Hydrogen Economy: Storage and Infrastructure

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Infrastructure Possibilities

- Centralized
  - Huge changes
  - “Astronomical” costs
- Distributed
  - Expensive for individuals
  - Safety is larger issue
- Transportation
  - Storage is largest problem

Safety

- Odorless, tasteless, colorless
- Very small size means more diffusion
- Less likely to build up
- Pressurized storage containers
- Ignition energy 10 times smaller than gas
- Invisible flame, low heat

http://www.hydrogen.energy.gov/pdfs/doe_h2_safety.pdf

Centralized - requirements

- Relatively few, large plants producing hydrogen
- Transportation to point of use
  - Refrigerated trucks
  - Pipelines
    - Convert natural gas lines?
- Large reservoirs underground?
- Inefficiency a major concern

http://www1.eere.energy.gov/hydrogenandfuelcells

Centralized - costs

- Pipelines look most feasible at this point
- 700 miles of H2 pipeline nationally (1000 psi)
- 1 million miles of natural gas pipeline
- Underground storage is cheapest long-term method
- Truck delivery is better for small amounts, long distances

Distributed - requirements

- Processor/source of H2, fuel cell, storage
- Source could be reformed natural gas
- Most homes need < 5 kW capacity
- Average fuel cell is refrigerator-sized
- Co-generation provides heat
- Safety is larger issue

http://www.treehugger.com/files/2009/01/residential-hydrogen-fuel-cell-japan-nippon-oil.php

Distributed - costs

- Residential fuel cells are expensive
- $50,000 + installation
- Estimated savings of 40% annual electricity costs (avg. $880/yr)
- $700 per kilowatt to compete with current grid
- In US, tax credit covers 30% of cost

Transportation - requirements

- Storage is biggest hurdle

- Minimum 300 mile range before refueling (about 8 kg H2)
- Quick refueling/release of H2
- Small volume
- Low weight (6% of storage system as H2)

- Need filling stations
- Safety – no H2 stations near gas

Transportation - costs

- Estimated costs of transition range from $500 billion to $4 billion

- For consumer, 1 car is $120,00-150,000
- Avg. cost of new car in 2006 was $28,000

- Easier to support bus fleets

- Currently 25 filling stations in CA
- Would need 500 -1000

http://www.hydrogencarsnow.com/blog2/index.php/infrastructure/cost-of-hydrogen-fueling-infrastructure/

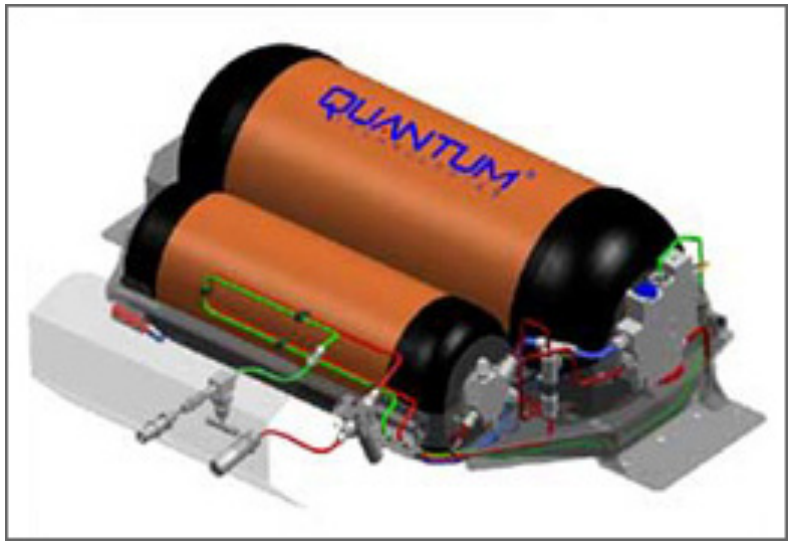
Storage Types

- Compressed Gas
  - Relatively simple technology
  - Large volume
- Liquid
  - Smaller volume
  - Takes more energy to produce
- Metal Hydrides
  - Low volume, safer
  - Heavy

Satyapal, Sunita, John Petrovic, and George Thomas. "GASSING UP with HYDROGEN." *Scientific American* 296.4 (2007): 80-87. *Academic Search Premier*. EBSCO. Web. 22 Mar. 2011.

Compressed Gas

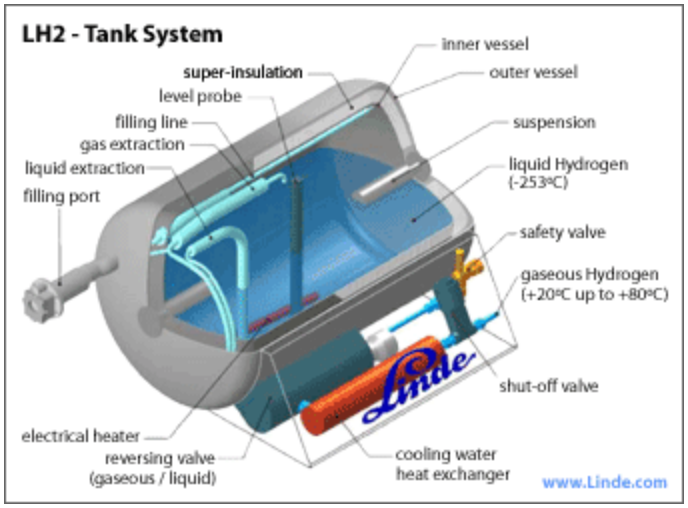
- Carbon-fiber tanks
- Cylindrical for structural reasons
- Safely store H2 up to 10,000 psi (4.5% H2)
  - 15% energy/volume of gas
- Cost is 10X higher than competitive
- Safety is more of a concern



http://www1.eere.energy.gov/hydrogenandfuelcells/

Liquid Fuel

- H2 becomes liquid at 20 K
- 30% energy/volume of gas
- Tanks must be more sophisticated
- H2 will boil off
- Hybrid tanks can handle higher temperatures



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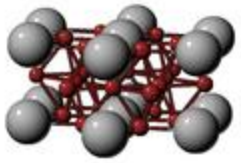
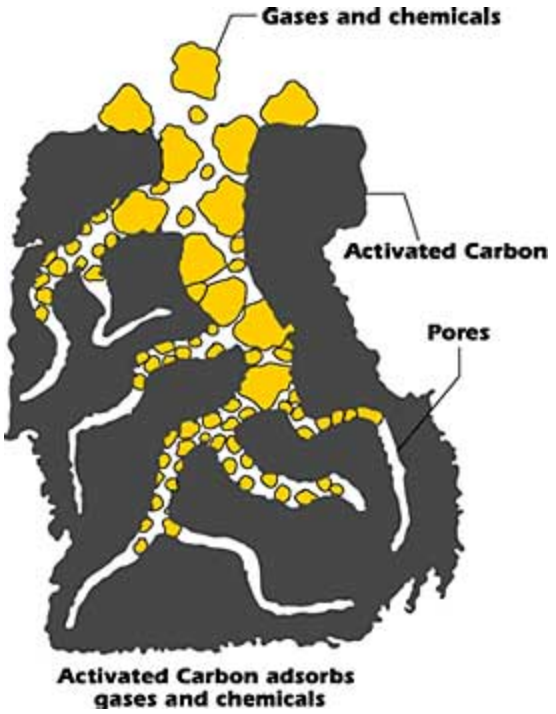
Chemical Storage Types

- Adsorption
- Chemisorption
- Reversible
- Irreversible



http://cst-www.nrl.navy.mil



http://innofresh.wordpress.com

http://www.springerlink.com.ezproxy.libraries.claremont.edu/content/k1702536m45t5136/fulltext.pdf

Adsorption

- H2 sticks to surface of material
- Key parameters are surface area and pore size
- Best options for now are carbon nanomaterials
- Activated carbon can store 5% H2 by weight
- Need to be kept cold (liquid N2 temp.) [6]
- Metal-organic structures are promising [6]

Chemisorption

- H atoms diffuse into material
- Heat of reaction a serious consideration
- Rare earth metal + nickel (LaNi5)
  - ~1.5% H2 by weight
  - expensive
- Ti, Zr, Ha + transition metal (AB2)
- Complex hydrides (NaAlH4)
  - ~7% H2 by weight

Irreversible Reactions

- Must reprocess storage material
- Simple hydrides (Na, Li, Ca, Mg)
- 7-15% H2 by weight