Geologic Storage of Hydrogen

Anna S. Lord

Geologist
Geotechnology & Engineering Department

&

Peter H. Kobos

Principal Staff Economist, Ph.D.
Earth Systems Department

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND2014-3954P

Sandia National Laboratories

Geologic Storage

Why underground storage?

Stored energy can be used to:

(1) meet seasonal energy demands and

(2) ensure continuity in supply during accidents or natural disasters

(3) look for economies of scale in storing large quantities of energy/fuels

Geologic Storage - Types

Types of Underground Storage

Salt Caverns

Salt caverns are solution mined cavities within either salt domes or bedded salts that do not match reservoir volume capacity.

Depleted Oil/Gas Reservoirs

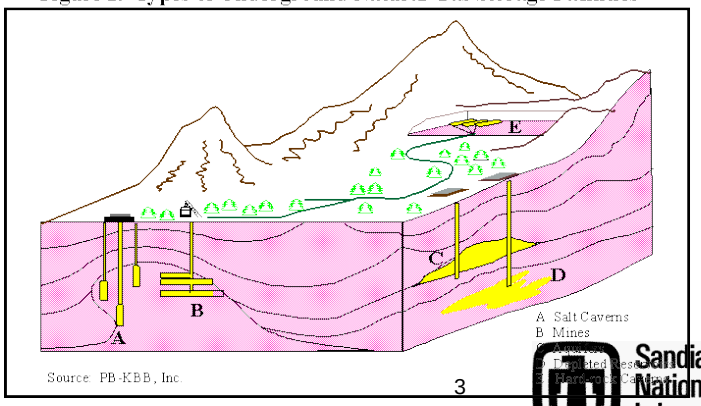
Depleted reservoirs are proven gas reservoirs that are easy to develop and operate due to existing infrastructure.

Aquifers

Aquifers are similar in geology to depleted reservoirs, but have not been proven to trap gas and must be developed.

There are other storage options available currently and in the near future, such as abandoned coal mines, lined hard rock caverns, and refrigerated mined caverns.

Figure 1. Types of Underground Natural Gas Storage Facilities



Sandia National Laboratories

Geologic Storage - Hydrogen

Because hydrogen is a light, small molecule

The molecule characteristics and the hydrogen purity demand may limit storage options. Future analyses may be needed to investigate possible issues with hydrogen storage.

Issues?

- **Mixing of hydrogen with natural gas? –depleted gas/oil reservoirs**
- **Flow, diffusion and fingering of hydrogen into water-bearing units? – depleted gas/oil reservoirs and aquifers?**
- **Hydrogen embrittlement? –all storage options?**
- **Chemical reactions? –depleted gas/oil reservoirs and aquifers?**

Hydrogen Containment Issues

Storage Integrity

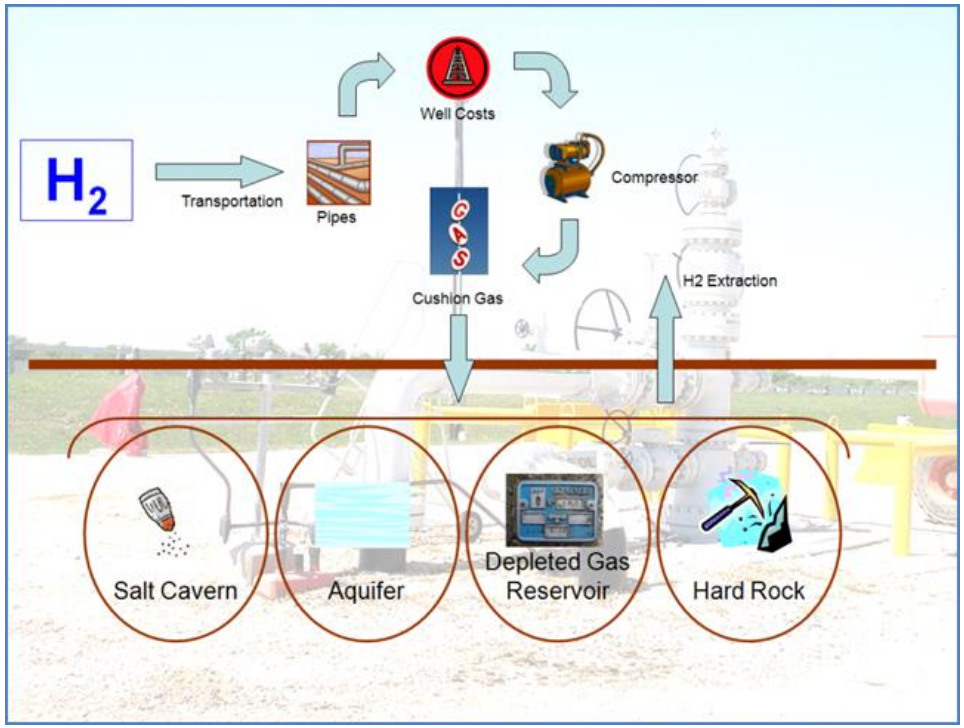
- Fingering of Hydrogen
- Dissolution into surrounding water
- Leaky wells
- Contamination

Hydrogen Mobility

- High mobility (2X that of natural gas)
- Low viscosity (1/2 that of natural gas)
- Leak potential higher than natural gas
- Fingering with surrounding water will be more prevalent

Hydrogen storage in Salt caverns does not pose significant issues.

Economic Model



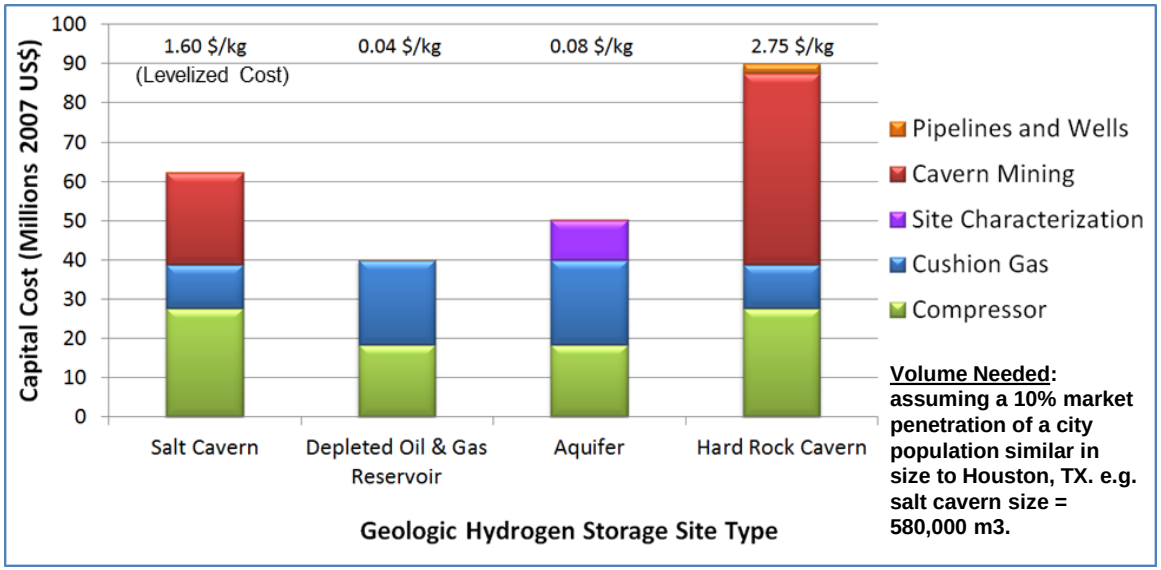
Model designed to provide a cost comparison between 4 types of geologic storage.

Second analysis illustrated storage options:

(1) Focused on city-specific demands considering storage within salt caverns.
(2) Salt caverns are known to successfully contain H_2
(3) More geotechnical certainty

Sandia National Laboratories

Cost Analysis Results
Geologic Storage



Depleted oil & gas reservoirs or aquifers are the most economically attractive option.

economy-of-scale advantage

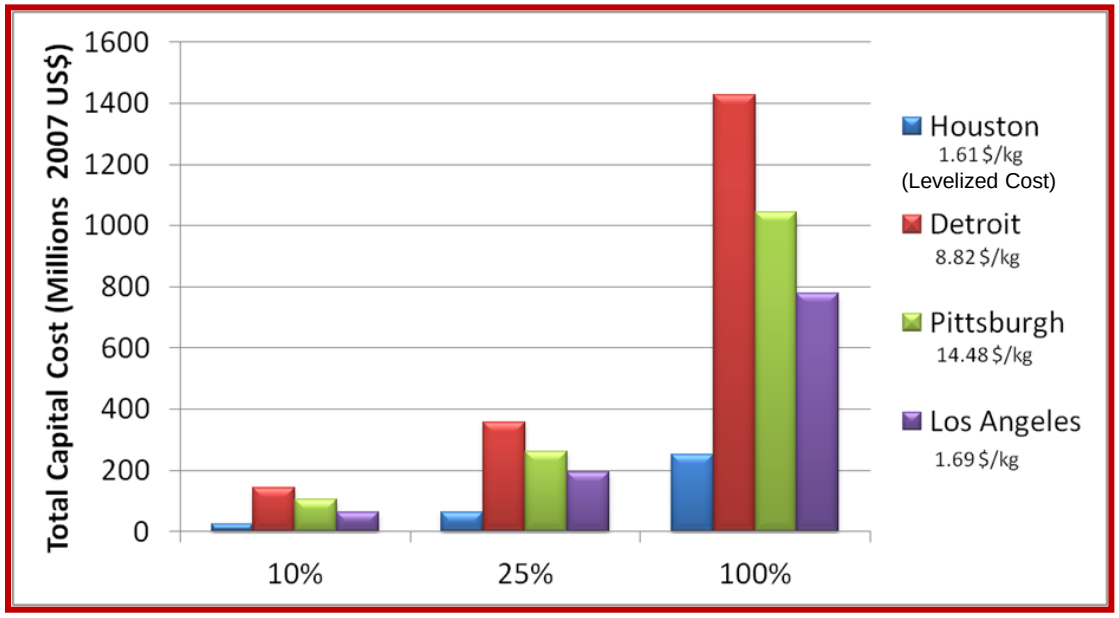
In this analysis in order to illustrate the initial capital cost outlay per geologic type, the costs developed include a single, annual set of costs (capital, O&M and levelized).

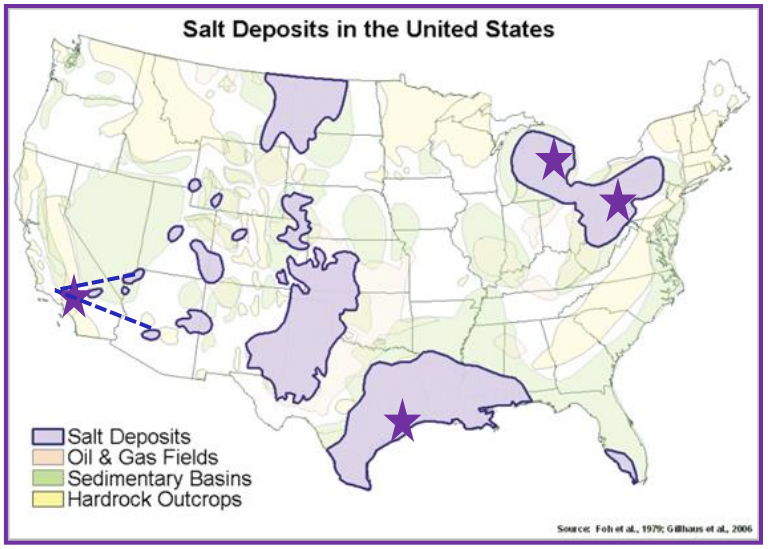
However, modeling cycle frequency would affect overall storage system cost and could make salt storage more economically attractive and hard rock caverns less cost prohibitive. The capability for a site to cycle product multiple times a year will decrease the levelized storage cost.

*See Lord et al. 2011 (SAND2011-6221) for more detail.

Cost Analysis Results
City Summer LDV H_2 Demands

Cities: Houston, Detroit, Pittsburgh, and Los Angeles; Demand: Surge in summer demand, 10% of normal demand for 120 days; Market Penetration Scenarios: 10%, 25%, & 100%; Storage Type: Salt





City	Number of Caverns (corresponding percentage market penetration level)		
	10%	25%	100%
Houston	1	1	4
Detroit	3	7	26
Pittsburgh	2	5	20
Los Angeles	1	3	10

Geologic limitations rather than city demand cause a larger disparity between costs from one city to the next.

Sandia National Laboratories

Future Work
Proposed

- Expand on scope by:
  - developing a full, U.S. wide hydrogen storage resource profile
  - provide representative cost estimates by illustrating regions of the U.S. that may be more favorable for hydrogen storage therefore determine the availability of economically viable storage.
- Continue to refine model, by including
  (1) cycle frequency
  (2) refining compressor costs
  (3) aquifer field costs
  (4) hydrogen grade material costs.
- Consider additional storage options, such as lined caverns within sedimentary rocks.

Thank you.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND2014-3954P

Sandia National Laboratories