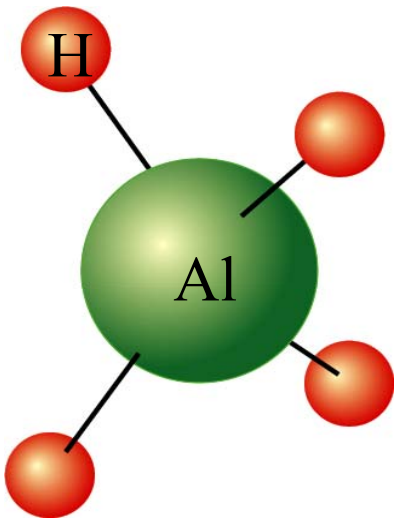
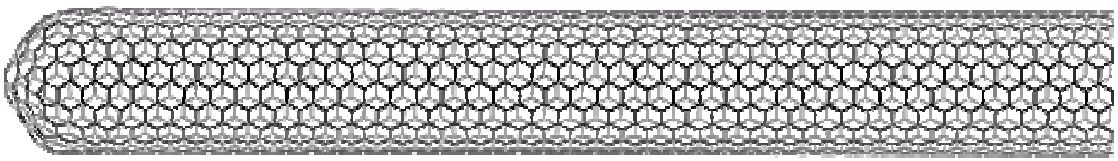
Hydrogen Storage





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Objectives
Hydrogen Storage Systems

Develop and verify:

- On-board hydrogen storage systems achieving:
  - 4.5 wt%, 1.2 kWh/L, and $6/kWh by 2005
  - 6 wt%, 1.5 kWh/L, and $4/kWh by 2010
  - 9 wt%, 2.7 kWh/L, and $2/kWh by 2015

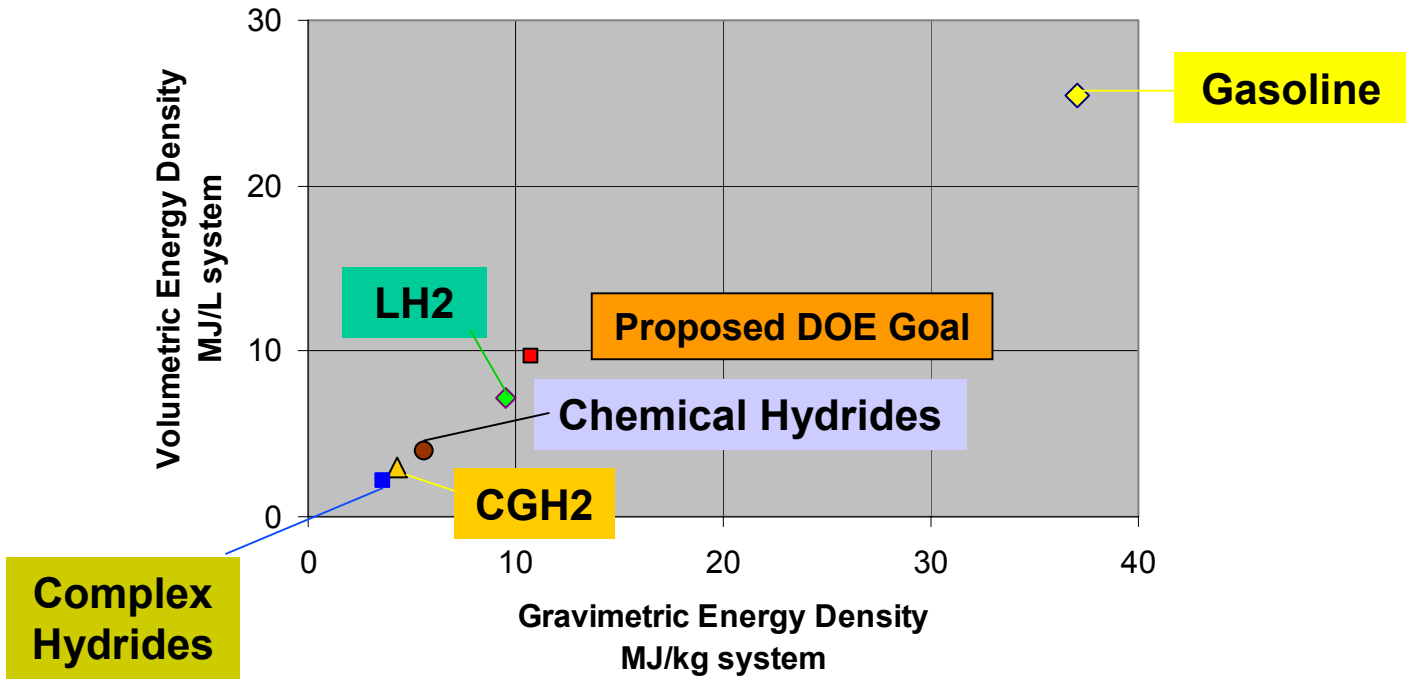
- Low cost, off-board H_2 storage systems for H_2 infrastructure needs by 2015.
- Vehicle interface technologies for fueling on-board H_2 storage systems by 2015.

Targets
On-Board H_2 Storage Systems

Storage Parameter	Units	2005	2010	2015
Specific energy	kWh/kg	1.5	2.0	3.0
Energy density	kWh/L	1.2	1.5	2.7
Storage system cost	$/kWh	6	4	2
Cycle life (1/4 tank to full)	Cycles	500	1,000	1,500
Refueling rate	kg H_2/min	0.5	1.5	2
Loss of usable H_2	(g/hr)/kg H_2 stored	1	.1	0.05

Status vs Targets
On-Board H_2 Storage Systems

No current material or technology meets DOE/FreedomCAR targets.



Barriers

Hydrogen Storage Systems

- Cost
- Weight & volume
- Efficiency
- Durability
- Refueling time
- Codes & standards
- Life-cycle & efficiency analyses

Planning
Hydrogen Storage Systems

Identify R&D Priorities

H_2 Storage Materials Workshop
Compressed/Liquid H_2 Workshop
H_2 Storage "Think Tank" Meeting

Issue "Grand Challenge"
Build Upon Existing Work

Create Virtual Centers
Initiate New Materials R&D
Complete Compressed/Liquid H_2 R&D

Workshop
Hydrogen Storage Materials

Conclusions & Recommendations

Complex Metal Hydrides

- Continue fundamental studies on $NaAlH_4$ as model system
- Identify other hydride materials that have greater storage capacity

Chemical Hydrides

- Identify improved/new process chemistry for regeneration
- Complete full lifecycle analysis of $NaBH_4$

Carbon

- Conduct definitive experiments to show where and how hydrogen is stored in nanotubes
- Better understand the science to engineer carbon for hydrogen storage

Advanced Concepts

- Discuss advanced storage concepts further to refine recommendations and to resolve controversial aspects

Workshop
Compressed/Liquid H_2

Conclusions & Recommendations

Safety

- Understand failure modes

Economics of fibers and resins

- New materials

Smart tanks

- Sensors to detect tank health

Advanced concepts

- High pressure conformable tank structures

Manufacturing processes

- High volume production techniques

Hydrogen Storage "Think Tank" Meeting

Participants:

- Four Nobel Laureates
- Seven award-winning scientists (ACS, APS, and NSF awards; Presidential Young Investigators)

Conclusions/Recommendations

- R&D of Materials:
  - Nano-Materials
  - High Surface Area Materials, including Carbons
  - Synthetic Metals
  - Chemical and Metal Hydrides, Clathrates
- Issue a "Grand Challenge"
  - Educate the scientific community
  - Establish integrated teams (virtual centers)
  - Explore novel concepts through single investigator projects

Next Steps

National H_2 Storage R&D Project

Start Centers/ New Projects — January 2004

Selections — October 2003

Solicitation Release — June 2003

Pre-Solicitation Conference — June 2003

U.S. Department of Energy
Energy Efficiency and Renewable Energy

Projects
Hydrogen Storage Systems

Complex Metal Hydrides (UTRC, SNLL, U.Hawaii, FSEC)

- *$NaAlH_4$ System Integration*
- *Hydride Materials R&D*
- *Kinetics/Mechanistic Studies*

Chemical Hydrides (2004)

- *Aminoborane (FSEC)*
- *$NaBH_4$ Process Chemistry (TBD)*
- *Life-Cycle Analyses*
- *Other Hydrides*

Standard Test Protocols & Facilities (SwRI)

Advanced Concepts (2004)

- *TBD*

Compressed/Liquid Tanks (Quantum, JHU, LLNL, INEEL, Ergenics)

- *5,000/10,000 psi Tanks*
- *Semi-Conformal System*
- *Tank Liners/Overwrap Materials*
- *Insulated Pressure Vessels*
- *Unusual Shapes*

Carbon (NREL, CalTech, SRTC)

- *Kinetics/Mechanistic Studies*
- *Process R&D*
- *Structure/Property Analyses*