Overview of U.S. Materials Development Activities for Hydrogen Technologies

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Materials Innovations in an Emerging Hydrogen Economy Meeting

Cocoa Beach, FL

February 24-27, 2008

[1] Los Alamos National Laboratory - retired

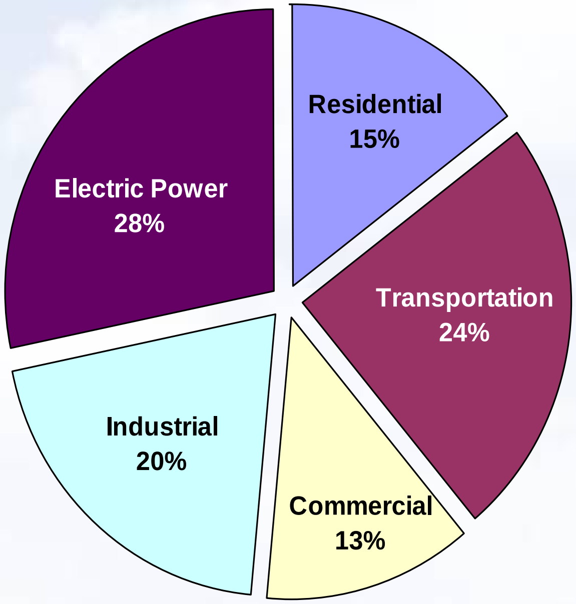
Acknowledgements/Contributors

- DOE Hydrogen Production Team:
  - Rick Farmer
  - Roxanne Garland
  - Jamie Holladay
  - Arlene Anderson (now in the Geothermal Program)
- DOE Hydrogen Delivery Team
  - Tim Armstrong
  - Monterey Gardiner
- DOE Hydrogen Storage Team
  - Sunita Satyapal
  - Carole Read
  - Grace Ordaz
  - George Thomas
  - John Petrovic
- DOD/DLA Projects
  - M. Ashraf Imam

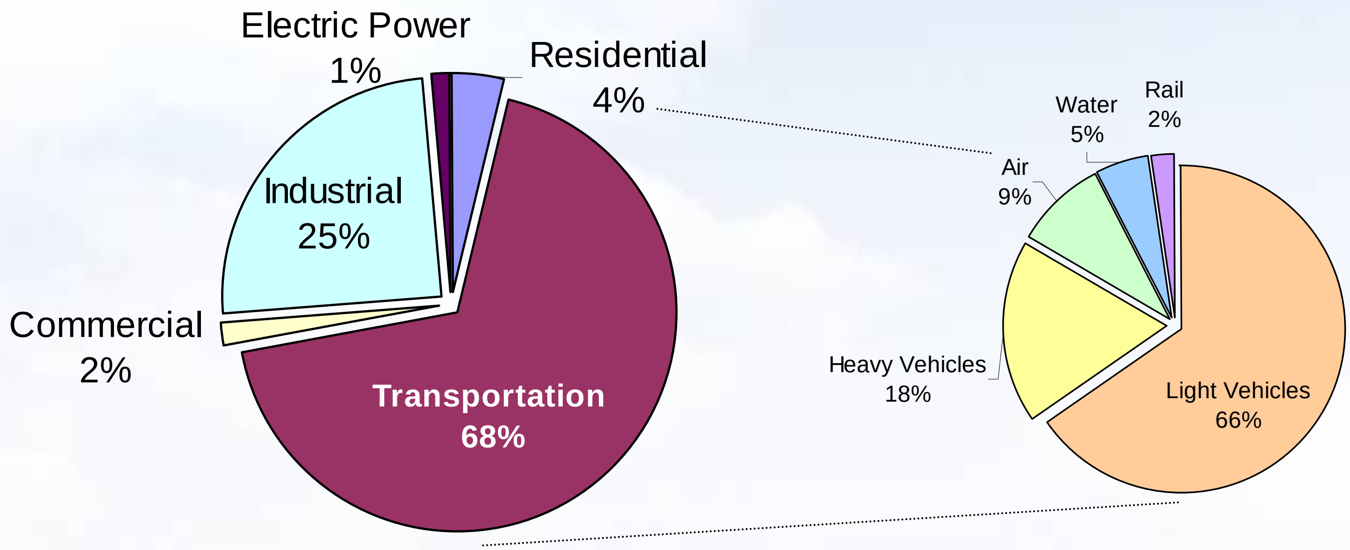
- **And all of the PI's and researchers that did/are doing the actual work discussed but are too numerous to name individually!**

Drivers for the introduction of Hydrogen

- Climate Change & Oil Consumption



Domestic CO_2 Emissions by Sector (2006)



Domestic Oil Consumption (2006)

- **Hydrogen is critical to addressing these issues and R&D will continue towards long-term solutions :**
  - ***Transportation: Use of Hydrogen in fuel cell vehicles can reduce oil use and carbon emissions in the transportation sector***
  - ***Power Generation: Hydrogen can enable clean, reliable energy for stationary and portable power applications***

U.S. Hydrogen-related Policy (2003-2006)

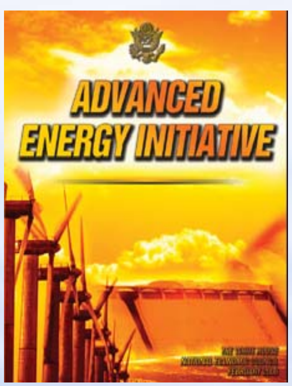
HYDROGEN FUEL INITIATIVE (Jan. 2003):

- $1.2 billion over five years
- Establishes partnerships with private sector
- Develops hydrogen, fuel cell and infrastructure technologies
- Goal: to make fuel cell vehicles practical and cost-effective by 2020

EPACT 2005 (Public Law 109-58) TITLE VIII HYDROGEN:

- “Codifies” **Hydrogen Fuel Initiative** and reinforces DOE timeline
- By 2015: Industry commitment for fuel cell vehicles & infrastructure
- By 2020: Vehicles and hydrogen available for consumers
- Program authorized through 2020

ADVANCED ENERGY INITIATIVE (Feb. 2006):



- Accelerates research to reduce dependency on oil and natural gas
- 22% increase in funding for clean energy research
- Reinforces **Hydrogen Fuel Initiative**
- Accelerates R&D of near-term transportation options

U.S. Hydrogen-related Policy (2007)

"20-in-10" INITIATIVE (Jan. 2007):

- Sets fuel standard at 35 billion gallons of renewable and alternative fuels by 2017, to displace 15% of annual gasoline use in 2017
- Expands scope of Renewable Fuel Standard (RFS) to "Alternative Fuel Standard"

Executive Order 13423 (Jan. 2007):

- Directs Federal agencies to implement sustainable practices for (1) energy efficiency and reductions in greenhouse gas emissions; (2) use of renewable energy; and (3) acquisition of green products and services.

ENERGY INDEPENDENCE & SECURITY ACT (Dec. 2007):

- **H-Prize:** Establishes an award to advance the research, development, demonstration, and commercial application of H2 energy technologies
- **Energy Storage Competitiveness Act of 2007:** Supports US global competitiveness in energy storage systems, including fuel cell technologies
- **Renewable Energy Innovation Manufacturing Partnership:** Makes awards available related to the manufacturing of renewable energy technologies, including fuel cells

HYDROGEN FUEL INITIATIVE FUNDING

- By Participant Organization

	Funding *($ in thousands)*					
	FY 2004 Approp.	**FY 2005** Approp.	**FY 2006** Approp.	**FY 2007** Approp.	**FY 2008** Approp.	**FY 2009** Request
HYDROGEN FUEL INITIATIVE						
EERE Hydrogen	144,881	166,772	153,451	189,511	211,062	177,713*
Fossil Energy (FE)	4,879	16,518	21,036	21,513	21,773	11,430
Nuclear Energy (NE)	6,201	8,682	24,057	18,855	9,909	16,600
Science (SC)	0	29,183	32,500	36,388	36,388	60,400
DOE Hydrogen TOTAL	**155,961**	**221,155**	**231,044**	**266,267**	**279,132**	**266,143**
Department of Transportation	555	549	1,411	1,420	1,425	1,425
Hydrogen Fuel Initiative TOTAL	**156,516**	**221,704**	**232,455**	**267,687**	**280,557**	**267,568**

$1.16B

US DOE Hydrogen Program, 25 March 2008

U.S. Hydrogen and Fuel Cell Funding Greater than just the HFI

The average U.S. investment in hydrogen and fuel cells over the past five years is approximately US$450 million per year!

Agency	FY 07 Estimate
Commerce	$11 million
Defense	$58 million
Energy	$400 million
Environmental Protection Agency	$0.2 million
NASA	$6 million
National Science Foundation	$23 million
Transportation	$23 million
Agriculture	$0.5 million
US Postal Service	$0.02 million

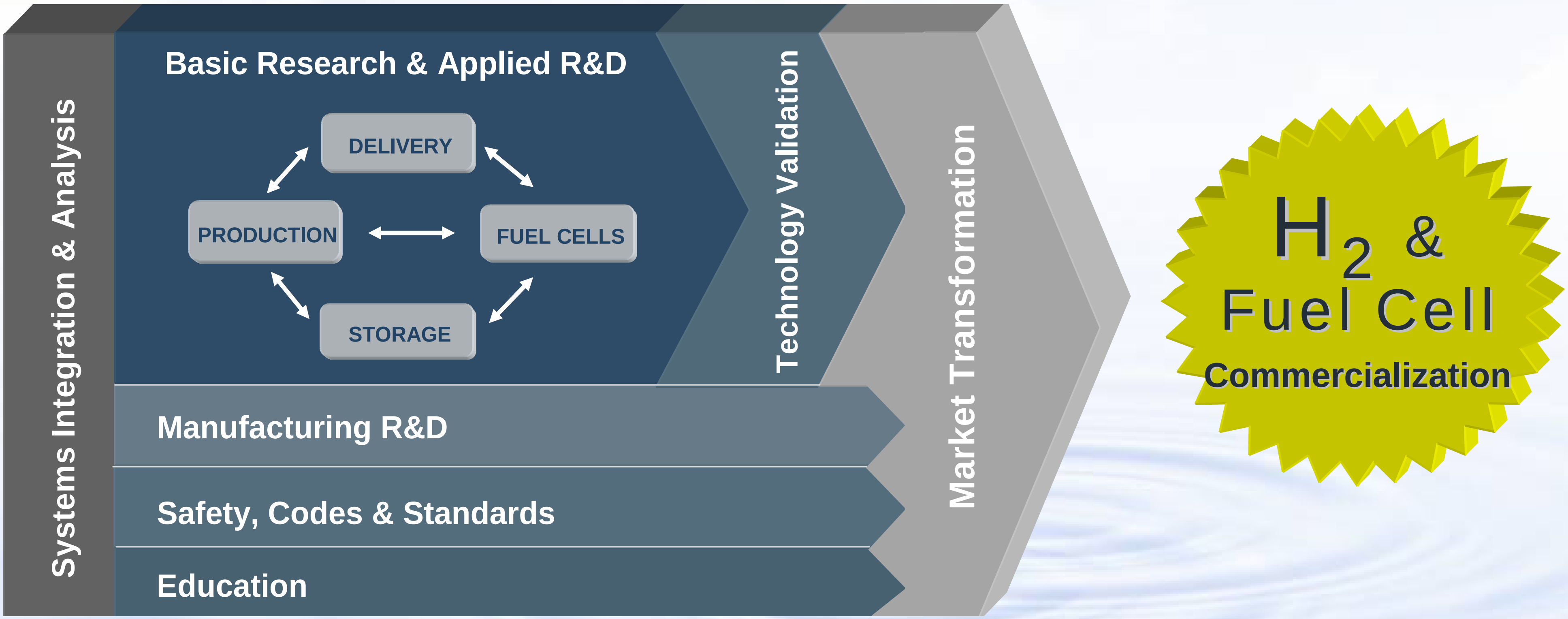
Focus Areas of this Talk!

- DOE EERE Hydrogen Program
  - Production
  - Delivery
  - Storage
- Department of Defense / Defense Logistics Agency

A high-level overview of materials related research activities and key challenges for each area will be given.

DOE-EERE Hydrogen Program Activities

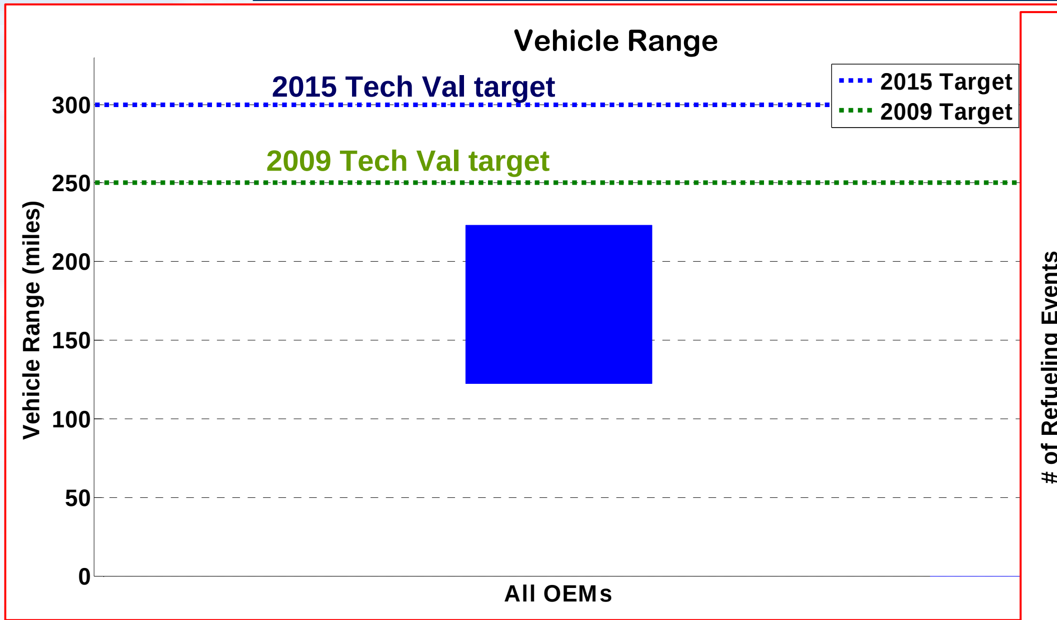
The DOE Hydrogen Program is structured to address the wide range of barriers facing hydrogen and fuel cell commercialization

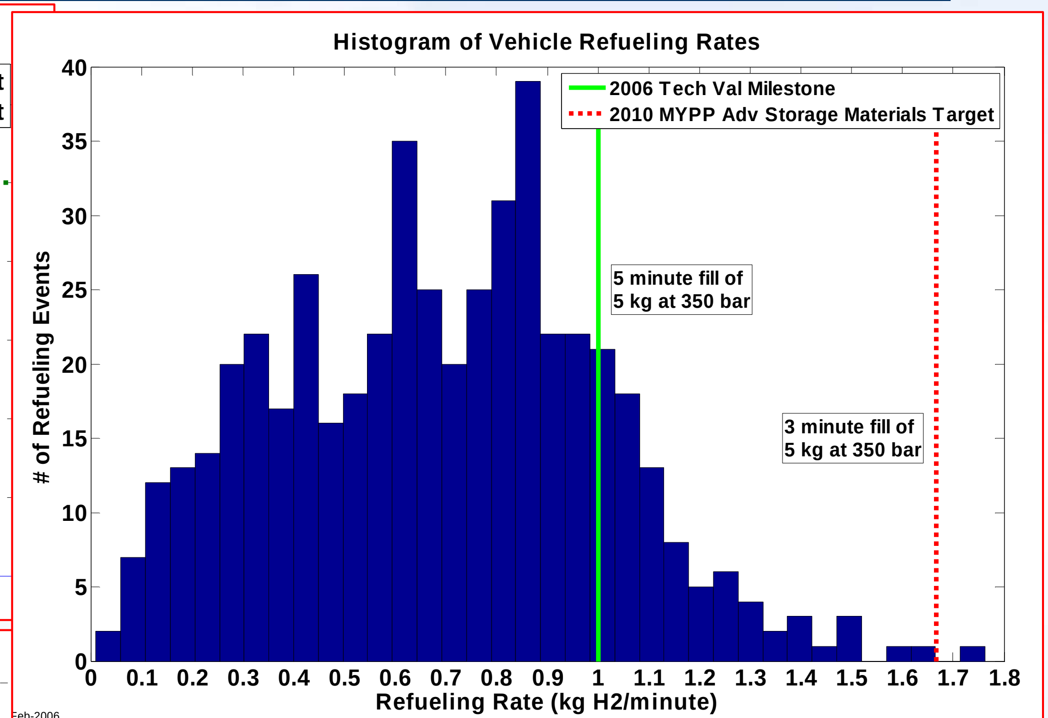


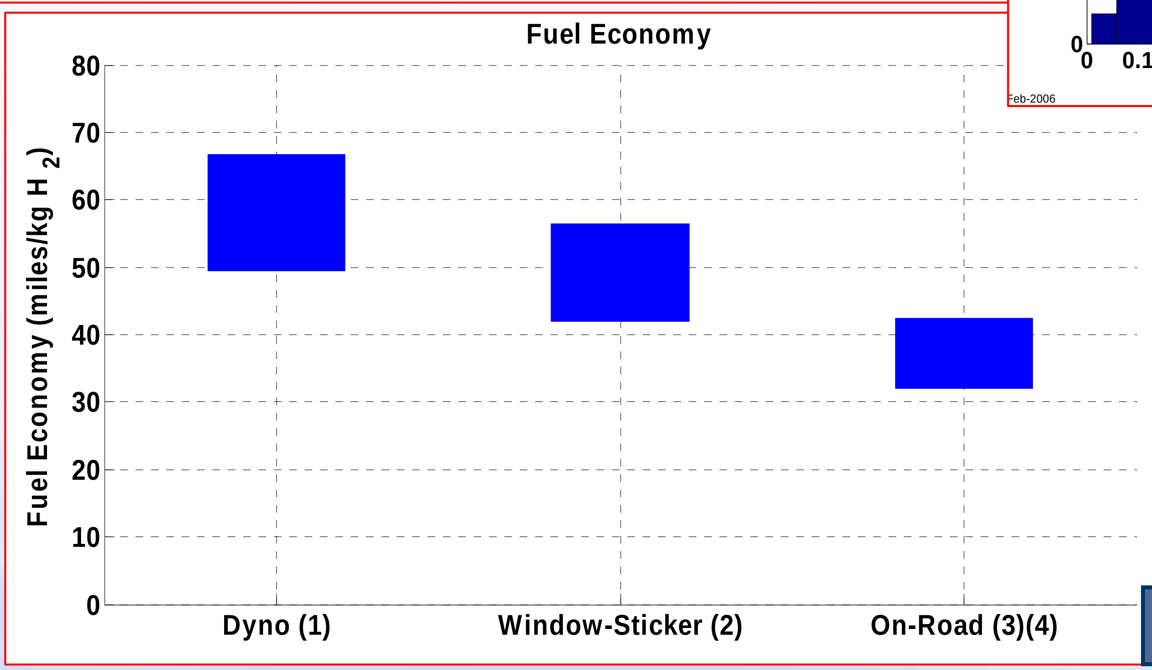
Technology Validation

- Real World Composite Data (>70 vehicles, 12 stations)

Current status: 103 to 190 mile range - Improved on-board hydrogen storage technologies are necessary to meet range targets

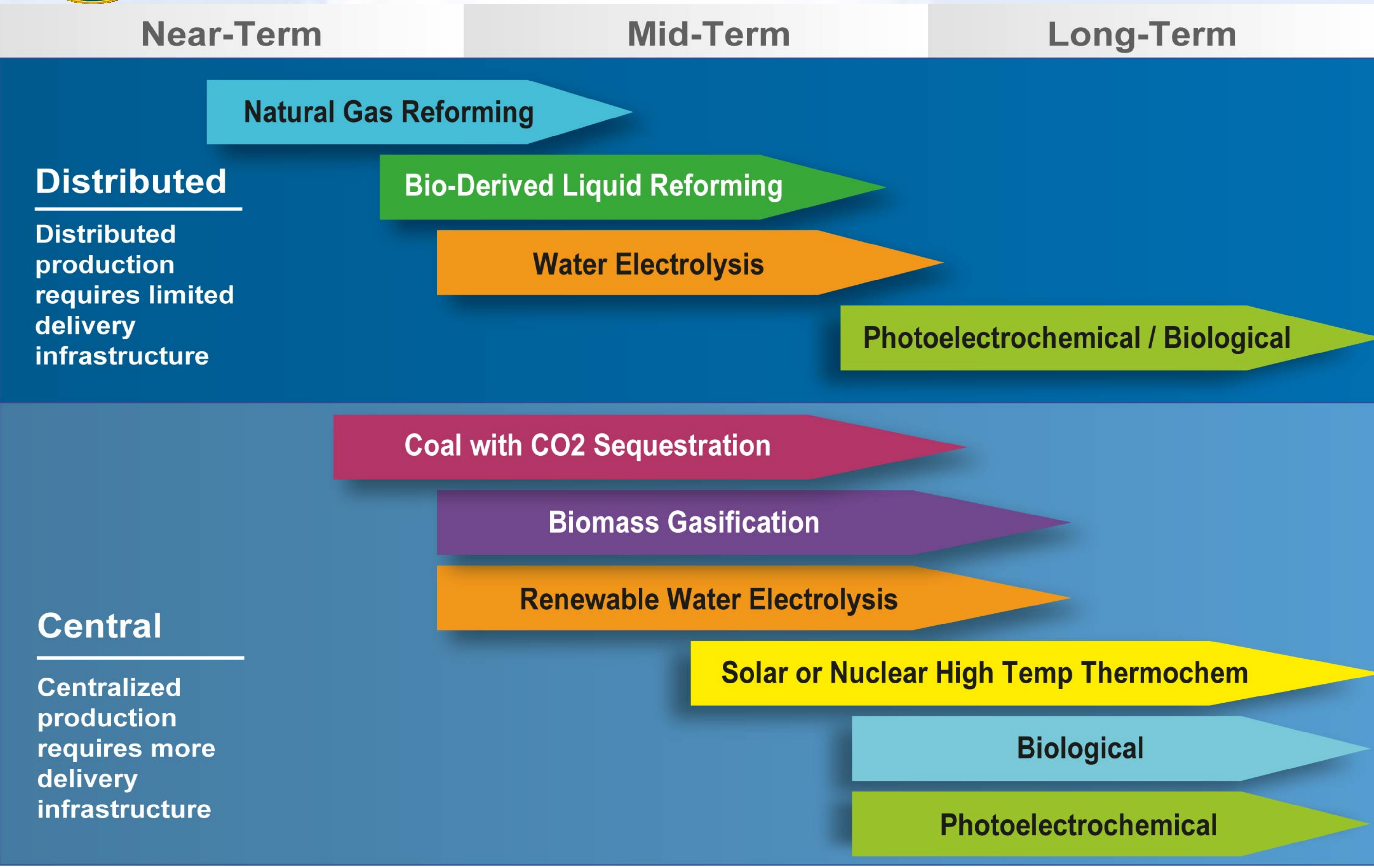






http://www.nrel.gov/hydrogen/cdp_topic.html

Production Technologies by Timeframe



Production: Reforming

Challenges

- ***Improve reforming and separation efficiencies***
- ***Identify more durable reforming catalysts***
- ***Incorporate breakthrough separations technology***
- ***Improved membrane technology***
- *Reduce space needed*
- *Optimize system operation*
- *Intensify and consolidate the number of process steps, unit operations*

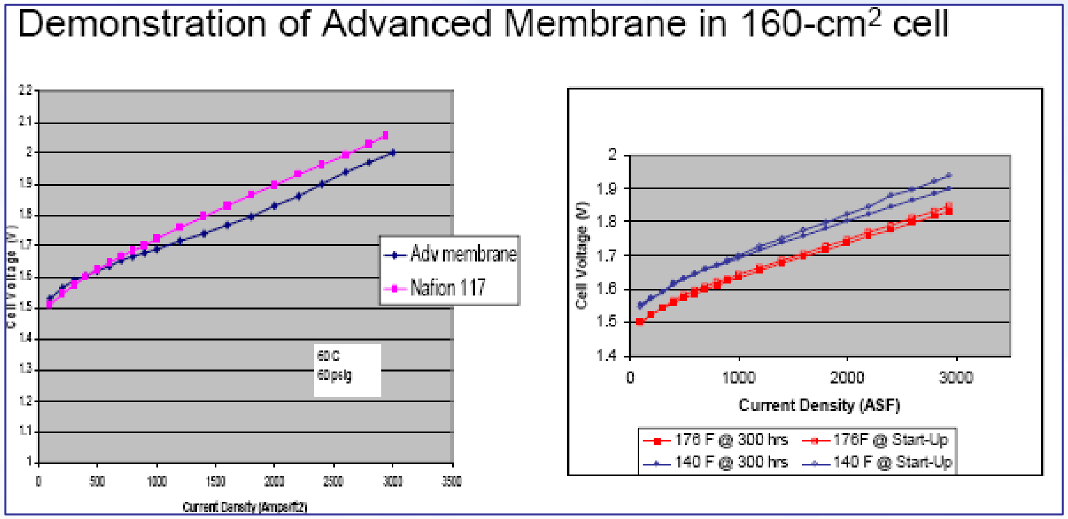
Accomplishments

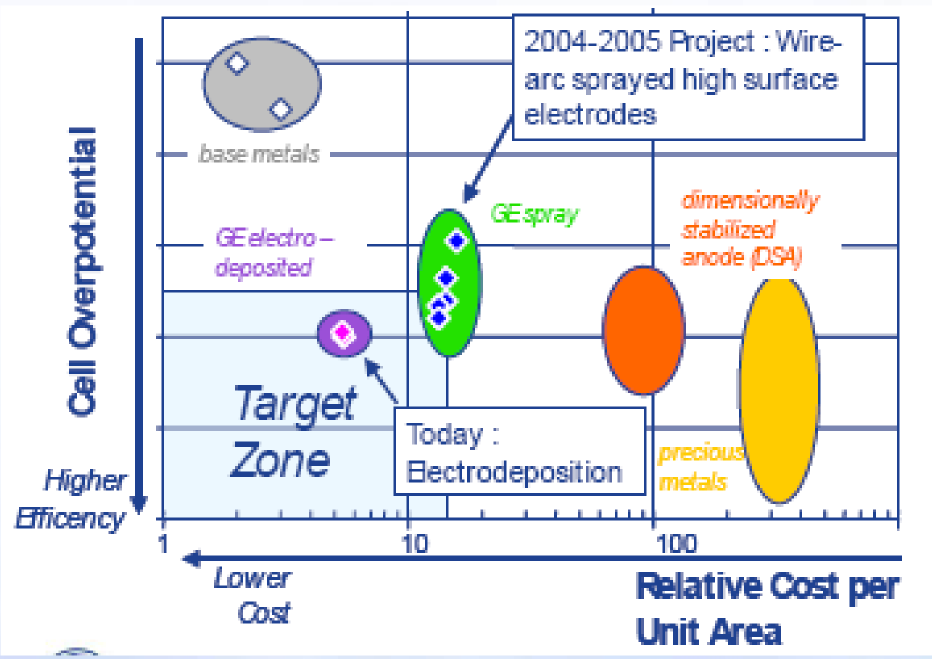
- *DOE Cost target validated at $3.03/kg*
- *DOE Efficiency target met at 65.1%*
- *PSA efficiency 82%*
- *U Penn fueling station transferred to technology validation program in 2006*

Production: Water Electrolysis

Challenges

- ***Develop new materials and systems to improve efficiency to reduce hydrogen cost***
- ***Reduce capital costs through new designs with lower cost materials***
- *Develop low-cost hydrogen production from electrolysis using wind and other renewable electricity sources*





Accomplishments

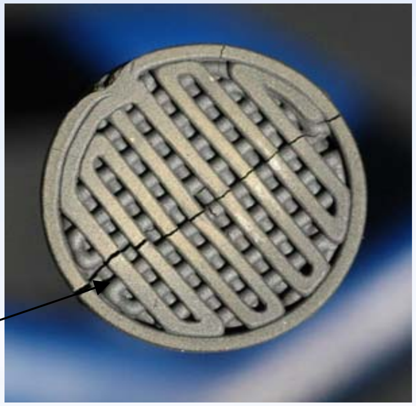
- *Electrodeposited proprietary catalyst to surpass catalyst cost target (GE).*
- *Plastic stacks with molded passages (GE).*
- *Part count reduction by 60% (Giner)*
- *Demonstrated an advanced high-efficiency membrane and developed lower cost fabrication methods for two key cell components. (Giner)*
- ***Electrolyzer efficiency >64% with clear pathway to 69%.***

Production: Solar Driven HT Thermochemical

Solar Ferrite Cycle Closure Demonstrated

$$Co_{0.67}Fe_{2.33}O_4 \xrightarrow{1400^\circ C} Co_{0.67}Fe_{2.33}O_{4-\delta} + \frac{\delta}{2}O_2$$

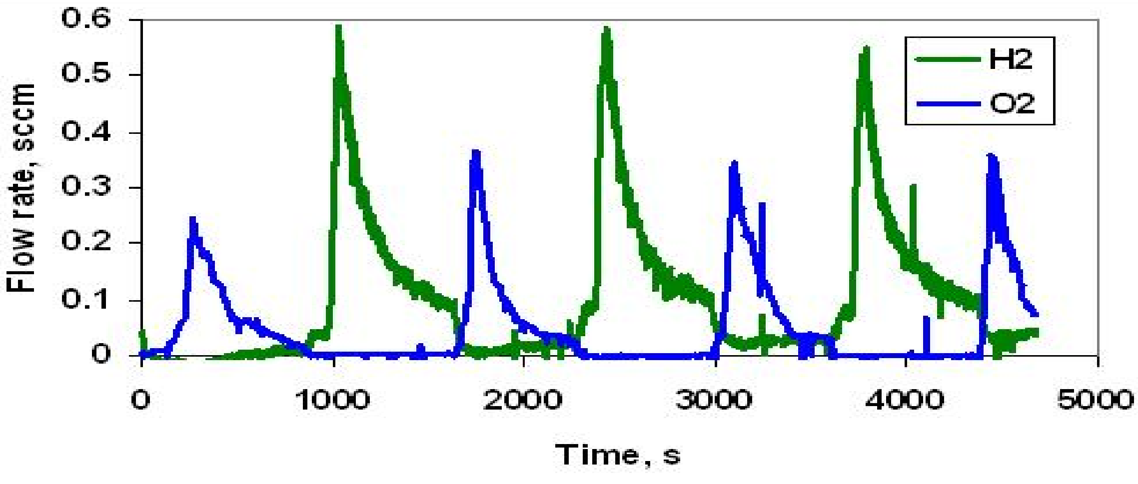
$$Co_{0.67}Fe_{2.33}O_{4-\delta} + \delta H_2O \xrightarrow{1000^\circ C} Co_{0.67}Fe_{2.33}O_4 + \delta H_2$$



Ferrite monoliths

Challenges

- *Resolve the uncertainties of down-selected cycles and research and develop most promising cycles.*
- *Optimize system designs for temperatures and power requirements*
- *Develop and validate Reactor/ Receivers and/or Falling Particle Receiver/heat transfer system*
- ***Investigate materials challenges for solar reactor/receivers and other system components***
- ***Reduce the cost of heliostats***



Accomplishments

- *On-sun reduction at 1550 °C, H2 production at 1100 °C*
- ***YSZ-stabilized ferrite shows stability, repeatability***
- *First cycle closed "on-sun"*

Production: Nuclear Hydrogen

Challenges

- ***Need for high temperature resistant, corrosion resistant materials***
- ***Need for advanced catalysts and membrane materials***
- *Water management*
- ***Durable electrode materials and seals for electrolysis cells***
- *Selection of intermediate loop heat transport fluid*

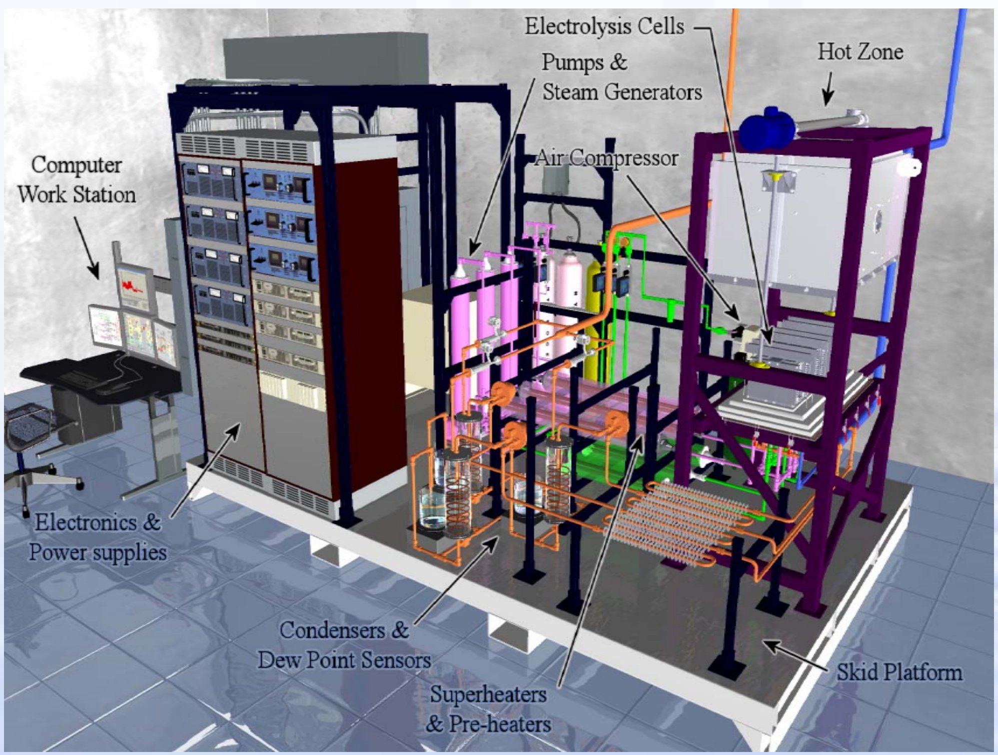
$$H_2SO_4 \xrightarrow{820^\circ C} H_2O + SO_2 + \tfrac{1}{2}O_2$$

$$I_2 + SO_2 + 2H_2O \xrightarrow[120^\circ C]{} H_2SO_4 + 2HI$$

$$2HI \xrightarrow{320^\circ C} I_2 + H_2$$

$$H_2SO_4 \xrightarrow{800\text{–}900^\circ C} H_2O + SO_2 + \tfrac{1}{2}O_2$$

$$SO_2 + 2H_2O \xrightarrow{80\text{–}120^\circ C} H_2SO_4 + H_2$$



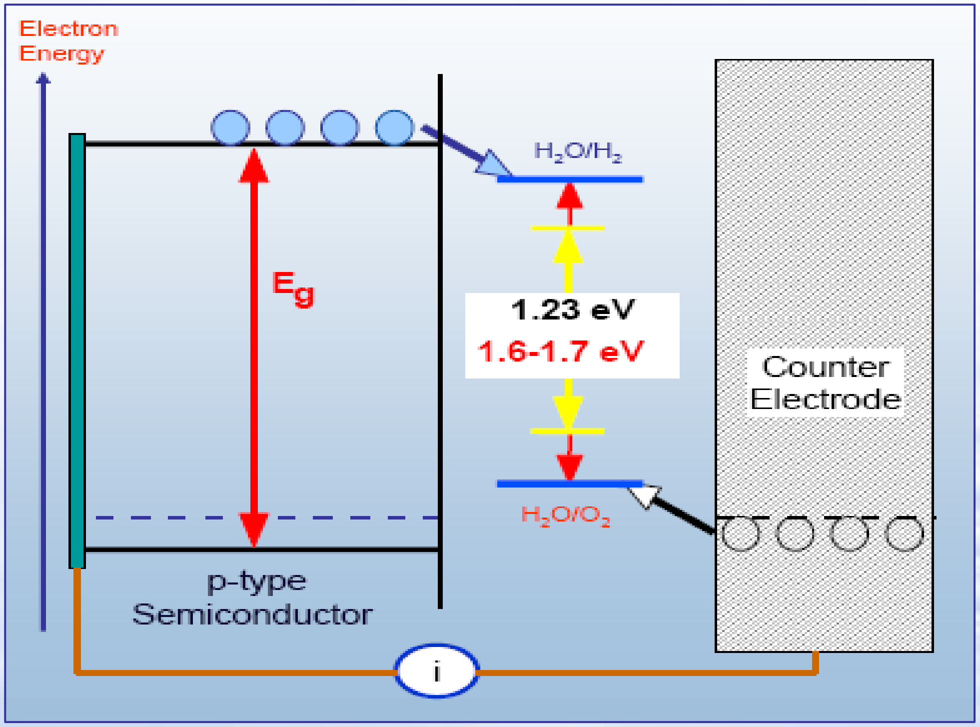
Accomplishments

- ***Thermochemical Cycles***
  - *Bayonet Design, Si-C, H_2SO_4 Decomposer for Sulfur-Iodine Cycle*
  - *SO_2-depolarized Electrolyzer for Hybrid Sulfur Cycle; 100-hr test scheduled for June 2007*
  - *H_2SO_4 Decomposition Skid for Sulfur-Iodine Integrated Lab-Scale Experiment*
- ***High Temperature Electrolysis***
  - *2,000-hr test of 120-cell “half-module”, September 2006*
  - *Post-test evaluation of electrodes*
  - *Integrated Laboratory-Scale Experiment to start operation September 2007*

Production: Photoelectrochemical

Challenges

- ***Increase materials efficiency and durability***
- *Develop device and system configurations*



Accomplishments

- **Collaborative Research Team Established:** *Combining materials theory, synthesis and characterizations*
- **Focus Materials Classes Established:** *Including Tungsten-, Zinc-Iron (oxide nanorods)-, Silicon- , and Copper-chalcopyrite-based thin film compounds*
- **Key Targets Met in Recent Focus Materials Experiments:**
  - *Photocurrents in excess of 6.5 mA/cm^2 in Si- and chalcopyrite-based films*
  - *STH Device efficiencies in excess of 3% in WO_3-based multi-junction structures (under 1-sun)*

Delivery: Pipeline Materials

Challenges

- ***Potential for hydrogen embrittlement in steels***
- *Existing pipeline infrastructure at/near capacity*
- ***Compression cost/reliability and high volume storage***
- *Public acceptance, along with ROW and permit issues, requires high confidence in safety/reliability*

Accomplishments

- **Focused effort to resolve embrittlement for steel pipelines**
- **Expanded effort on FRP pipeline**
  - **Novel low leak rate polymer identified**
- **Established a Pipeline Working Group**
  - National Labs (ORNL, SRNL, SNL), industry (CTC, APCi, RDC, SECAT, Chemical Composite Coatings Intl., Columbia Gas of KY, Oregon Steel Mills, Hatch Moss MacDonald, AME Stds., etc.), and universities (U. of Illinois)
  - Carrying out “round robin” testing on fatigue and permeations of steels

Storage: *"The Grand Challenge"*

- ***Application-driven*** **system storage targets**
- Example 2010 ***SYSTEM*** targets:
  - System Gravimetric Capacity (net) — **6 wt.% (2.0 kWh/kg)**
  - System Volumetric Capacity (net) — **45 g/L (1.5 kWh/L)**
  - Storage System Cost — **\$4/kWh (~\$133/kg H_2)**
  - Min. Full Flow Rate — **0.02 g/s/kW**
  - Refueling Time (for 5 kg) — **3 min (28 g/s)**
  - Cycle Life (Durability) — **1000 cycles**

Hydrogen Densities (NOT Systems)		
Gas at 15 °C and	*350 bar:*	*23 g/L*
	700 bar:	*38 g/L*
Liquid hydrogen at -253 °C:		*71 g/L*

The Grand Challenge: the 2010 system target is greater than the theoretical density of compressed hydrogen at 700 bar – advanced storage methods must be developed!

Storage: *"Better storage through Chemistry"*

Reversible metal hydrides

Advantages

- Onboard refueling
- High volumetric densities

Key Challenges

- Lowering desorption temperatures
- Improving kinetic response
- Heat management during refill

Adsorbent materials

Advantages

- Onboard refueling
- Generally good kinetics
- Thermal mgmt may be minimal

Key Challenges

- Improving volumetric capacities
- Increasing desorption temperatures

Non-reversible chemical hydrides (hydrogen carriers)

Advantages

- High capacities
- Potentially liquid, some systems have demonstrated good kinetics, low-T operation

Key Challenges

- Complexity (e.g., two-way infrastructure, onboard processor)
- Decreasing regeneration costs (& life cycle energy requirements)

EERE Hydrogen Storage Program

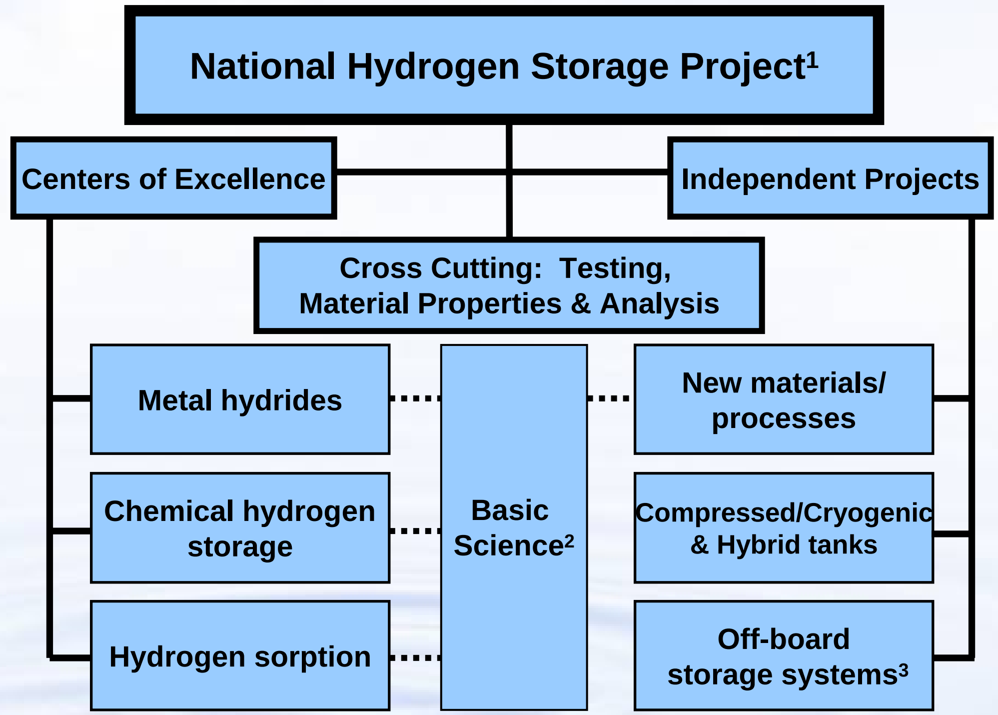
KEY OBJECTIVE: *On-board H_2 storage to enable **> 300 mile driving range** while meeting all requirements for safety, cost, and performance (weight, volume, kinetics, etc.)*

NEAR TERM: *Allows for early market use of H_2 vehicles, but won't provide full range on all platforms*

- Pressurized tanks: *currently in use in most H_2 vehicles*
- Cryo-compressed storage: *combines low-temperature H_2 storage with pressurization*

LONGER TERM: *Needed to enable >300-mile range*

- *Diverse portfolio with materials focus, for low-pressure storage*
- *Focus materials research on temperature, pressure, kinetics (as well as capacity)*



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
3. Coordinated with Delivery Program element

National Hydrogen Storage Program

- Collaborations

Applied R&D under President's Hydrogen Fuel and Advanced Energy Initiatives led by DOE Office of Energy Efficiency and Renewable Energy (EERE)

INTERNATIONAL ACTIVITIES

- **IEA HIA Task 22**

  15 countries, 43 projects

- **IPHE**

  5 projects *(EU, Russia, Canada, US, New Zealand, Singapore)*

DOE – EERE

H_2 Storage Applied R&D

- **3 Centers of Excellence**
- **Independent projects**
- **Total of ~80 projects**

INDUSTRY

- **FreedomCAR & Fuel Partnership**

  ***Tech teams*:**
  - H_2 Storage
  - Fuel Cells
  - Fuel Pathways
  - Vehicle Systems
- **Codes & Standards Organizations**

TECHNOLOGY VALIDATION (DOE EERE)

~75 vehicles & 12 stations

National Collaborations *(inter- and intra-agency efforts)*

DOE – Basic Energy Sciences

~25 Projects

DOT

Material handling/transport

DOD – Defense Logistics Agency

5 Projects

NASA

Tanks

NIST

- **Neutron scattering**
- **Measurements**

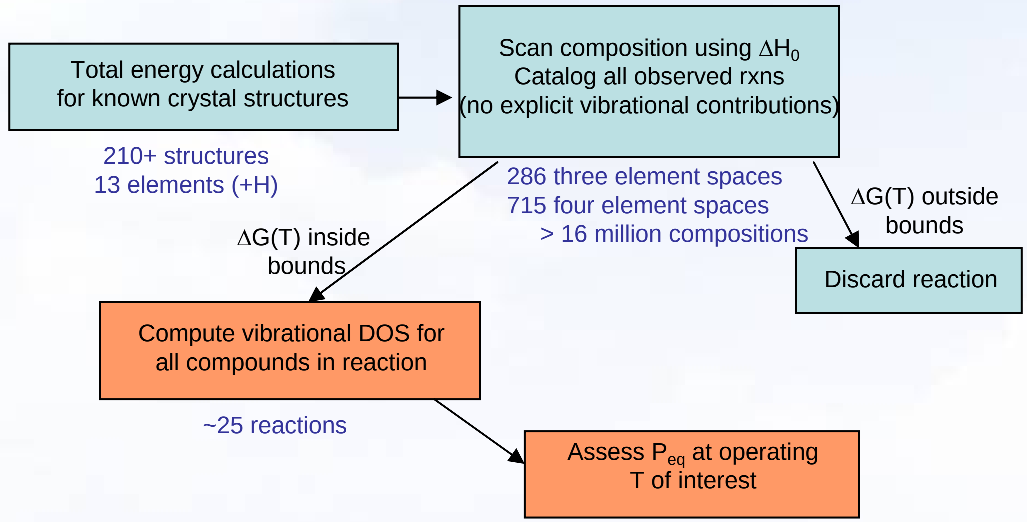
NSF

New projects to be selected

Storage: Using Density Functional Theory to Predict Potential Reaction Systems

Accomplishments

- Developed and tested method for computing and identifying reactions with the lowest grand potential at given temperature, H_2 pressure, and overall atomic composition.
- Implemented a linear program in conjunction with a database of 212 compounds containing Al, B, C, Ca, K, Li, Mg, N, Na, Sc, Si, Ti, V, and H.
- Examined all 715 element spaces of the form E1-E2-E3-E4-H, where Ei is an element from the list above. Includes analysis of all 286/98/13 spaces of the form E1-E2-E3-H/E1-E2-H/E1-H.
- **>16 million distinct mixtures examined.**
- **Identified 43 distinct reactions** that met set boundary conditions (release **>6.0 wt.% H**, the ground state enthalpy of reaction **(ΔU_0) in the range 15-75 kJ/mol H_2**).
- MHCoE Theory Group Members include: U. Pittsburgh, Georgia Tech (ex. Carnegie Mellon), U. Illinois, NIST, Sandia, U. Missouri



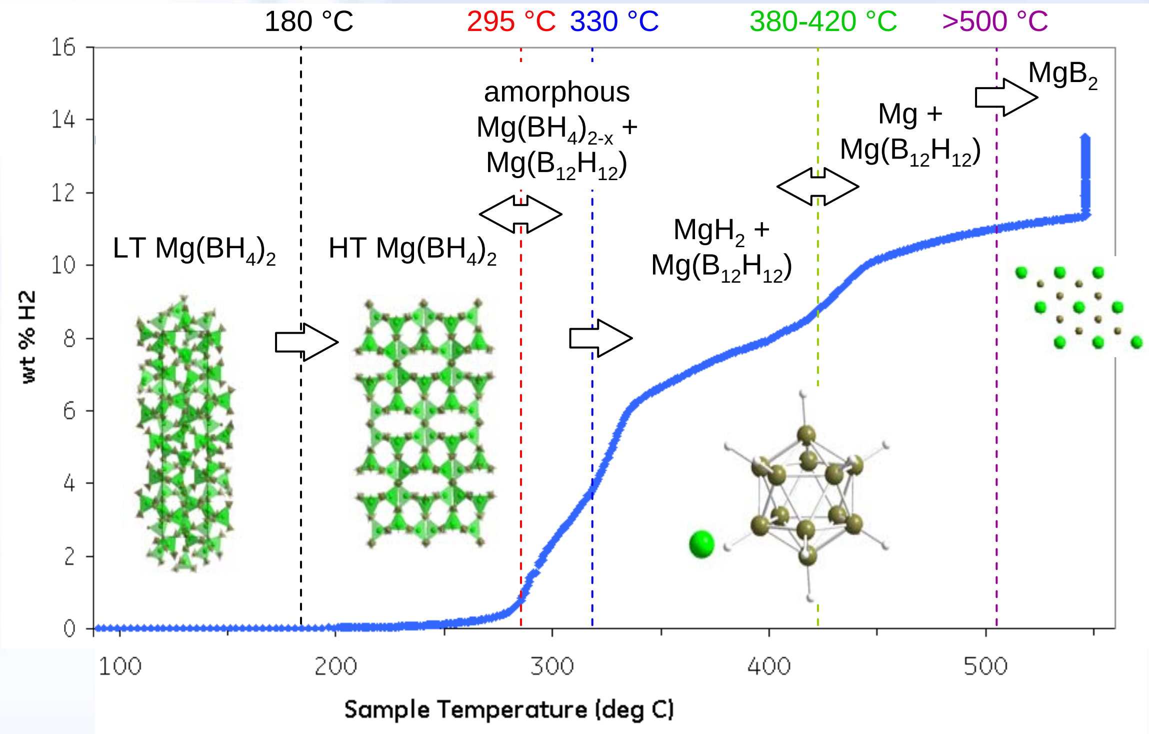
Challenges

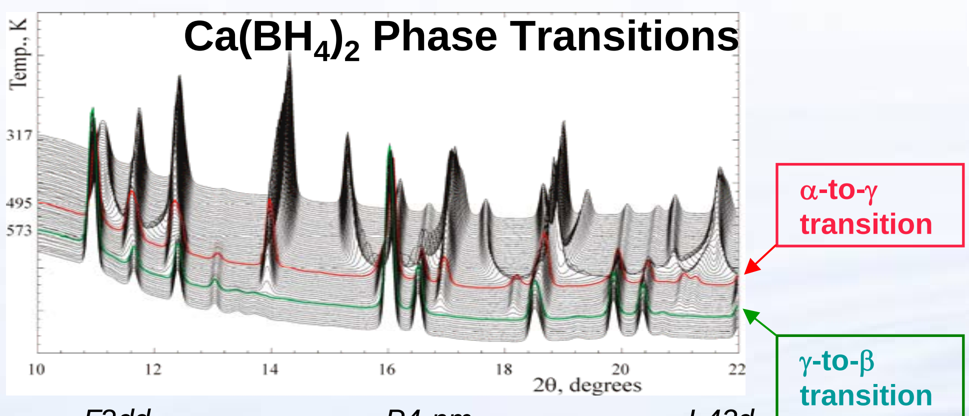
- ***Identification of reaction pathways***
- ***Need to know structure to apply DFT***
- *Application of energy corrections for non-zero (K) temperatures*

Storage: Reversible Complex Metal Hydrides

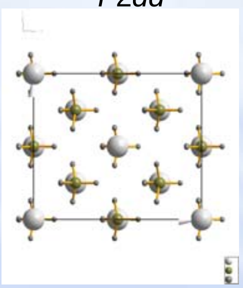
Challenges

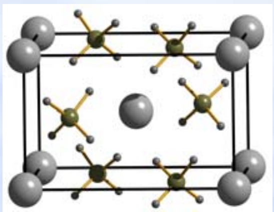
- ***To meet gravimetric target limited to lightweight elements***
- ***Reversibility within "reasonable" temperature/pressure/time constraints***
- ***Sorption kinetics***
- ***Volatile reaction by-products (e.g. ammonia and diborane)***

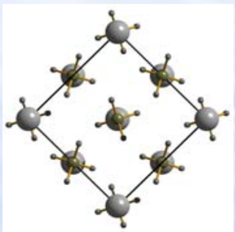




F2dd *$P4_2nm$* *I-42d*


α

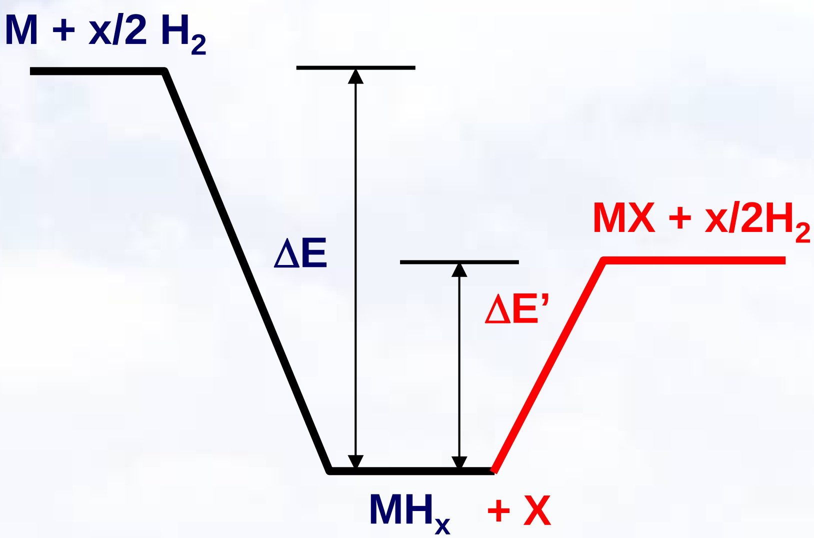

β


γ

Accomplishments

- **Predicted and verified new reaction pathway for $Ca(BH_4)_2$**
- **Identified $(B_{12}H_{12})$ in borohydride thermal decompostions**
- **Identified reversible composite amide systems**
- Participants include: Sandia, U. Utah, U. Nevada-Reno, GE, JPL, Cal Tech, U. Pittsburgh, Carnegie Mellon U., Savannah River, U. Hawaii, U. Illinois, Oak Ridge, NIST, Intematix, Stanford, United Technologies Research Center

Storage: Destabilization of metal hydrides



Challenges

- ***Destabilize hydride phase with respect to H_2 gas and solid phase to allow low-T desorption***
- ***System reversibility***
- ***Improve kinetics – catalysts/reaction facilitators***
- ***Improve cycle life***

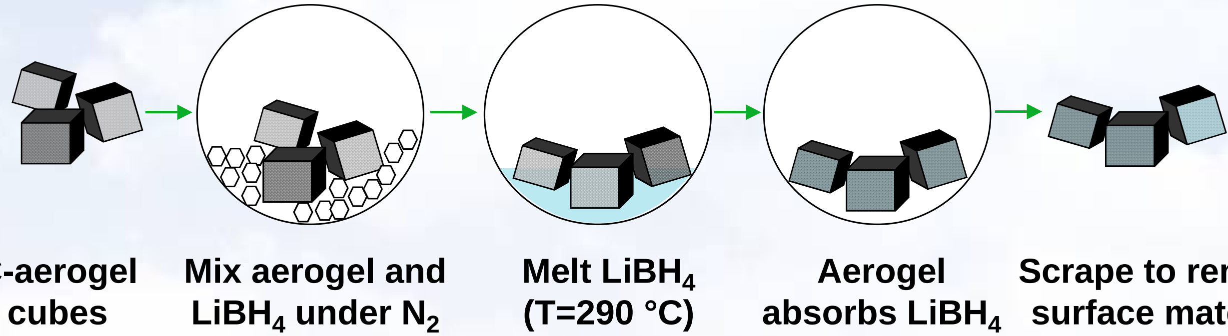
Accomplishments

- Theory (DFT) used to identify potential reaction systems of interest
- 21 reactions of interest being investigated experimentally, 7 still under study
- Identified systems with were destabilizing components also contained H_2
- An example system:

  $$2LiBH_4 + MgH_2 \rightarrow 2LiH + MgB_2 + 4H_2$$

- Participants include: HRL, Cal Tech, JPL, Stanford, U. Hawaii, U. Illinois, Intematix, U. Pittsburgh, U. Utah and NIST

Storage: Nano-confinement of hydrides

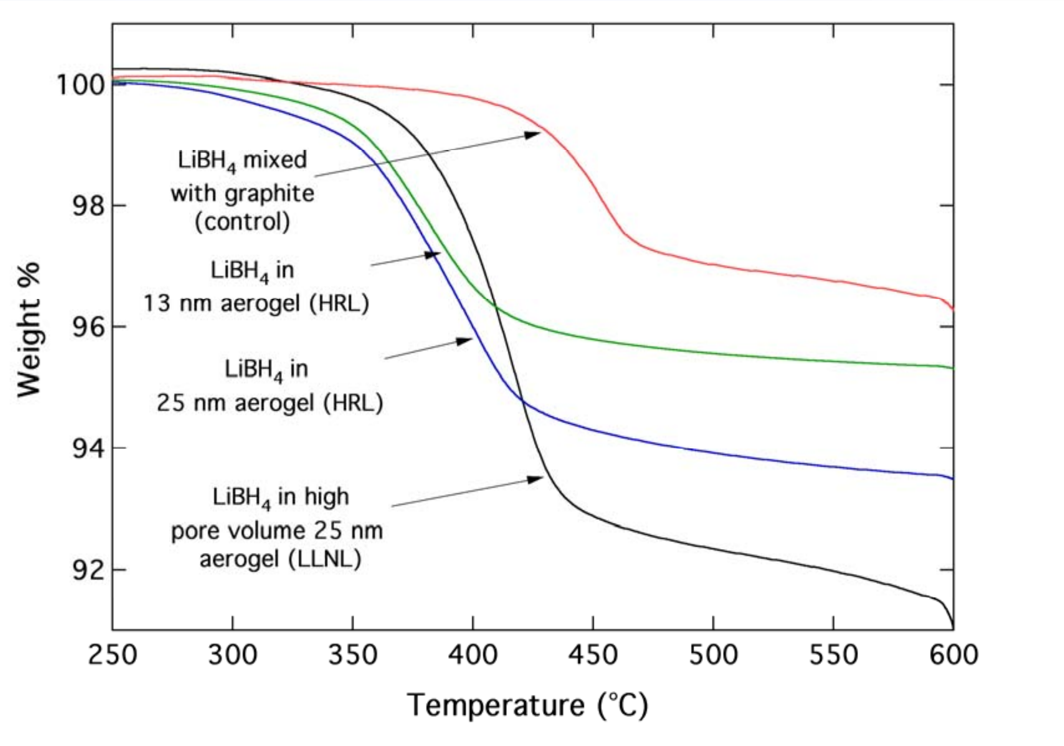


Challenges

- *Maintain high mass and volume capacities*
- *Obtain high loading into framework*
- *Maintain structural integrity of framework*

Accomplishments

- Demonstrated ability to load $LiBH_4/MgH_2$ and Mg (Ni/Cu) into carbon aerogels
- Demonstrated improved kinetics, capacity and cycleability when loaded into aerogels
- Found need for H_2 "pathways" through aerogels
- Initiated work on using oxide xerogels/ aerogels for confinement/catalysis investigations
- Participants include: HRL, LLNL, UTRC and SNL

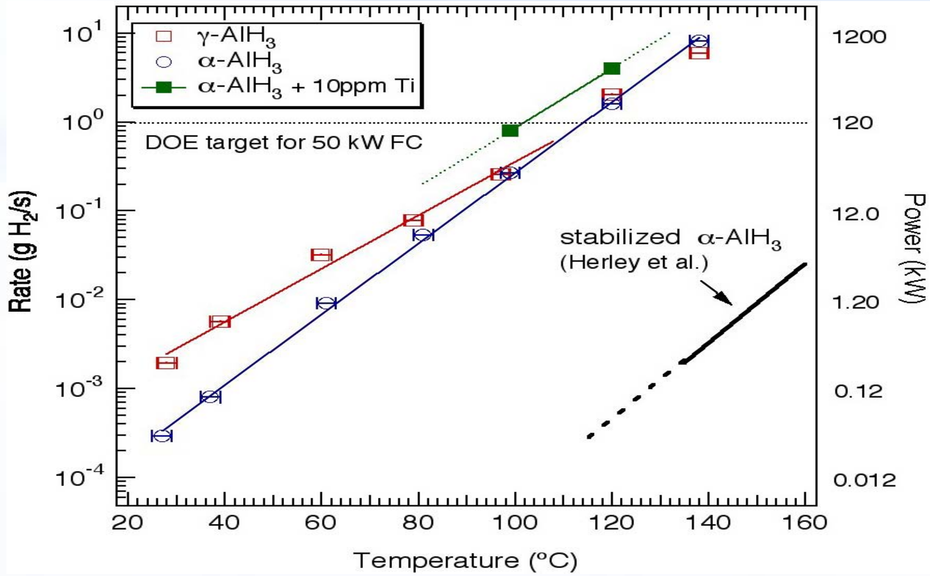


Storage: Alane (AlH_3)

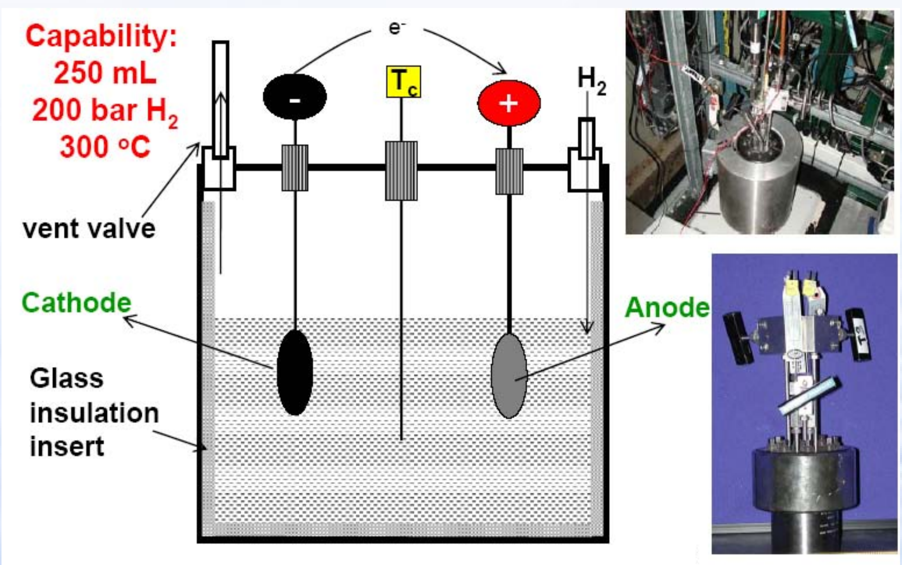
Challenges

- *Develop low-cost energy efficient method to regenerate alane from aluminum and hydrogen*
- *Improve kinetics while not sacrificing stability (dormancy)*
- *Develop methods for moving alane and reaction products on and off-board*

Improved Desorption Kinetics



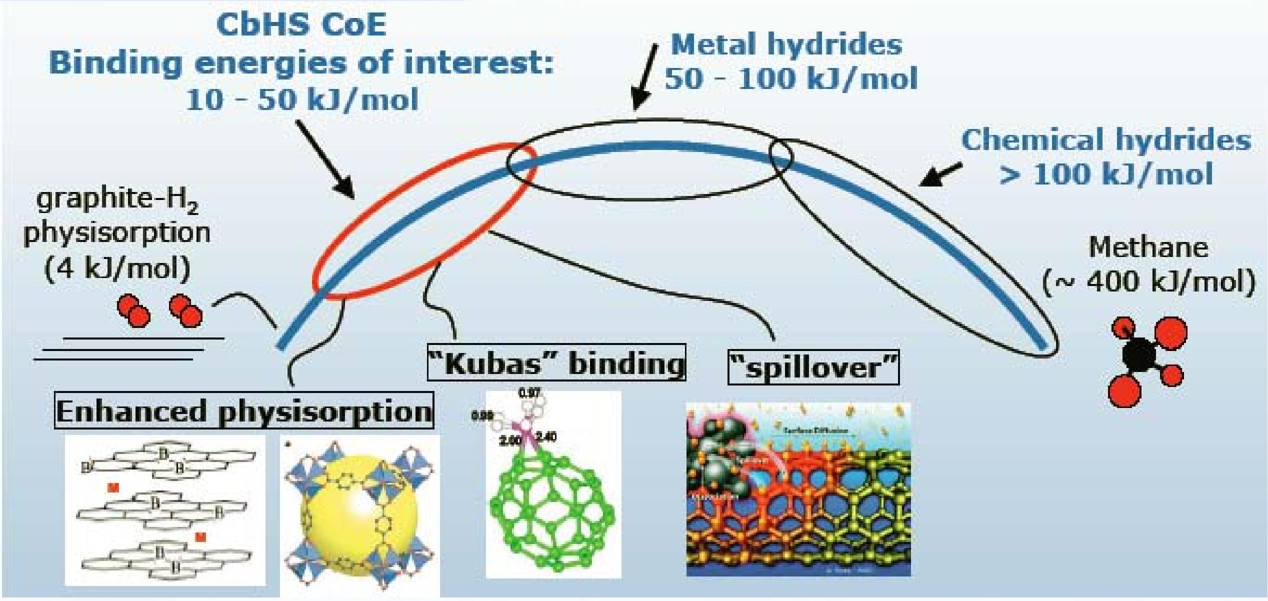
High P Electrochemical Cell to Control Thermodynamic Parameters



Accomplishments

- Demonstrated ability to form AlH_3 through adduct formation with TEDA, TEA, etc.
- Demonstrated evidence of Al-H bond formation through electrochemical methods and with use of supercritical fluids
- Demonstrated effect of Ti-doping on desorption kinetics
- Determined structures for β and γ polymorphs
- Participants include: BNL, SRNL, U. Hawaii and U. New Brunswick

Storage: Adsorbent Materials

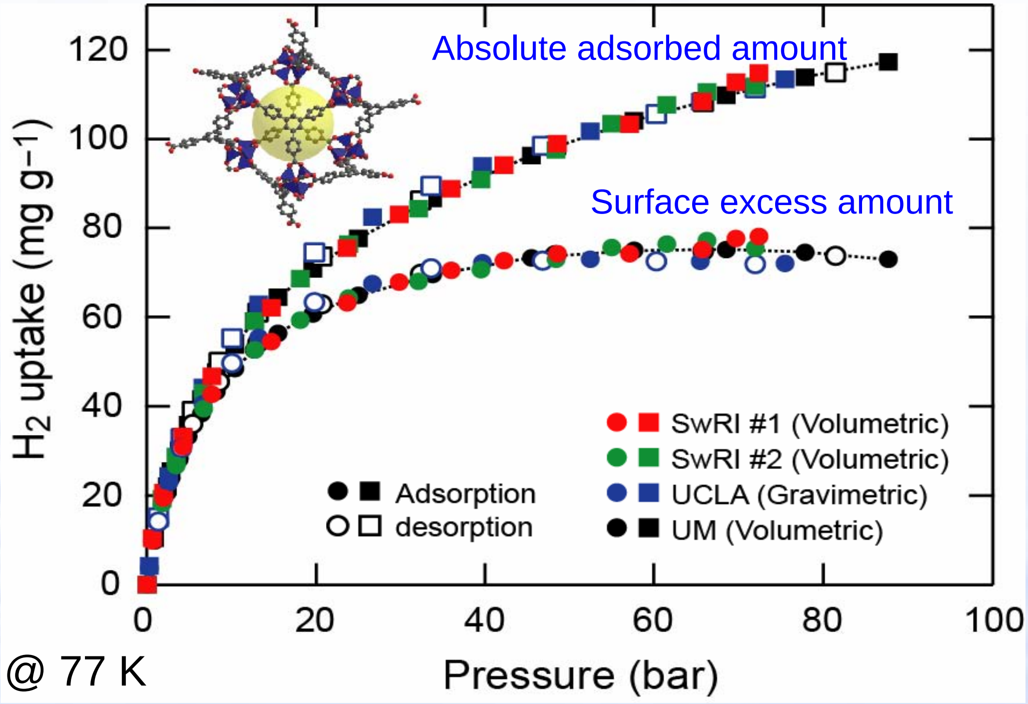


Challenges

- ***Increase binding energy for room temperature storage***
- ***Improve volumetric storage capacities***

Accomplishments

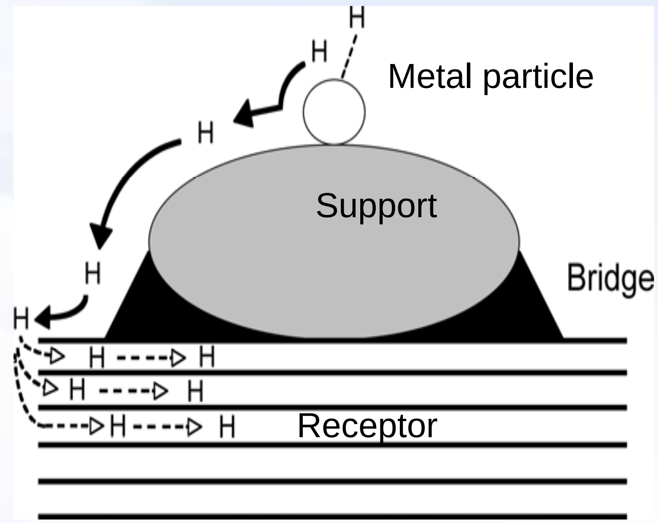
- Demonstrated 7 wt% excess hydrogen storage at 77K in MOF-177
- Created carbide-derived nanoporous carbon structures with narrow, "tunable" pore diameters and high pore volumes
- Elucidation of preferred hydrogen binding sites in various adsorbants
- Participants include: NREL, U. Michigan, U. Penn, Rice, UCLA, UC Berkeley, Miami U., NIST, ORNL



Storage: Spillover onto Adsorbents

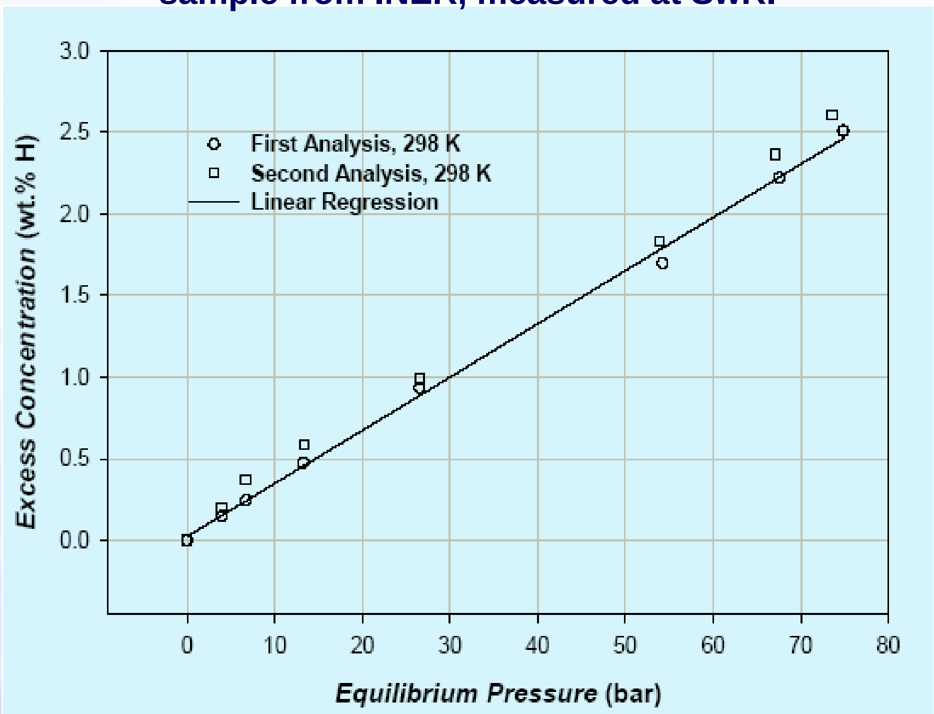
Challenges

- ***Increase room temperature capacity***
- ***Improve sorption kinetics***
- ***Improve reproducibility***
- ***Develop more thorough understanding of mechanism***



R. Yang, U. MI

Excess capacity at RT for IRMOF-8 with bridged catalyst: sample from INER, measured at SwRI

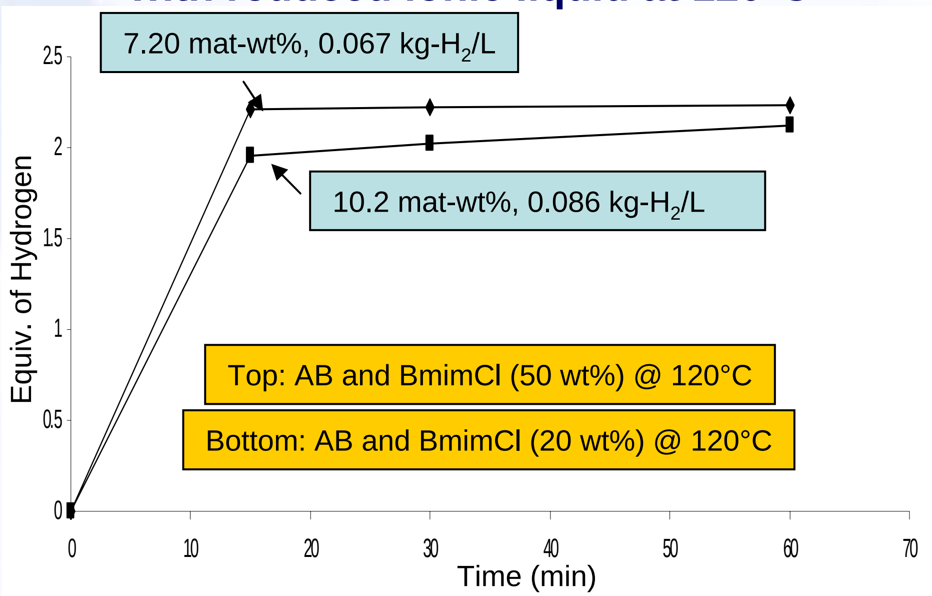


Accomplishments

- Developed carbonaceous bridge between metal catalyst and receptor material
- Demonstrated ~1 wt% on Pt/AX-21 and ~2.5 wt% excess on Pt/IRMOF-8 at room temperature and 70 MPa
- Results independently verified at Southwest Research Institute and on sample prepared by INER
- Participants include: U. Michigan, SwRI, INER, NREL

Storage: Ammonia borane (AB)

High H_2 release and no induction time with reduced ionic liquid at 120°C

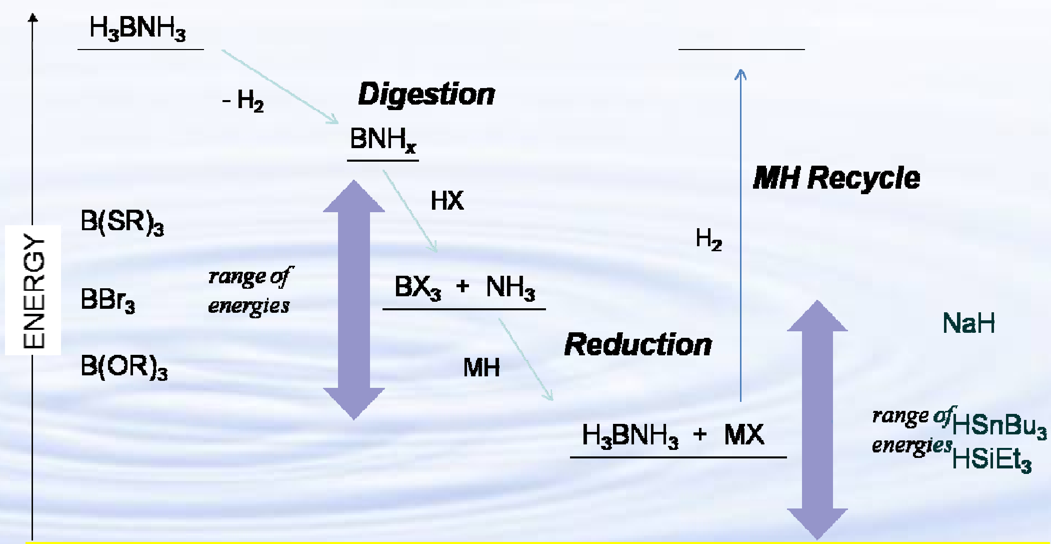


Accomplishments

- Significant reduction of induction time in ionic liquids
- Increased release kinetics and reduced foaming using proton sponge
- New AB derivatives formed by reactions with MH or MX
- Demonstrated effects of scaffolds in improving kinetics and lowering reaction enthalpies
- Demonstrated a regeneration process
  - Used theory to guide reducing agent selection
  - Rationally designed digestion agent based upon successful reduction strategies
- Participants include: LANL, PNNL, U. Penn, U. Alabama, UC Davis

Challenges

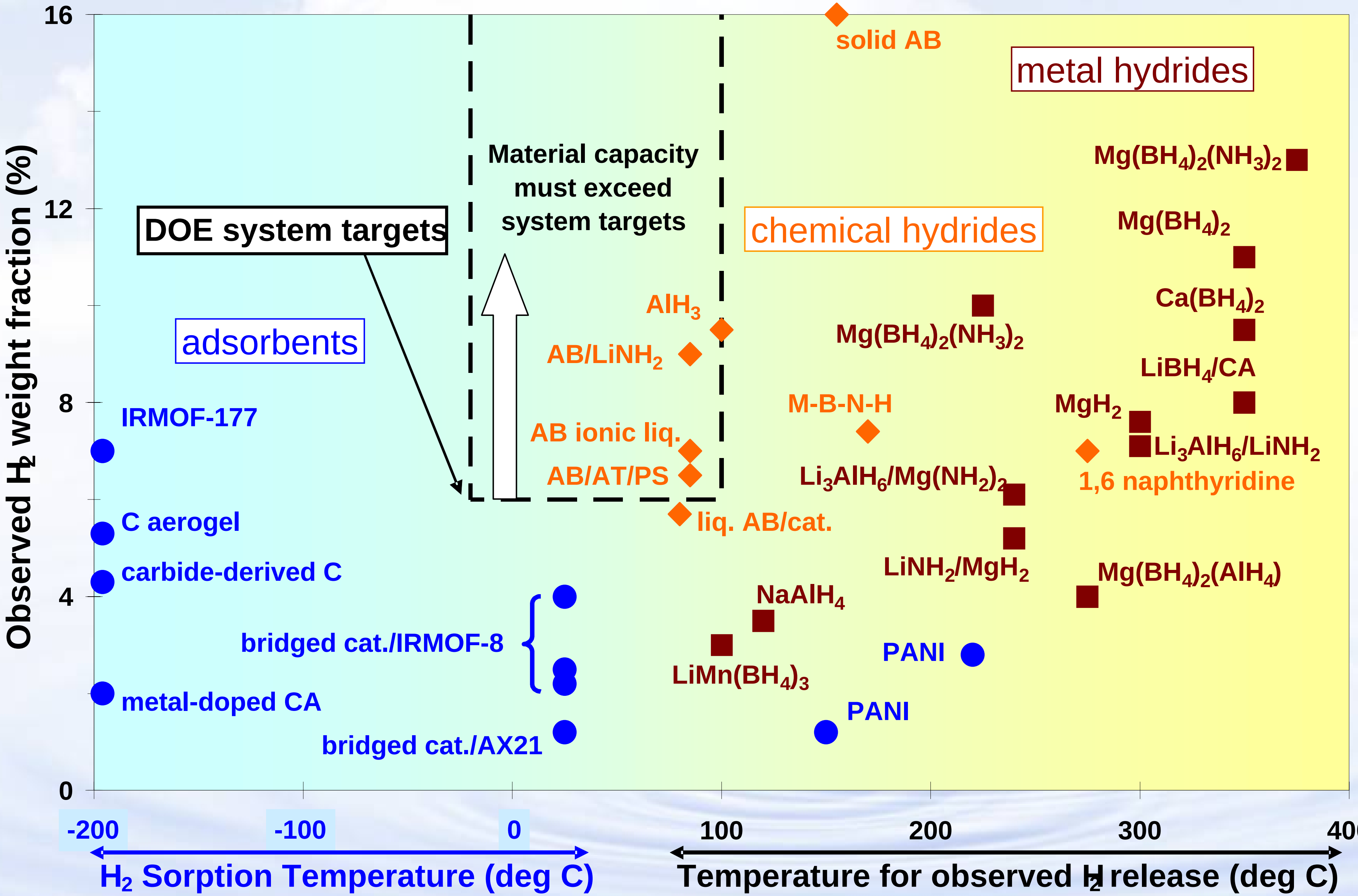
- ***Develop energy efficient, low-cost regeneration method***
- ***Develop one-pot, high-yield regeneration chemistry***
- ***Develop catalysts/additives for maximum H_2 release and release rate***
- ***Develop AB material that remains in the same phase throughout fuel cycle***
- ***Material handling for moving on/off-board***



Minimize energy of MH and BX_3 formations to make overall process more energy efficient

Storage: Current Status

- Material Capacity vs. Temperature



G. Thomas, et al, U.S. Department of Energy (2007)

Defense Logistics Agency Projects for H_2 Storage

- **High-Throughput Methodology for Discovery of Metal-Organic Frameworks with a High Hydrogen Binding Enthalpy**
  - UC Berkeley with Symyx Technologies; PI: J. Long
- **High-Throughput Combinatorial Screening of Biomimetic Metal-Organic Materials for Military Hydrogen-Storage Applications**
  - Miami University with NREL; PI: H. Zhou
- **Demonstration of Higher Gravimetric Density Low-Temperature Metal Hydride Alloys in a High Volumetric Density Storage System**
  - Ovonic Hydrogen Systems; PI: B. Chao
- **Advanced Nanoporous Carbon for Reversible Hydrogen Storage — Proof of Concept Study**
  - Univ. of Missouri; PI: P. Pfeifer
- **Design, Fabricate, Test and Verify a High Throughput Screening System Using H_2 Sensing Polymers**
  - Florida Solar Energy Center (Univ. Central Florida); PI: A. Raissi

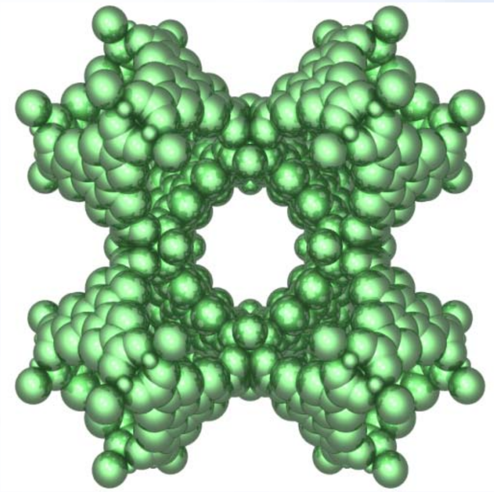
DOD/DLA Points of contact:

- **COR Points of Contact: Kenneth Burt, NSWC Crane**
- **Program Manager: Leo Plonsky, DLA**
- **Tech. Points of Contact: Ashraf Imam, NRL**
- **PCO Points of Contact: James D. Martin, NSWC Crane**

DOD/DLA: High-Throughput Screening

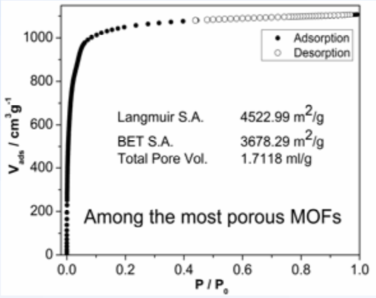
Challenges

- *Develop rapid screening methods and techniques for MOF fabrication*
- *Develop MOF materials with increased hydrogen binding energy (>15 kJ/mol)*
- *Develop MOF materials with high storage density*
- *Develop optical screening techniques*

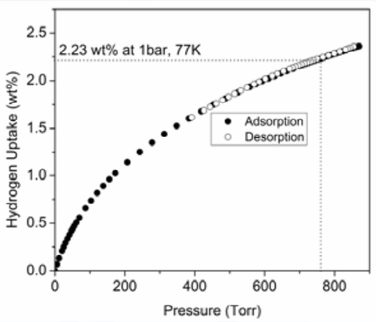


PCN-50

N_2

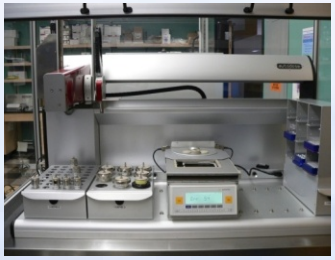


H_2



Accomplishments

- Initiated high-throughput MOF fabrication line, further analysis techniques (thermal stability, high surface area and exposed metals) are under development (Berkeley)
- Investigated MOF fabrication with tritopic and hexatopic ligands; with Mn, Co and Cu; 75, 85 & 120°C under acidic, basic and neutral conditions. HP sorption measurements underway (Miami)
- Participants include: UC Berkeley, Symyx Technologies, Miami University and NREL

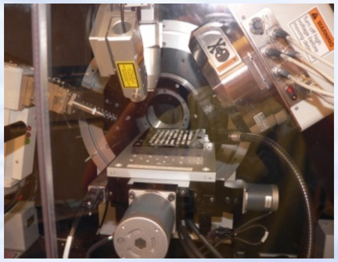


Powder Dosing

Liquid Dispense

Reaction

Photography

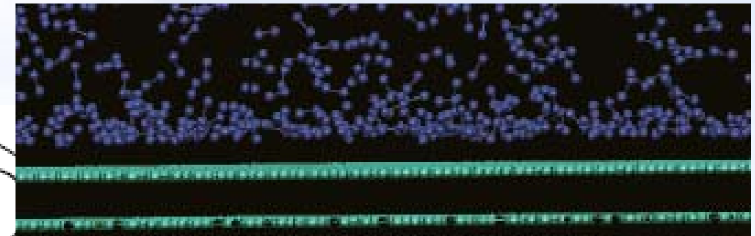


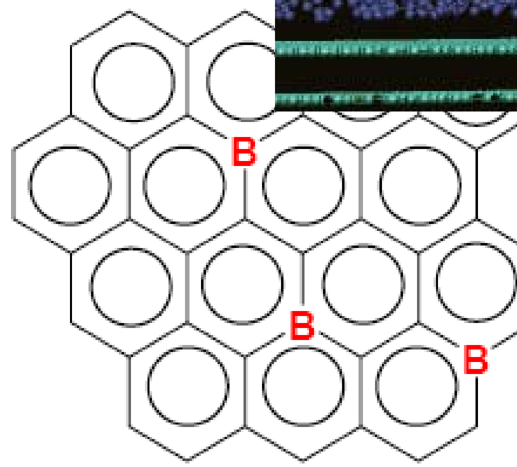
X-ray diffraction

DOD/DLA: Advanced Nanoporous Carbon

Challenges

- ***Fabrication of B-doped monolithic nanoporous carbon derived from corncob***
- **Optimize pore architecture and composition**
- **Construct and demonstrate a prototype tank**





Accomplishments

- Demonstrated natural gas adsorption in nanoporous carbon materials derived from corncob (S-33/k) meeting DOE volumetric target
- Achieved hydrogen storage capacity of ~8 wt% (total) at 77 K and ~1.2 wt% at 300 K and 47 bar pressure with S-33/k
- Performed computer simulations of H_2 adsorption on graphitic materials, computations for B-doped carbons underway
- Participants include: U. Missouri and Midwest Research Institute

Available Information Resources

For more information visit: www.hydrogen.energy.gov

Hydrogen Posture Plan

For more information on the Hydrogen Program

www.hydrogen.energy.gov/roadmaps_vision.html

Learning Demonstration Interim Progress Report

For more information on the vehicle/infrastructure demonstration

www.hydrogen.energy.gov/news_learning_demo.html

Hydrogen Overview Book

For more information on hydrogen and fuel cell technologies

www1.eere.energy.gov/hydrogenandfuelcells/education/h2iq.html

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www.hydrogen.energy.gov

Thank you

2008 Annual Merit Review

Each year hydrogen and fuel cell projects funded by DOE's Hydrogen Program are evaluated during the* Annual Merit Review and Peer Evaluation Meeting*.

June 9 -13, 2008

Crystal Gateway Marriott Hotel

Arlington, Virginia

Hydrogen and fuel cell principal investigators representing the offices of ***Energy Efficiency and Renewable Energy***, ***Fossil Energy***, ***Nuclear Energy***, and ***Science*** will present their project status and results in oral and poster presentations.

www.hydrogen.energy.gov