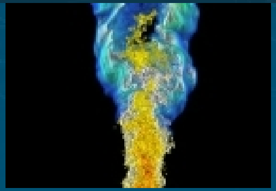
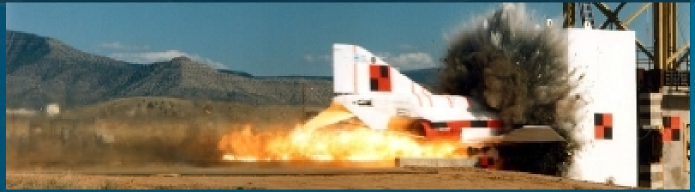
SAND2020-13590PE

Geologic Storage of Hydrogen





Presented by

Anna S. Lord

Acknowledgments

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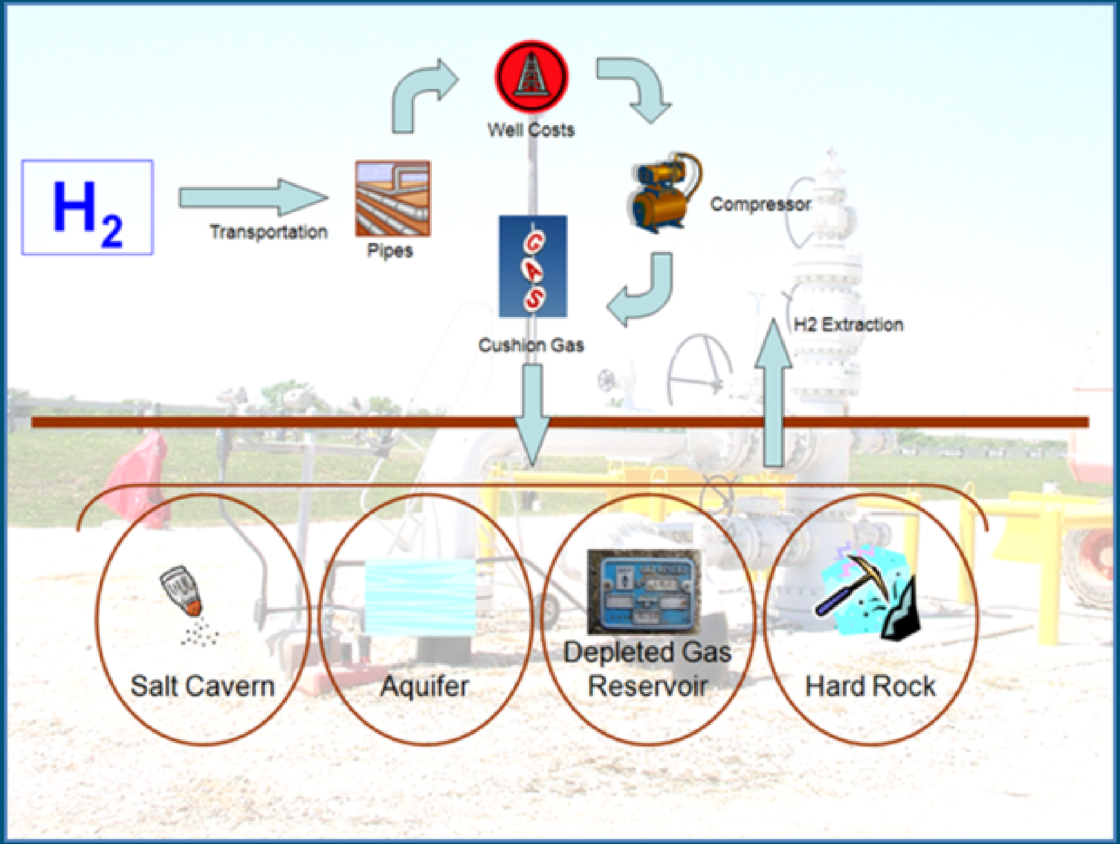
Lord, A.C., Kobos, P.H. and D.J. Borns, 2014, Geologic Storage of Hydrogen: Scaling up to Meet City Transportation Demands, International Journal of Hydrogen Energy, 39, pp. 15570 – 15582



Team Members

Peter Kobos

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Outline

- Why geologic storage
- Types of geologic storage
- H_2 geologic storage challenges
- Economic study – addressing H_2 fuel cell city demands

Geologic Storage

Why underground storage?

Stored energy can be used to:

(1) meet seasonal energy demands

(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

Basic Storage Requirements

High porosity, high permeability, hold adequate volumes of gas, extract gas at high rates, contain and trap gas, and cushion gas

Geologic storage is used for oil, natural gas, compressed air, helium, & hydrogen

Geologic Storage - Types

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

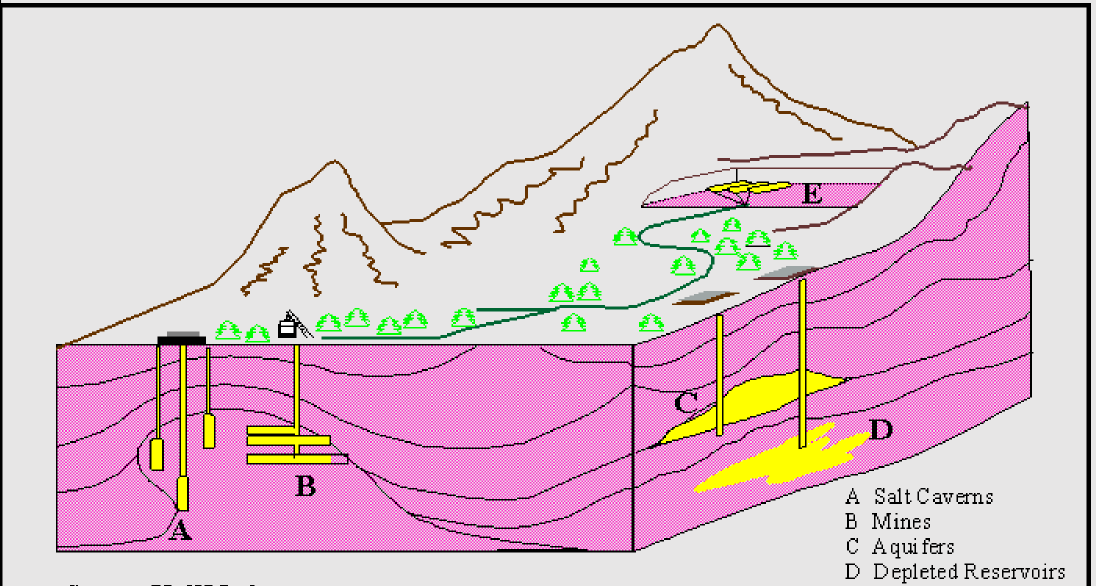
Depleted reservoirs are proven gas reservoirs that are easy to develop and operate due to existing infrastructure.

Aquifers

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

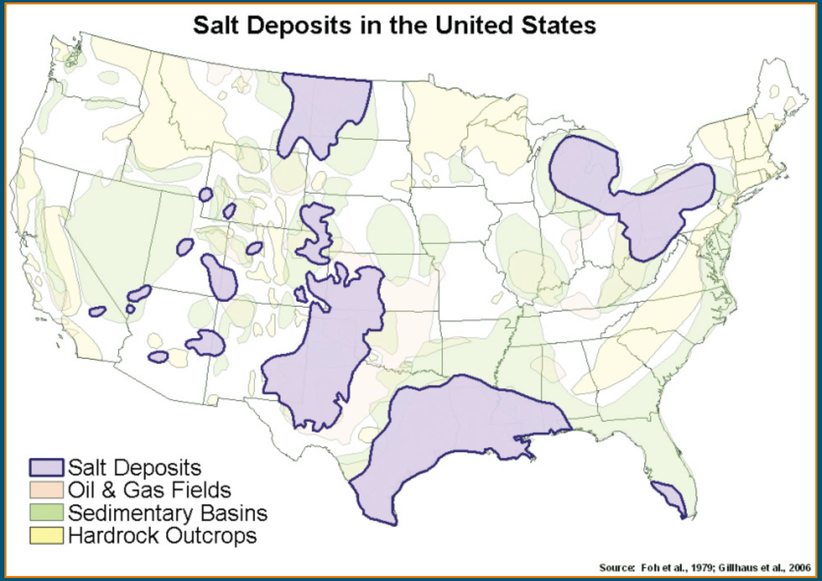
There are other storage options available currently and in the near future, such as abandoned coal mines, lined hard rock caverns, and refrigerated mined caverns.

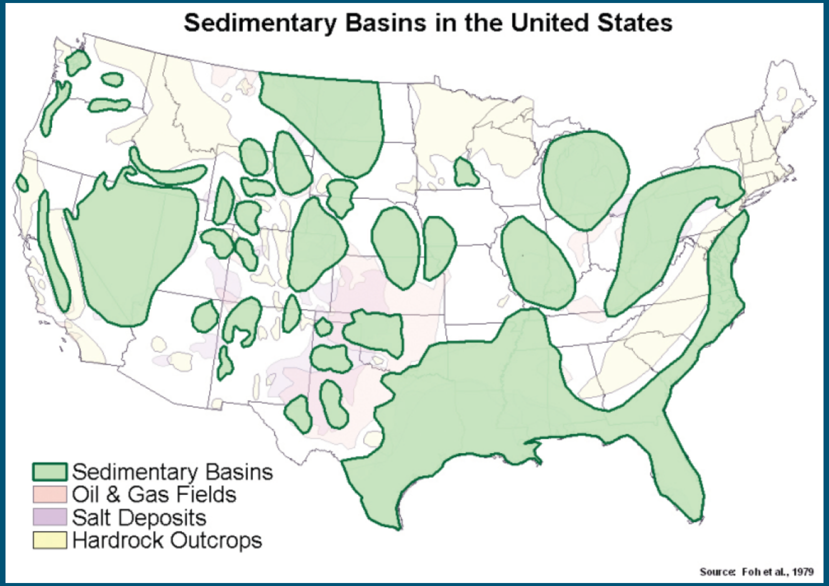
Figure 1. Types of Underground Natural Gas Storage Facilities

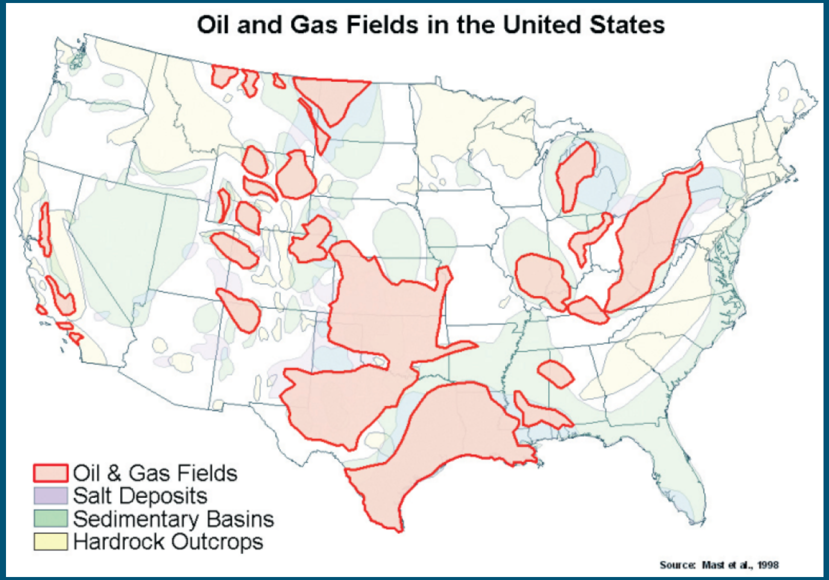


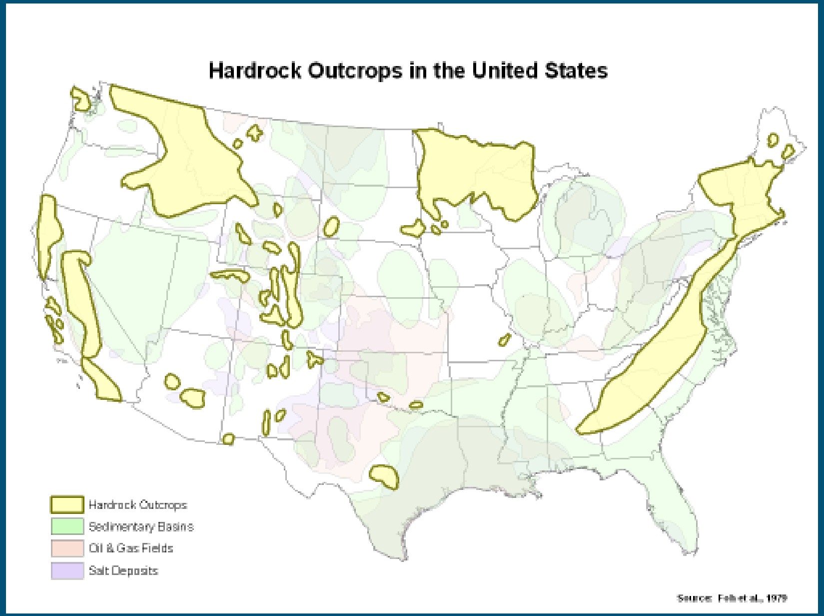
Source: PB-KBB, Inc.

Geologic Storage - Locations









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.

Potential 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?
- Biological reactions? –depleted gas/oil reservoirs and aquifers?

Hydrogen Issues - Containment

Storage Integrity

- Fingering of Hydrogen
- Dissolution into surrounding water
- Leaky wells
- Contamination
- Chemical/mineral reactions

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.

Hydrogen Issues – Purity Requirements

Purity Integrity

- H_2 Mixing – depleted natural gas reservoirs
- Biological reactions/methanogenesis – the loss of H2 to production of methane
- Chemical reactions – loss of H_2 and production of toxic gas

Possible Solutions

- Mixing – several known examples suggest mixing can be controlled by production rate and cushion gas
- Methanogenesis – a study suggests control by pH and salinity
- Chemical reactions - unlikely if pressure and temperature increased

Hydrogen Issues - Materials

Hydrogen Embrittlement

- Wells
- Surface infrastructure
- Hard Rock Cavern liners

Well Sealing Materials

- elastomers, casing cements, etc.

Possible Solutions

- Operation at low pressure and temperatures for existing infrastructure
- Use of alternate materials, such as carbon steel

Hydrogen Issues - Materials

Hard Rock Cavern Liners

Must be gas-tight, chemically resistant to H_2, resist stress and strain caused by elastic and static deformation, and resist strain from rock fractures and cracks. Must resist repeated mechanical deformation and chemical reactions.

(1) Steel

- Carbon Steel
- Stainless steel – more resistant to corrosion

(2) Plastics

- Low-density polyethylene –good deformation capabilities
- PVC -good deformation capabilities
- Polypropylenes –chemically stable

Note: Stress fractures within steel can lead to an increased rate of H_2 reaction with steel and subsequent corrosion.

Hydrogen Issues - Materials

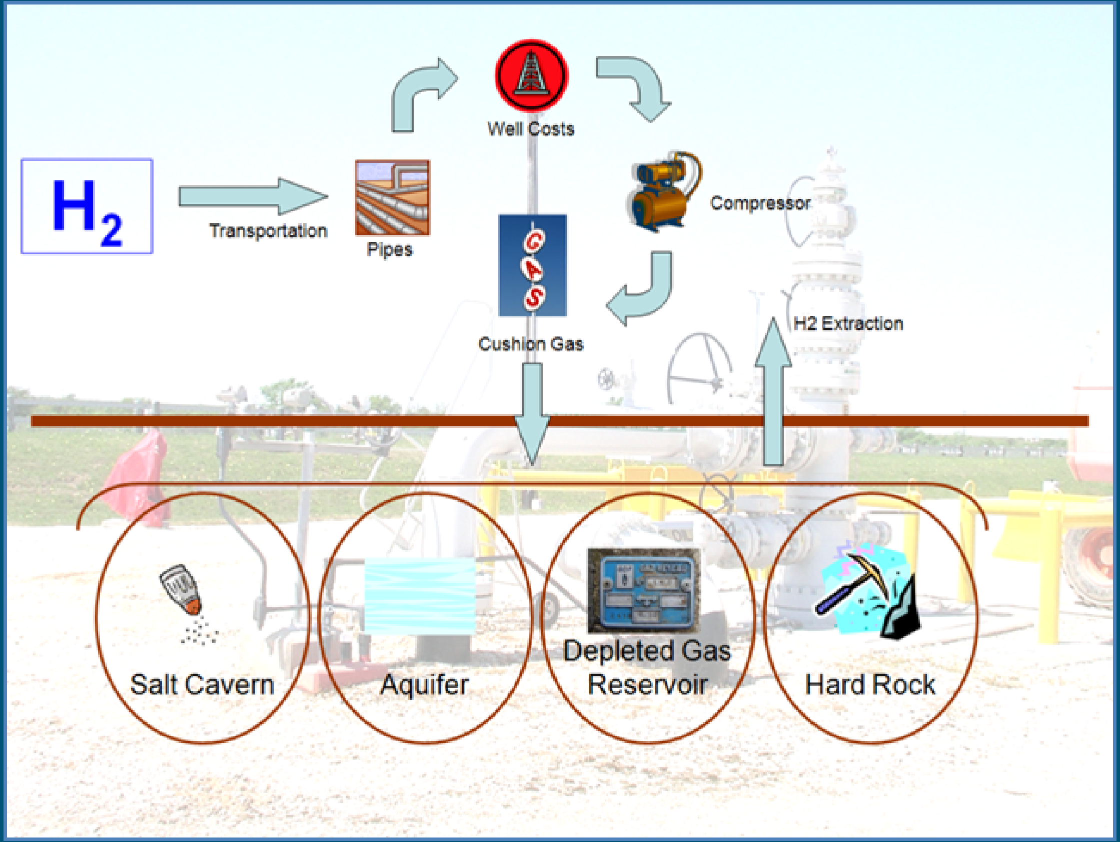
Questions to be Addressed

Q: Can H_2 permeate through these materials?
Q: Does H_2 chemically alter the materials?
Q: What is an acceptable leak volume? Affect the environment?
Q: What is the latest technology available for large scale H_2 containment?

- liners
- coatings/sprays?
- alternate materials?

Q: Is there a cost effective solution?

Economic Model

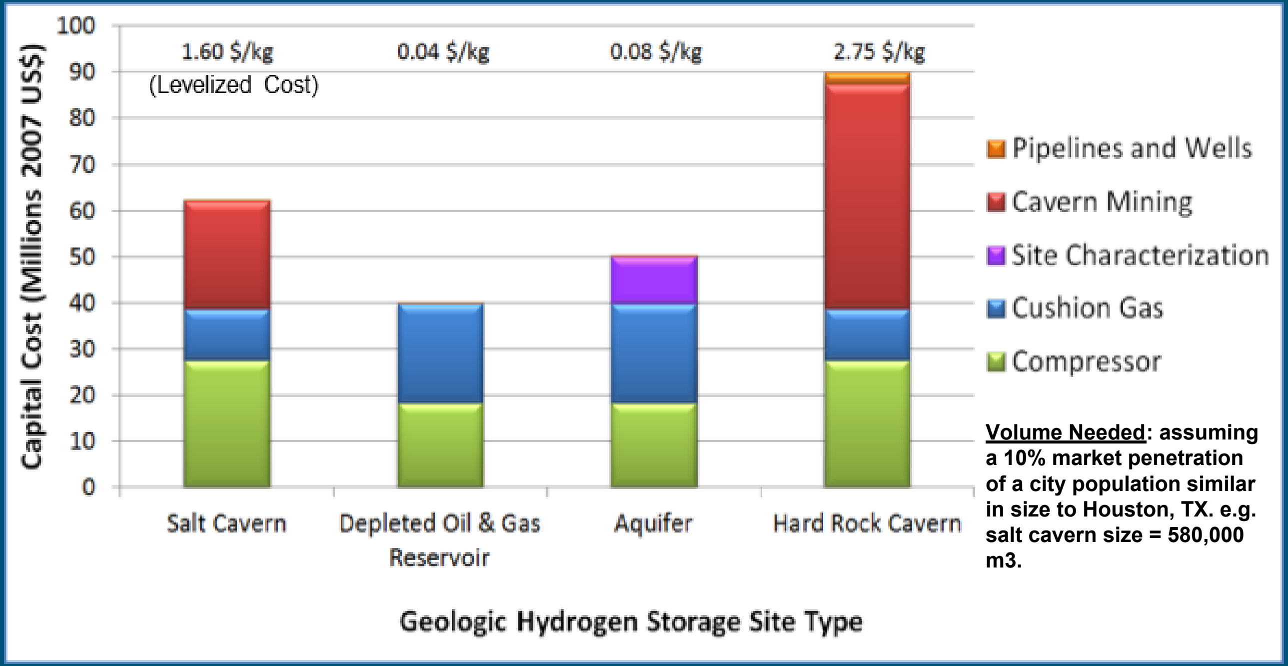


Model designed to provide a cost comparison between 4 types of geologic storage.

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

Economic - Cost Analysis Results



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

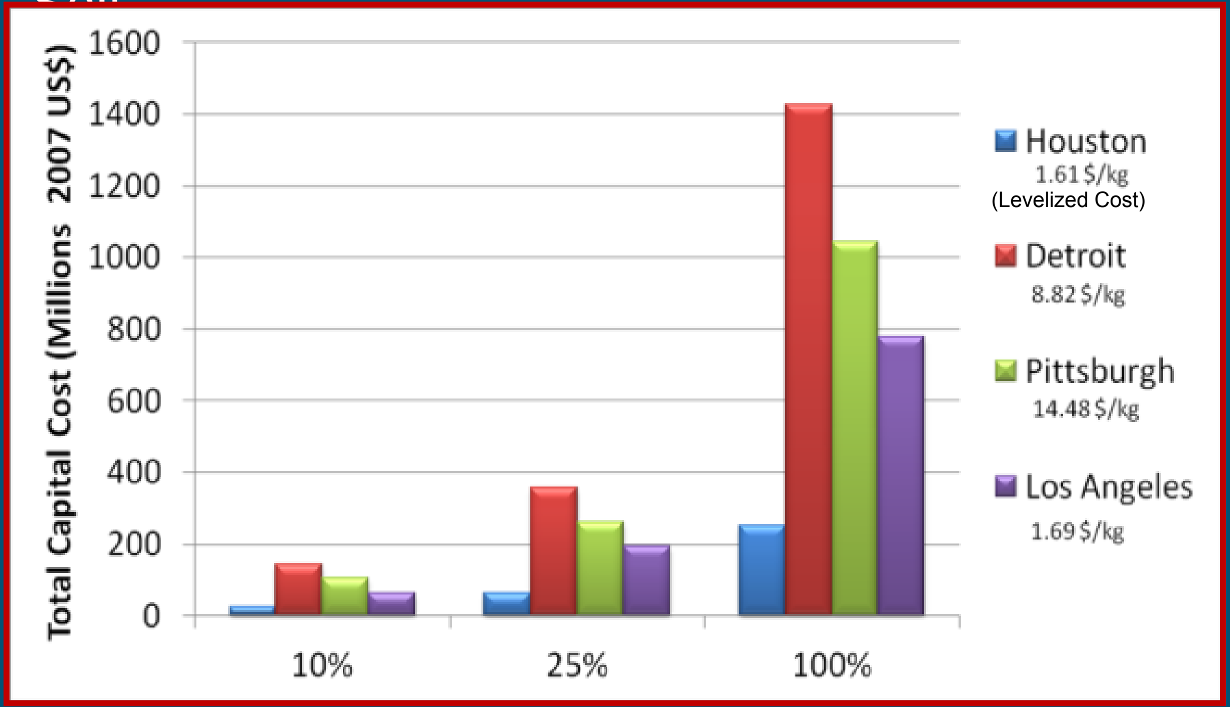
economy-of-scale advantage

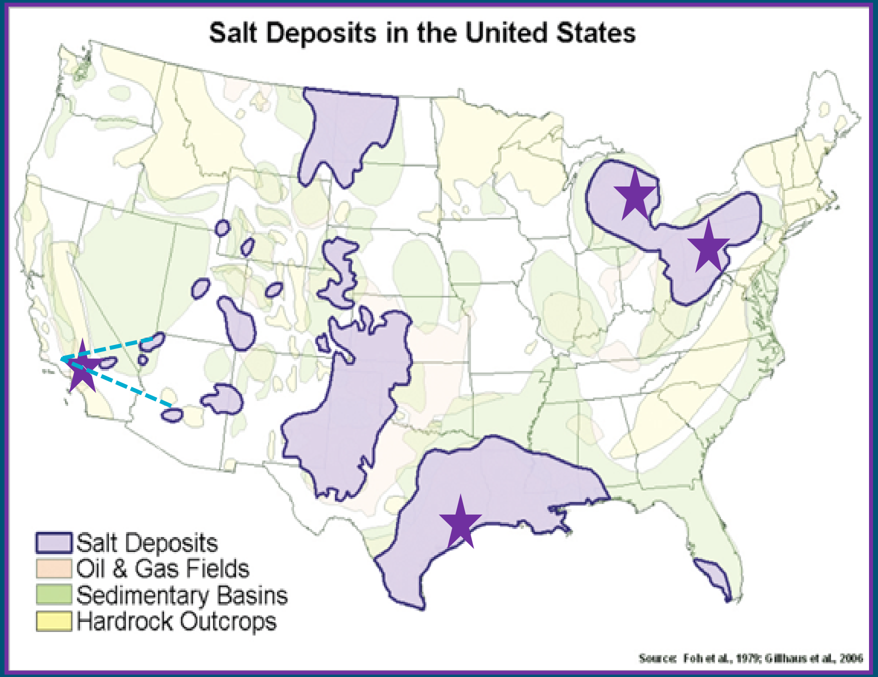
In this analysis in order to illustrate the initial capital cost outlay per geologic type, the costs developed include a single, annual set of costs (capital, O&M and levelized).

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.

Economic - Cost Analysis Results

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





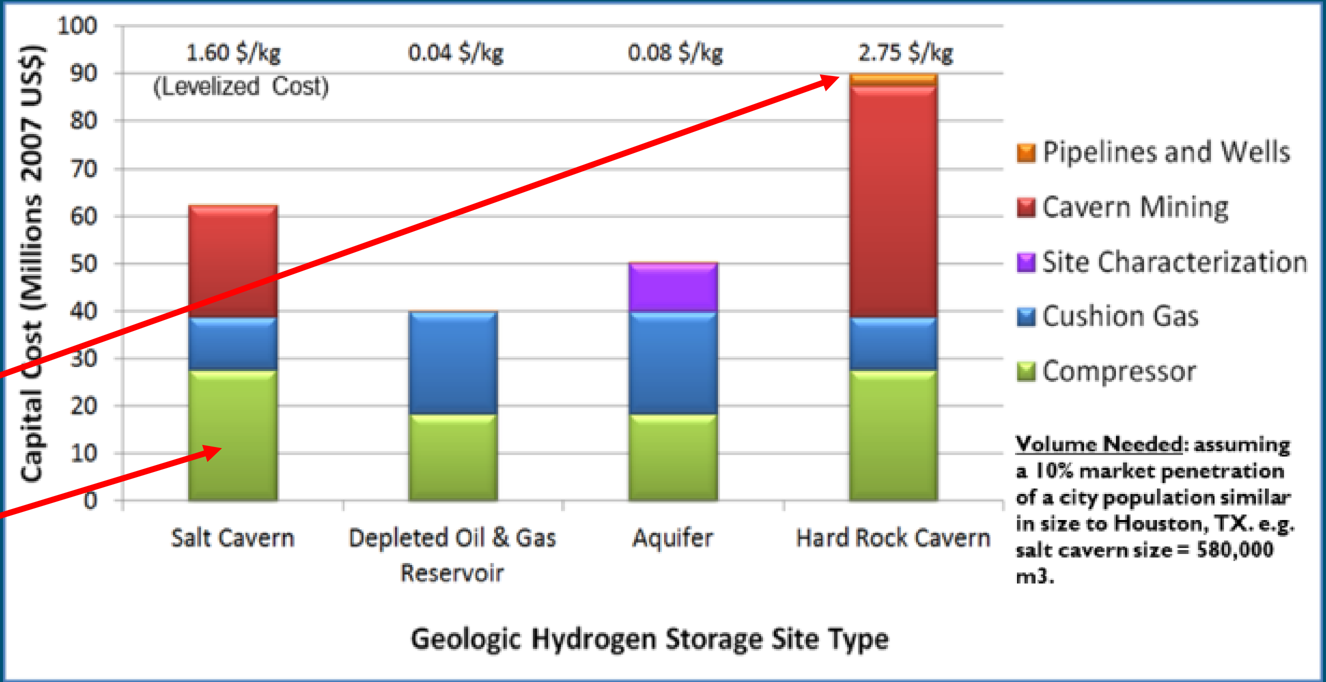
City	Number of Caverns (corresponding percentage market penetration level)		
	10%	25%	100%
Houston	1	1	4
Detroit	3	7	26
Pittsburgh	2	5	20
Los Angeles	1	3	10

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

Economic
Cost Uncertainty

Capital

Pipeline and well assessment (CO_2 literature)
Compressors and other equipment
Steel (prices highly variable)



Levelized

Cycling

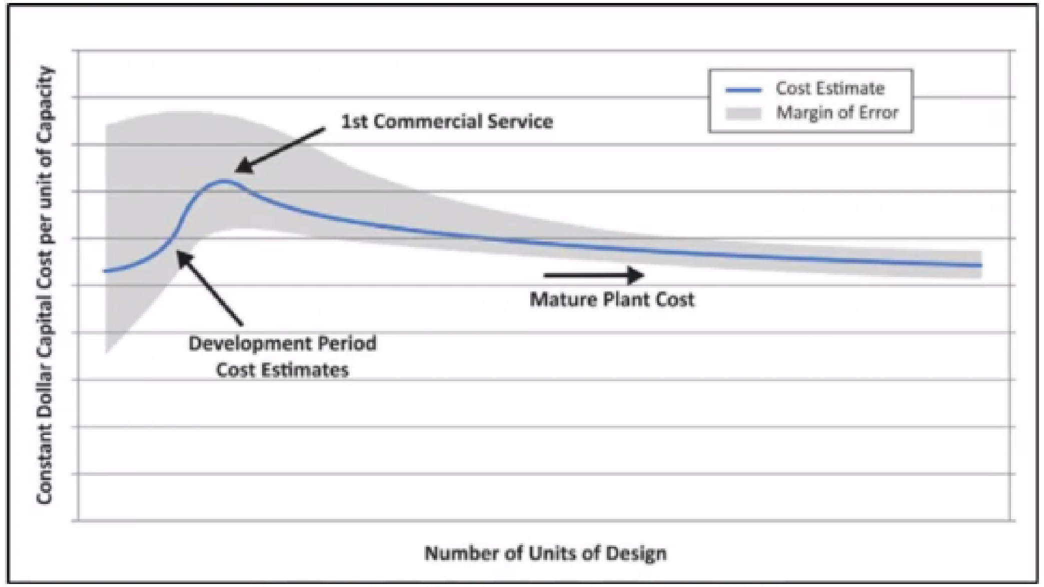


Figure 9. Theoretical Learning Curve (NETL, 2013).

Kobos et al., 2020, Techno-Economic Analysis: Best Practices and Assessment Tools, SAND2020-13473.

National Energy Technology Lab (NETL), 2013. *Technology Learning Curve (FOAK to NOAK)*, DOE/NETL-341/081213, August.

Summary

1. Geologic Storage of Hydrogen is technically proven, but very site -specific

2. Value-Added to existing infrastructure in Oil & Gas Industry (used in cracking) and possible transportation and energy grid systems.

3. Transportation Hydrogen use and related options highly dependent on H_2 purity requirements (e.g., H_2 combustion vs. fuel cells) and will affect Levelized cost of Hydrogen.