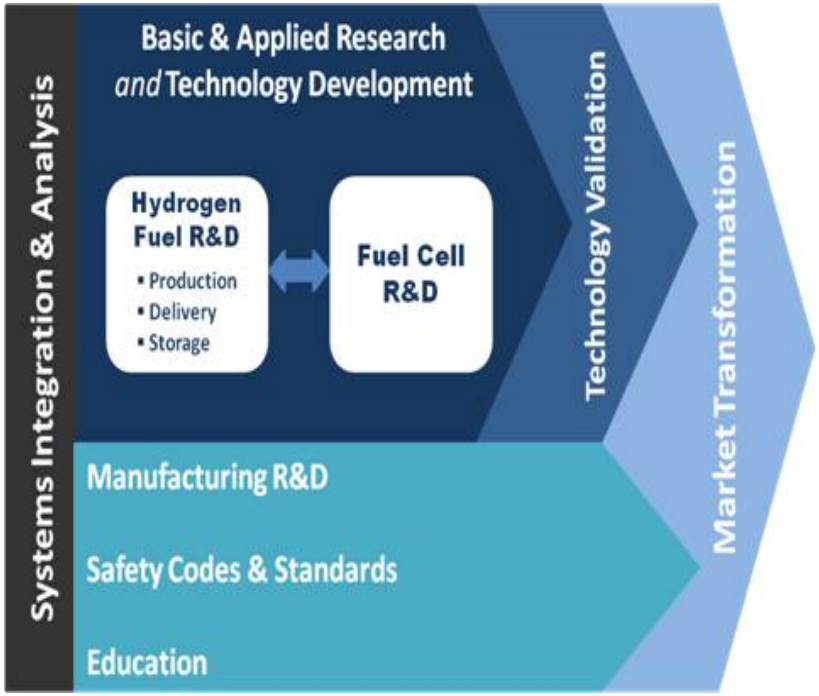
***DOE Hydrogen and Fuel Cells Program Plan,* http://www.hydrogen.energy.gov/pdfs/program_plan2011.pdf;**

Hydrogen &Fuel Cells Program Overview

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Mission: Enable widespread commercialization of a portfolio of hydrogen and fuel cell technologies through applied research, technology development and demonstration, and diverse efforts to overcome institutional and market challenges.

Key Goals : Develop hydrogen and fuel cell technologies for early markets (stationary power, lift trucks, portable power), mid-term markets (CHP, APUs, fleets and buses), and long-term markets (light duty vehicles).



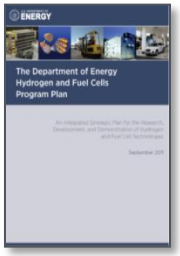
WIDESPREAD COMMERCIALIZATION ACROSS ALL SECTORS

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

Examples of Key Targets

- **Fuel Cells:**
  - **Transportation: $30/kW, 5K hours**
  - **Stationary: $1,500/kW, 60-80K hours**
- **Hydrogen: $2 to $4/gge**

DOE H_2 and Fuel Cell Program includes: EERE (Fuel Cell Technologies Office), and DOE Offices of Science, Fossil Energy and Nuclear Energy



Nearly 300 projects currently funded at companies, national labs, and universities/institutes

Program Plan at: http://www.hydrogen.energy.gov/pdfs/program_plan2011.pdf

Basic research conducted thru Office of Science; Applied RD&D conducted through EERE, FE, NE

Budget: Key Activities

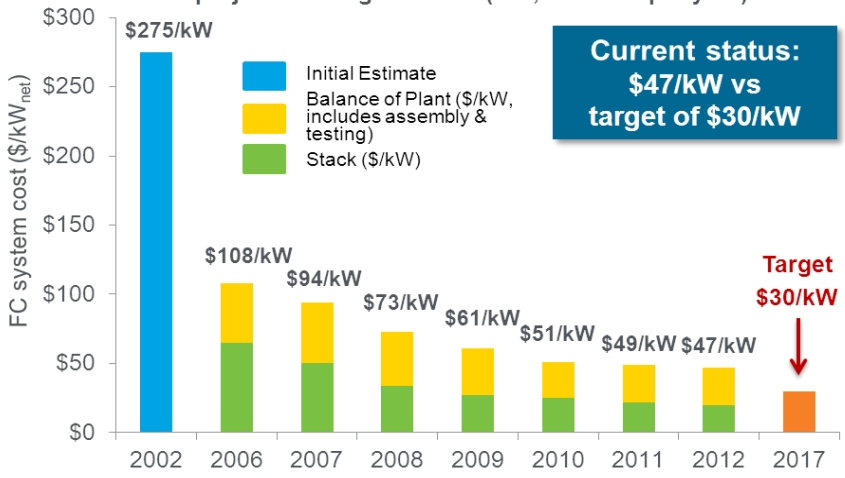
Funding *($ in thousands)*		
Key Activity	**FY 2013 Request**	**FY 2014 Request**
Fuel Cell R&D	38,000	37,500
Hydrogen Fuel R&D	27,000	38,500
Manufacturing R&D	2,000	4,000
Technology Validation	5,000	6,000
Safety, Codes and Standards	5,000	7,000
Market Transformation	0	3,000
Systems Analysis	3,000	3,000
NREL Site-Wide Facilities Support	0	1,000
Total	$80,000	$100,000

Note: The FY 2012 and FY 2013 numbers shown on page 384 of the White House's FY 2014 Budget Request (www.whitehouse.gov/sites/default/files/omb/budget/fy2014/assets/doe.pdf) reflect $9.7 million that was carried over from FY 2012 to FY 2013 for obligation in FY 2013.

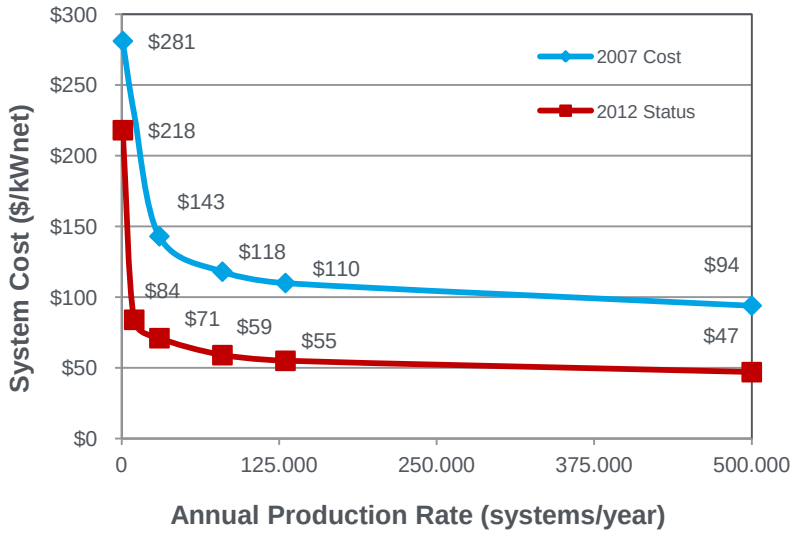
Reduced high-volume cost of automotive fuel cells to $47/kW (2012)*

More than 35% reduction since 2008, more than 80% reduction since 2002

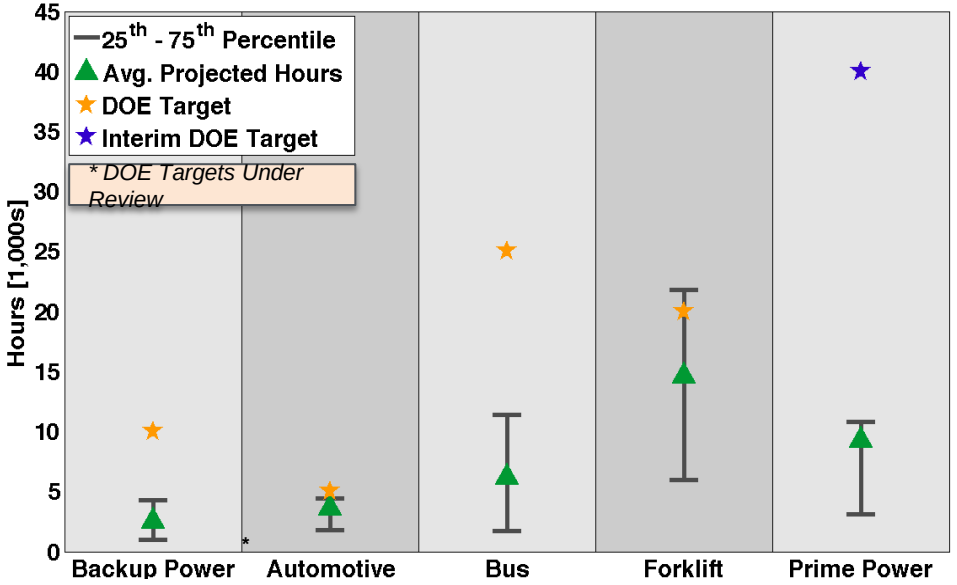
Projected Transportation Fuel Cell System Cost
-projected to high-volume (500,000 units per year)-



Projected Costs at Different Manufacturing Rates



NREL- aggregated state-of-the-art fuel cell durability



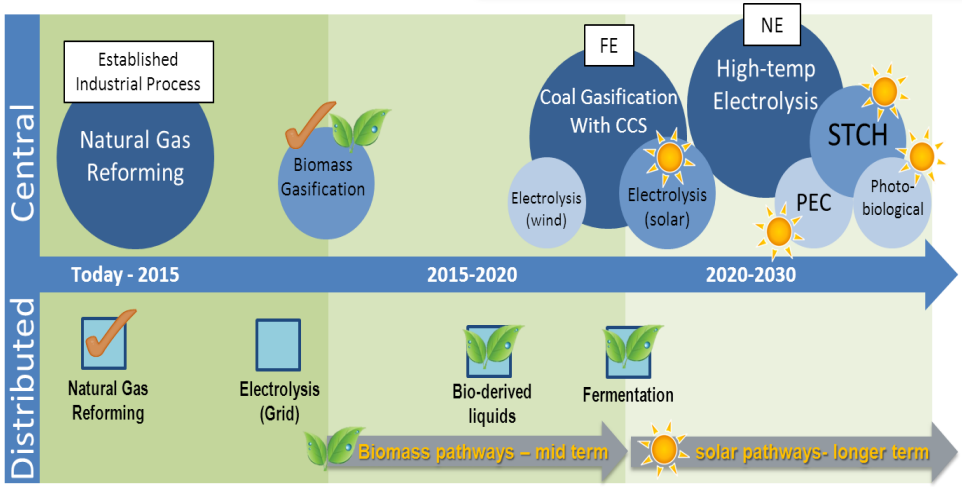
*Based on state-of-the-art lab scale technology projection to high-volume manufacturing (500,000 units/year).

Hydrogen Production

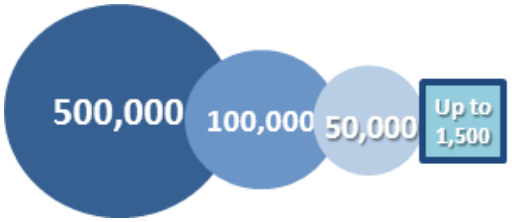
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Current Status

- Over **9MMT** of H_2 produced per year
- Over **1,200 miles** of H_2 pipelines in use (CA, TX, LA, IL, IN)
- Over **50 fueling stations** in the U.S.



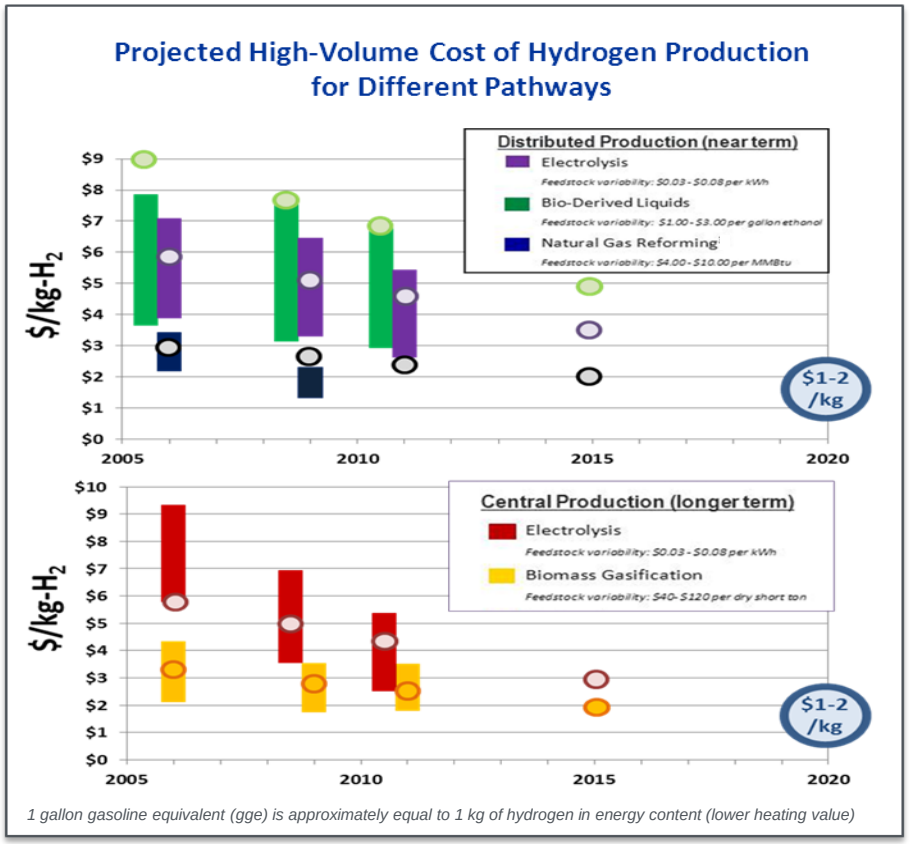
Estimated Plant Capacity (kg/day)



P&D Subprogram R&D efforts successfully concluded

FE = *R&D efforts in DOE Office of Fossil Energy*

NE = *R&D efforts in DOE Office of Nuclear Energy*



1 gallon gasoline equivalent (gge) is approximately equal to 1 kg of hydrogen in energy content (lower heating value)

Additional information in Program Record #12002
http://www.hydrogen.energy.gov/pdfs/12002_h2_prod_status_cost_plots.pdf

*Based on information from Proton OnSite, Giner,

Validated >500 fuel cell forklifts

Accomplishments:

>1.4M hours of operation

~250,000 hydrogen fills

>185,000 kg hydrogen dispensed

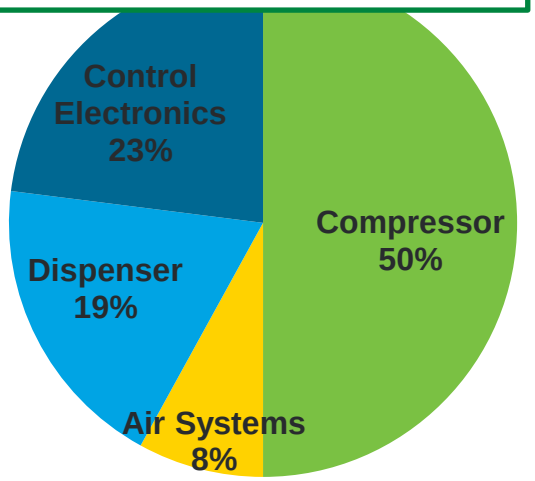
Average forklift fill of 0.6 kg in 2.3 minutes

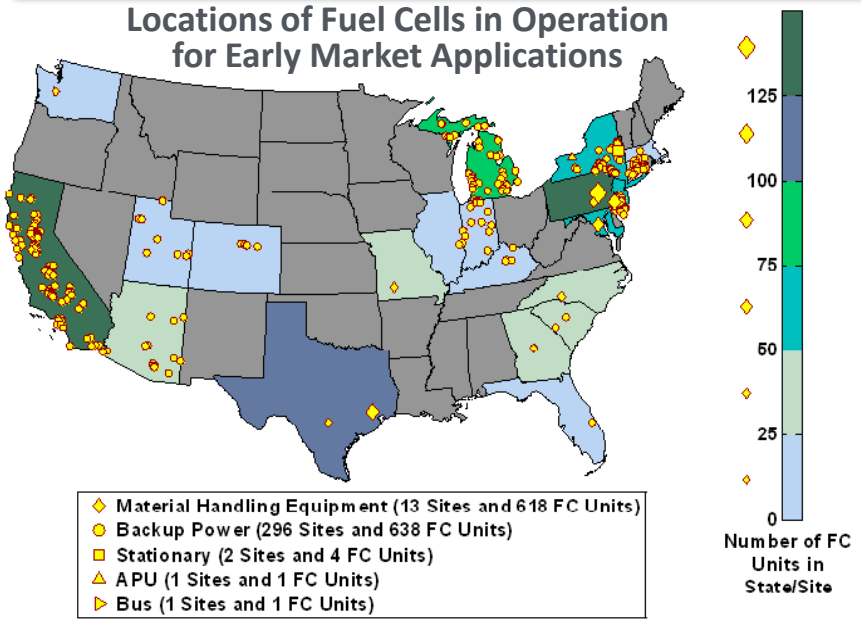
Delivered H_2 Maintenance Count by Category

1,058 Maintenance Events, 64% unscheduled

Infrastructure consistently delivering H2 with a MTBF of 25 days or less.

Identifying areas for further effort: e.g. ~500 are compressor failures.





Exceeded DOE goal of 1,000 operating hours for back up power

Successful operation of units in 19 states

- **>800 systems in operation**
- **1.86 MW installed capacity**
- **99.6% successful starts**

Fuel Cells for Resiliency – Hurricane Sandy, October 2012

Hurricane Sandy was the largest Atlantic hurricane on record.

Winds spanning more than 1,100 miles

More than $60 billion in damages

- Cellphone outages reported in more than 150 counties from VA to MA
- 25% of cell towers in 10-state area stopped operating
- 8.5 million power outages reported across 21 states

NREL CDP_BU_15
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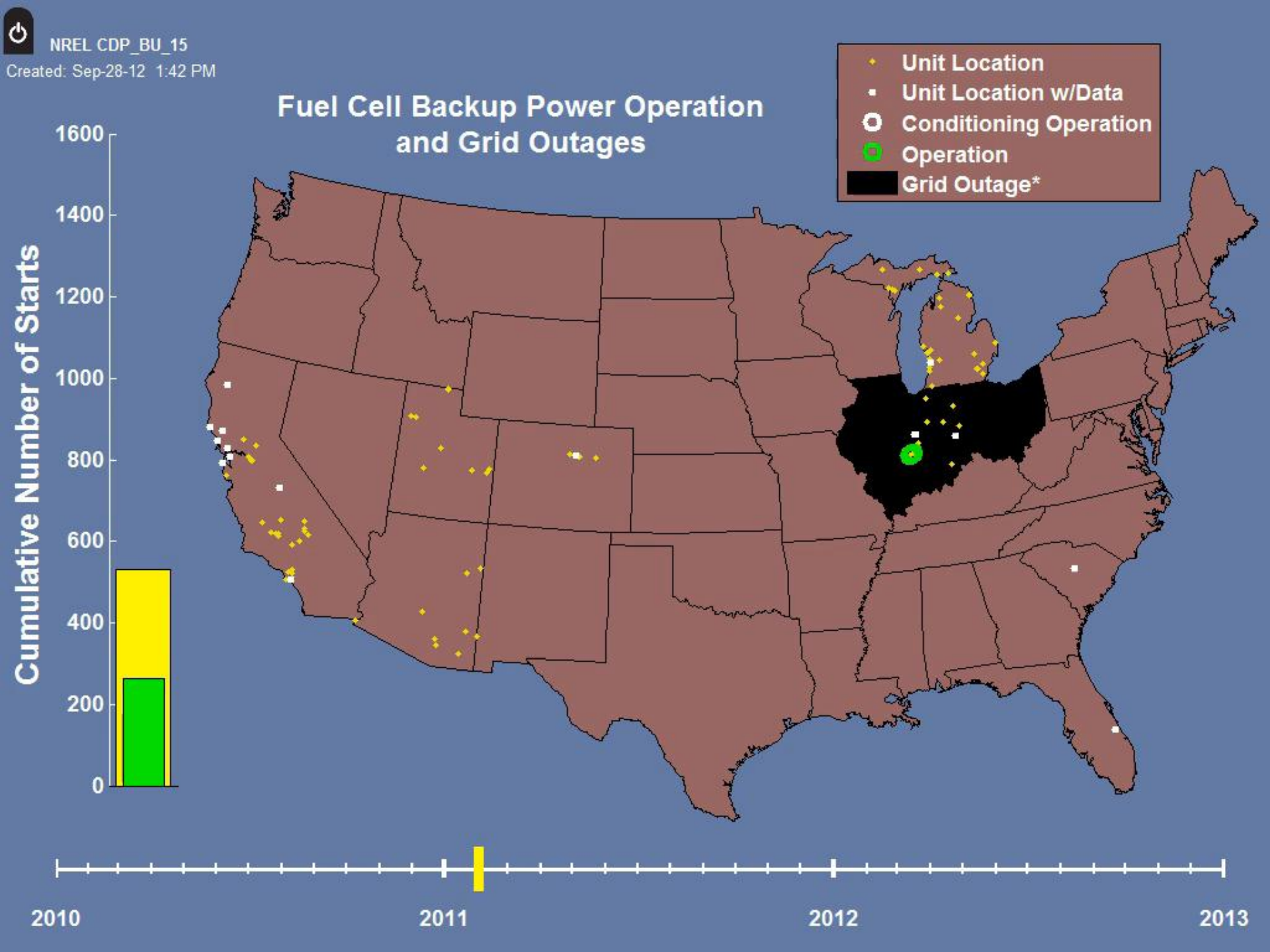
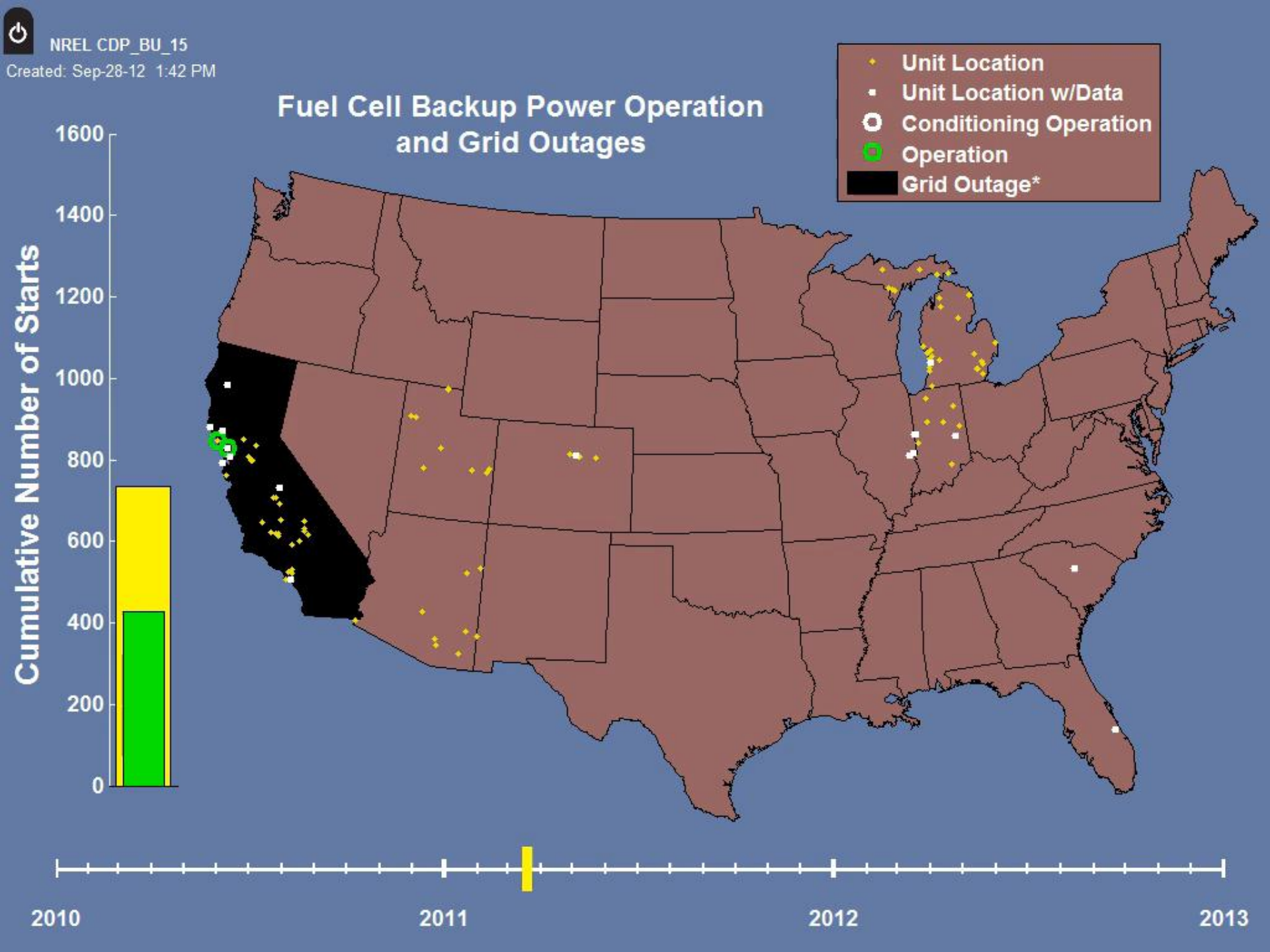
Fuel Cell Backup Power Operation and Grid Outages




NREL CDP_BU_15
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Fuel Cell Backup Power Operation and Grid Outages
Unit Location
Unit Location w/Data
Conditioning Operation
Operation
Grid Outage*
Cumulative Number of Starts
1600
1400
1200
1000
800
600
400
200
0
2010
2011
2012
2013

NREL CDP_BU_15
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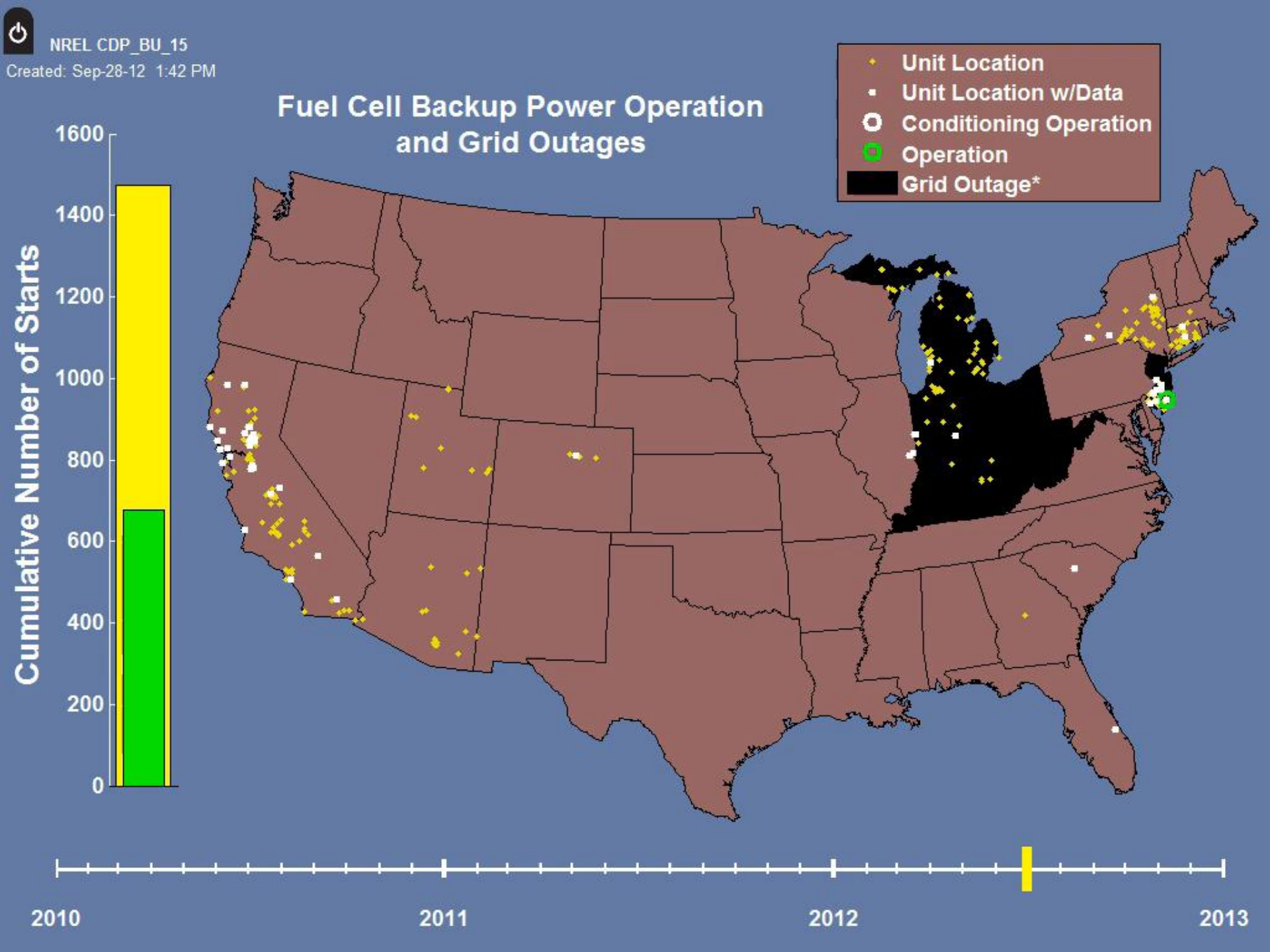
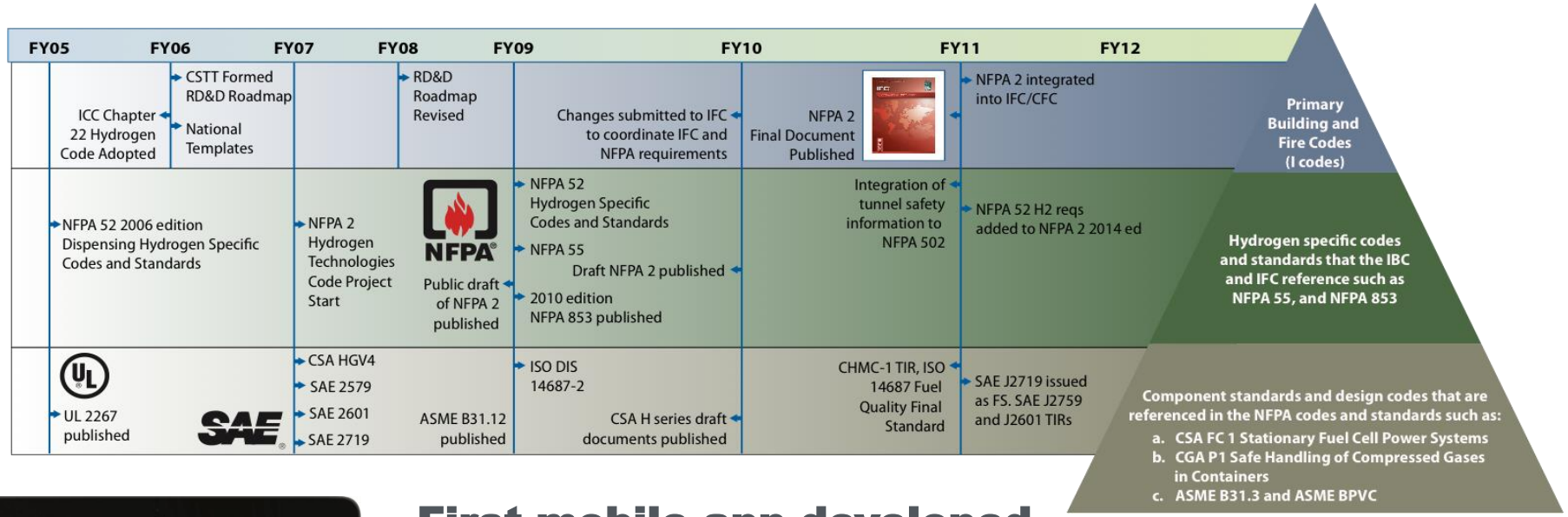
Fuel Cell Backup Power Operation and Grid Outages



Safety, Codes & Standards Progress

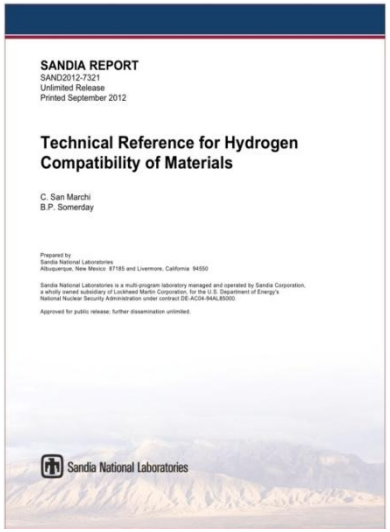
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



First mobile app developed to accelerate H_2 and fuel cell deployments (PNNL)

- Integrates H_2incidents.org and H_2bestpractices.org into a single, searchable iPad and iPhone app

- Full acceptance of the **Global Technical Regulation** targeted for June 2013.
- **SAE J2579** published March 2013


SANDIA REPORT
SAND2012-7321
Unlimited Release
Printed September 2012

Technical Reference for Hydrogen Compatibility of Materials

C. San Marchi
B.P. Somerday

Sandia National Laboratories

Information placed on OpenEI website:
http://en.openei.org/wiki/Gateway:Hydrogen

H2 Safety Sharing- Examples

Equipment	Total Incidents
Piping/Fitting/Valves	102
Hydrogen Storage	49
Vehicle & Fueling System	40
Safety Systems	25
Ventilation System	22
Laboratory Equipment	19
Pressure Relief Devices	16
Motive Power Systems	15
Heating Equipment	14
Electrical Equipment	14
Process Equipment	14
Batteries and Related Equipment	13

Database web address – www.h2incidents.org

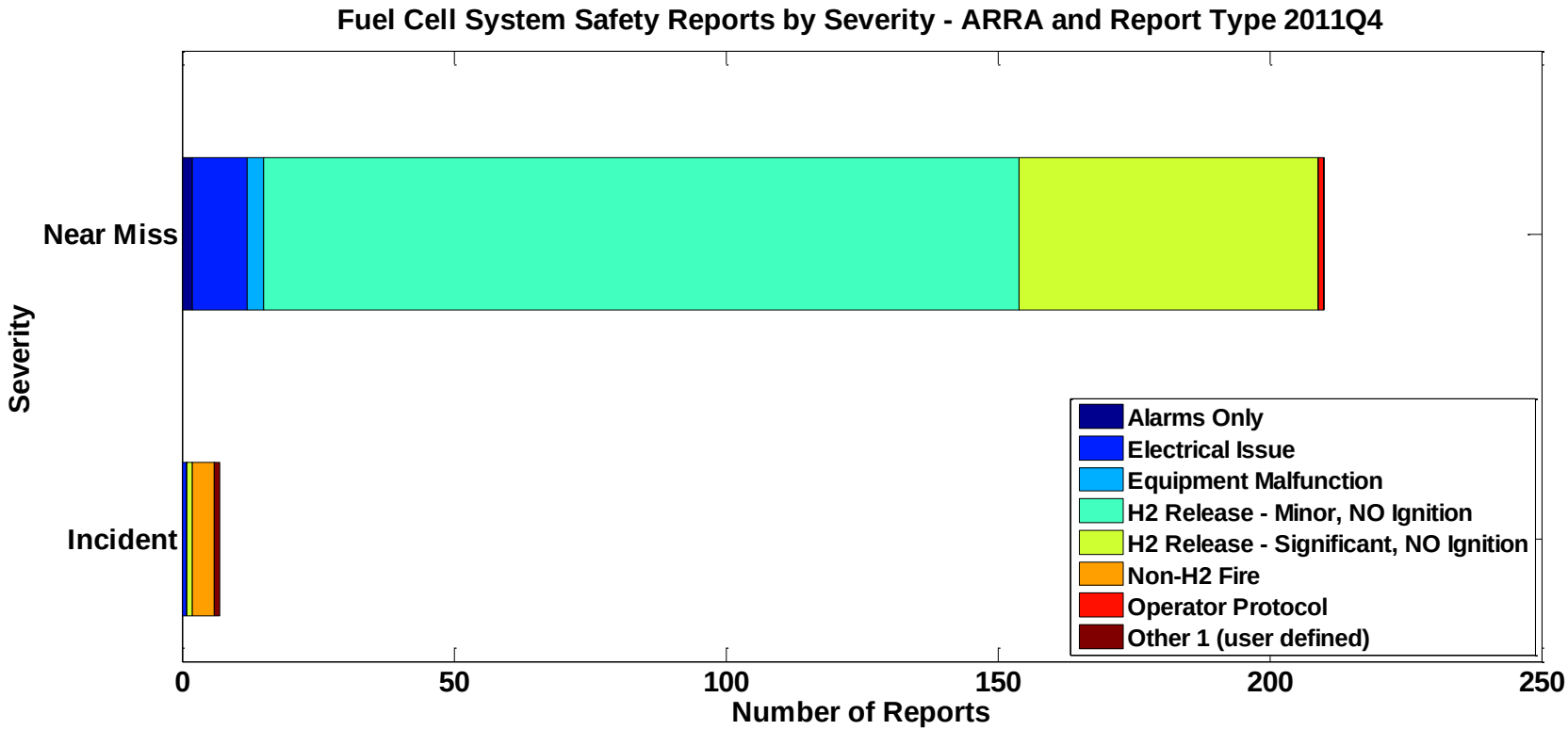
Examples:

- Piping (36)
- Valve (36)
- Flexible Tubing (8)
- Gasket (6)
- Bolts (6)

Cross–Search Categories :

- Settings
- Damage and Injuries
- Probable Causes
- Contributing Factors

Fuel Cell System Safety Reports by Severity and Type



An INCIDENT is an event that results in:
- a lost time accident and/or injury to personnel
- damage/unplanned downtime for project equipment, facilities or property
- impact to the public or environment
- any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited
- release of any volatile, hydrogen containing compound (other than the hydrocarbons used as common fuels)

A NEAR-MISS is:
- an event that under slightly different circumstances could have become an incident
- unplanned H2 release insufficient to sustain a flame

NREL cdparra_mhe_27

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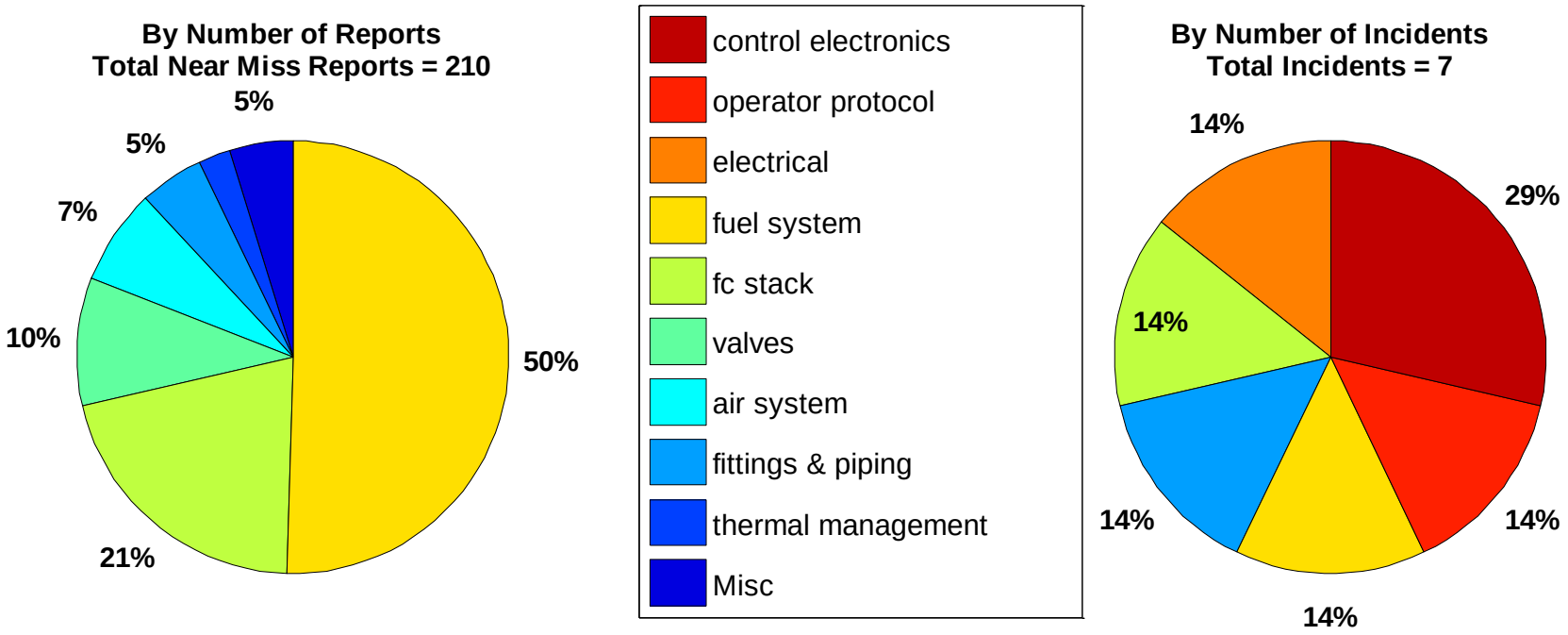
MHE Equipment Category of Safety Events

Safety Reports By Equipment Category: ARRA MHE



MISC includes the following categories:
SOFTWARE
ELECTRICAL
REFORMER
SENSORS
SEAL
OTHER

An INCIDENT is an event that results in:
- a lost time accident and/or injury to personnel
- damage/unplanned downtime for project equipment, facilities or property
- impact to the public or environment
- any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited
- release of any volatile, hydrogen containing compound (other than the hydrocarbons used as common fuels)

A NEAR-MISS is:
- an event that under slightly different circumstances could have become an incident
- unplanned H2 release insufficient to sustain a flame

NREL cdparra_mhe_57

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http://www.nrel.gov/hydrogen/cfm/images/cdparra_mhe_57_mhesafetyeventsbyequipcat.jpg

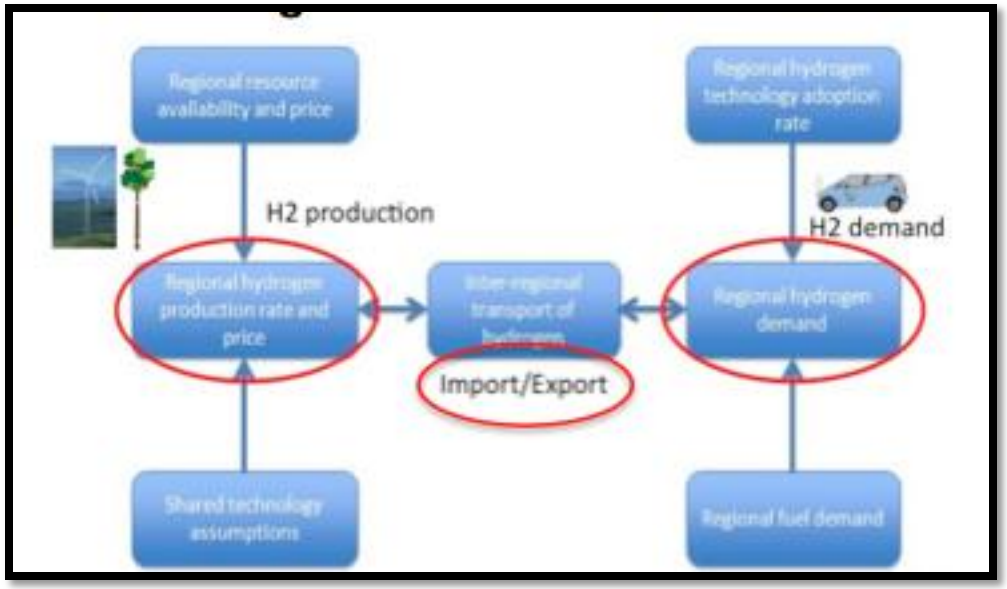
H2 Pathways Analysis Tool

Sandia National Laboratories | U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Approach

- **Developed dynamic H_2 pathways analysis tool that:**
  - Projects H_2 demand by country specific fuel-cell vehicle vehicle scenarios
  - Calculates least-cost pathways for H_2 supply by country, including feedstock, production, distribution (regional and long-distance), and carbon costs leveraging existing H2 production and distribution models (H2A, HDSAM, MSM)
  - Estimates petroleum savings and transport-related GHG emission reductions
  - Compares feedstock use for H_2 production through 2050 with 2010 primary energy consumption

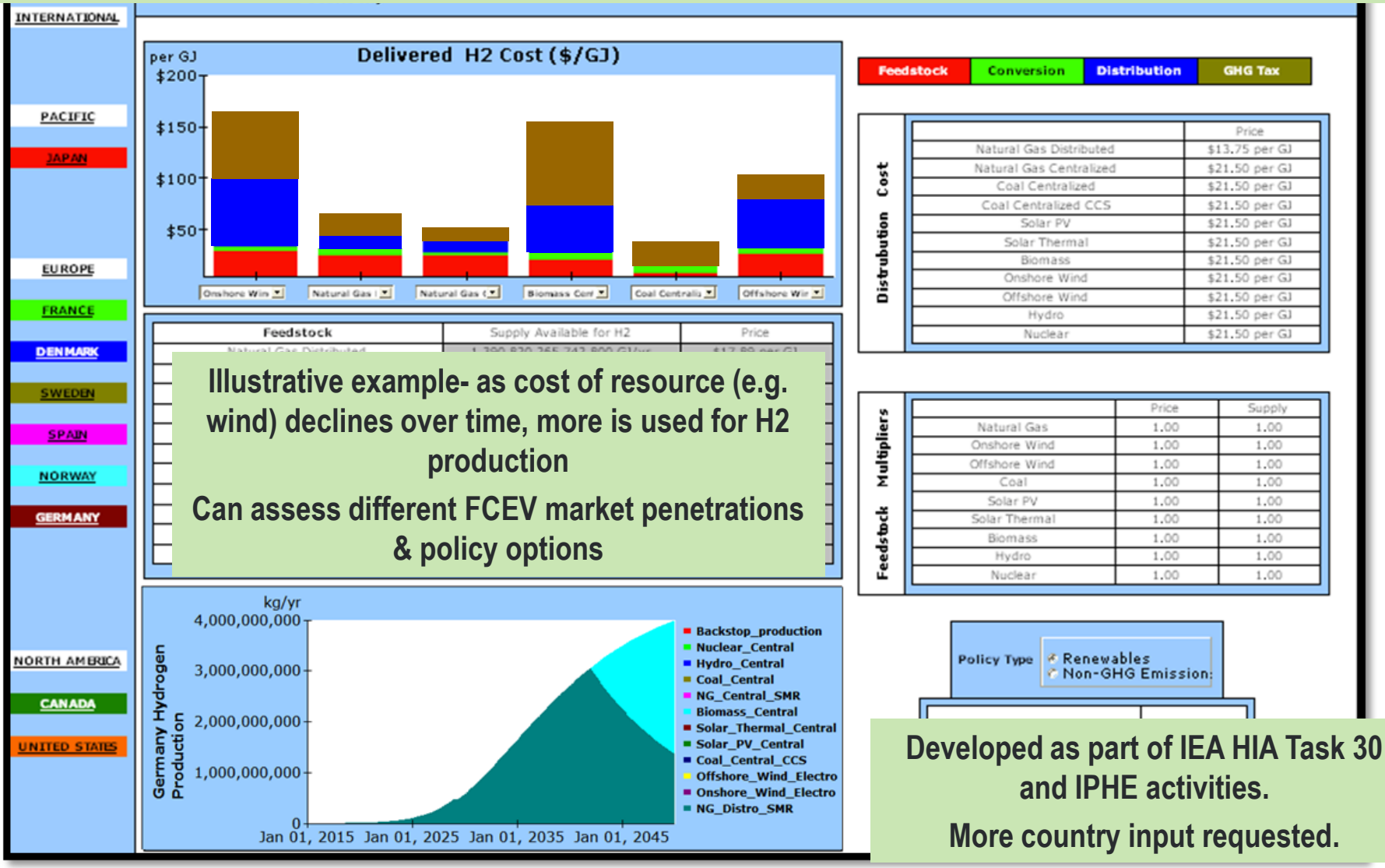
- **Data input**
  - Country-level data supplied by country experts (Task 30A)
  - Where country-level data not available, U.S.-based analysis estimates used.
  - Integration with Task 30B (Technology Database) and Task 28 (Distribution) expected by year end



Global Hydrogen Resource Analysis Tool

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Tool developed by Sandia to assess resource options for hydrogen in different countries



Developed as part of IEA HIA Task 30 and IPHE activities.

More country input requested.

Future Directions- Energy Systems Integration Facility (ESIF)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Future directions include increased cross-cutting activities and collaboration such as through DOE's new national asset for energy systems integration research, development, and testing

www.nrel.gov/esif

H_2USA

Mission: To promote the commercial introduction and widespread adoption of FCEVs across America through creation of a public-private partnership to overcome the hurdle of establishing hydrogen infrastructure.

Current partners (additional in process):

- American Gas Association
- Association of Global Automakers
- California Fuel Cell Partnership
- Electric Drive Transportation Association
- Fuel Cell and Hydrogen Energy Association
- Hyundai Motor America
- ITM Power
- Massachusetts Hydrogen Coalition
- Mercedes-Benz USA
- Nissan North America Research and Development
- Proton OnSite
- Toyota Motor North America

Additional Information

Education Programs

Educating First Responders

- **Developed safety courses for researchers and held permitted workshops that reached >250 code officials**
- **Educated over 26,000 first responders and code officials through introductory web-based courses and advanced hands-on training.**
- **Expanded web-based resources, including: Hydrogen Safety Best Practices Manual & Hydrogen Permitting Compendium**

Educating Teachers

- **Developed education materials and educated more than 9,600 teachers on H_2 and fuel cells.**
- **Conducted seminars and developed fact-sheets and case studies for end-users**

Educating the Community

- **Published more than 70 news articles this year - including blogs, progress alerts, DOE news alerts**
- **Conducted more than 80 workshops to help state officials identify deployment opportunities**
- **Monthly Webinar Series**
  - Jobs Tool
  - Recent fuel cell licenses
  - Portable power
  - Mobile lighting
  - Register at - http://www1.eere.energy.gov/hydrogenandfuelcells/webinars.html
- ***Monthly Newsletter***
  - Visit the web site to register or to see archives (http://www1.eere.energy.gov/hydrogenandfuelcells/newsletter.html)

Future Directions

Funding Opportunity Announcements (FOAs)	Funding Planned
Production & Delivery (FY14)	~$6M
Hydrogen Storage (FY14)	~$6M
Technology Validation and Market Transformation (FY13 & FY14)	~$6.5M
Manufacturing R&D (FY14)	~$3M

Notice of Intent Issued- May 2013

Technology Validation & Market Transformation

- Demonstration & Deployment of Fuel Cell Hybrid-Electric Medium-Duty Trucks
- Validation of Advanced Hydrogen Refueling Components
- Demonstration and Case Study for Roof-top Installation of Hydrogen Fuel Cell Backup Power Systems
- Hydrogen Meter R&D

Requests for Information

- RFI on Home Hydrogen Refueling Systems and Potential H-Prize Topics Issued (https://eere-exchange.energy.gov/default.aspx#FoaId2e67f6df-fd51-4da2-953c-ab515231abb0)
- Additional RFIs see: https://eere-exchange.energy.gov/

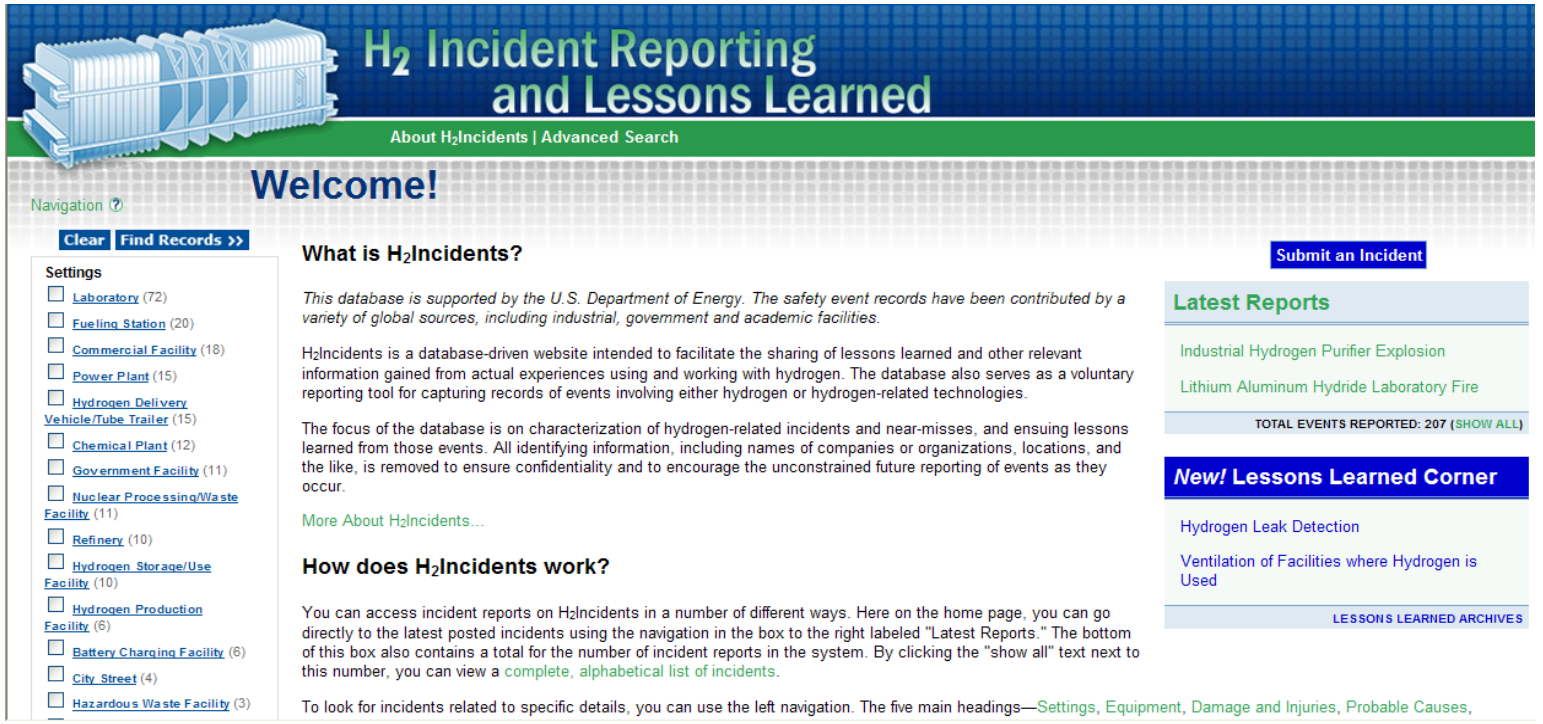
Federal Policies Promoting Fuel Cells

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Some tax credits affecting fuel cells were expanded and a new act was proposed that can help facilitate federal deployments.

Investment Tax Credit	30% for qualified fuel cell property or $3,000/kW of the fuel cell nameplate capacity (i.e., expected system output), whichever is less. The equipment must be installed by Dec. 31, 2016. In addition, it features a credit of 10% for combined heat-and-power-system property.
Fuel Cell and Hydrogen Energy Infrastructure (proposed)	Designed to accelerate the adoption of stationary fuel cell power generation and hydrogen infrastructure. Also addresses fuel cells in transportation applications, by increasing the tax credit for hydrogen refueling stations from 30% to 50% and removing the dollar limit. Allows for the credit to be extended to hydrogen refueling stations for fuel cell material handling vehicles.
H-Prize	Cash prizes to advance the commercial application of hydrogen energy technologies by incentivizing accelerated research production, storage, distribution, utilization, and prototypes and transformational technologies. $1M, $4M, and $10M categories.

H2 Incident Database - Objectives



H_2 Incident Reporting and Lessons Learned ("H_2incidents.org")

- Collect information and share lessons learned from hydrogen incidents and near-misses, with a goal of preventing similar safety events from occurring in the future.
- Increase number of records in database by convincing "incident owners" to share lessons learned with the hydrogen community.
- Analyze and summarize lessons learned from incidents and near-misses.

Approach – "H_2incidents.org"

- Establish and maintain a mechanism for online submission of records.
- Encourage all DOE projects to submit records of incidents and near-misses with clear descriptions of lessons learned.
- Pursue addition of new records by actively reviewing media reports of hydrogen incidents.
- Contact private-sector companies/organizations that experience hydrogen incidents and near-misses to solicit permission to publish records.
- Publish quarterly Lessons Learned Corner to analyze, summarize, and expand upon lessons learned for specific hydrogen safety vulnerabilities.
- Add links to "H_2bestpractices.org" to emphasize safe practices for working with hydrogen.
- Provide expert review of incident records and lessons learned by Hydrogen Safety Panel and PNNL subject matter experts.

Example Incident - Burst Disk

Incident Report

Tube Trailer Leak through Over-Pressure-Protection Rupture Disk

Incident Date: 2008

Severity:	Was Hydrogen released?	Was there Ignition?
Incident	Yes	No

Description

A pressure relief device (frangible burst disk) on one of a hydrogen delivery tube trailer's 26 tubes failed prematurely and released hydrogen while filling a hydrogen storage tank at a government facility (see Attachment 1). Prior to the filling process, all procedures and safety checks, including connection to the facility's regulator/distribution control system with leak checking and follow-up verification of leak checking by facility personnel, were completed (see Attachment 2 for more details). During the filling process, a person walking near the facility heard the noise of escaping gas that included occasional popping sounds typical of bursts of gas release. Facility personnel were alerted and the tube trailer vendor's incident response team was dispatched to the incident location.

The hydrogen leak was safely contained and mitigated by the tube trailer vendor's incident response team. On arrival, the response team first noted a decrease in pressure from the shipped pressure of 2100 to 1700 psi (145 to 117 bar) at the tube trailer's common supply manifold. The hydrogen leak was located to a single tube on the tube trailer coming from a burst disk

Safety Event Record Include:

- Location
- Equipment
- Probable Causes
- Contributing Factors
- Injury/Damage

Enhanced by International Collaboration

- Almost 20% of the safety event records come from outside the U.S.
- The network of the IEA Hydrogen Implementing Agreement (HIA) utilized to partner with IA HySafe's Hydrogen Incident and Accident Database (HIAD)
- An initiative with partners in Task 31 (Hydrogen Safety) adds safety event records to "H2incidents.org" and exchanges records with HIAD
  - Partners: Japan, Germany, Canada, France, Italy, European Commission, U.K., The Netherlands, Switzerland, Norway
- PNNL and the European Commission's Joint Research Center (JRC) share podium for topical session on safety event databases (International Conference on Hydrogen Safety, September 2011) and demonstrate "H2Incidents.org" and HIAD for ICHS attendees