LCRI LOW-CARBON RESOURCES INITIATIVE

EPRI GTI ENERGY

EXECUTIVE SUMMARY

HYDROGEN STORAGE FOR US-REGEN MODEL: COSTS AND AVAILABILITY

The capital costs of underground hydrogen storage facilities are an important input for energy system models that assess the role that different technologies play in decarbonizing the energy sector. This report describes the methodology and assumptions used to estimate the cost of building new underground storage facilities and retrofitting existing underground natural gas facilities for hydrogen service. Cost estimates for three types of underground hydrogen storage facilities were modeled: depleted oil and gas reservoirs, aquifers, and salt caverns. The study collects and analyzes data from various sources, including public databases, published papers, and EPRI and LCRI cost studies, to estimate the capital costs of these technologies. The results also present spatial data on the availability and location of existing natural gas storage in the United States which could be retrofitted to store hydrogen as well as scenarios for potential new hydrogen storage capacity.

Key Research Questions

How much would underground hydrogen storage cost to develop? How would these costs differ between newly built hydrogen storage facilities and natural gas storage facilities retrofitted to store hydrogen? How might new hydrogen storage capacity be geographically distributed across the United States?

Research Overview

This study uses databases of existing natural gas storage facilities and calculations of their capacity to store hydrogen to develop a state level data set of potential hydrogen storage capacity and withdrawal rate. It also develops cost assumptions for retrofit and new-built hydrogen storage facilities using data from published research papers and cost studies by EPRI/LCRI. These efforts are combined to produce a data set of costs and potential availability of hydrogen storage resources by state and storage type (depleted oil and gas reservoirs, aquifers, and salt caverns). This data set also includes possible scenarios of new storage facilities calculated based on existing natural gas capacity. These data sets will be used as input to EPRI's US-REGEN model.

Key Findings

- Existing natural gas storage capacity in salt caverns is concentrated in the Gulf Coast Region of the United States where salt domes are plentiful. However, salt anticlines and beds exist in many regions of the United States, which upon further site-specific investigation, feasibility, and economic analysis, could potentially be developed for hydrogen storage.
- Many states on the Atlantic coast lack suitable geology for onshore underground storage.

- The costs of a hydrogen storage facility can be broken into two categories. "Door" costs refer to the costs that scale with the maximum rate of withdrawal of a facility, such as wells and compressors, and are reported here in terms of $/kg H_2/day. "Room" costs refer to costs that scale with the total storage capacity of a facility, such as cushion gas and geologic site preparation, and are reported here in terms of $/kg H_2. Modeled results indicate:
  - The costs of new-build hydrogen storage in oil and gas reservoirs and any type of storage facility retrofit from natural gas to hydrogen scale predominantly with the "door" size and are relatively insensitive to the "room" size.
  - The costs of new-build aquifer and salt cavern hydrogen storage facilities scale with both due to the significant "room" costs of site preparation. All types also have cushion gas "room" costs, though this cost is lower for salt caverns.
- Retrofitting an existing salt cavern natural gas storage facility to store hydrogen may be the most economical hydrogen storage option because fewer compressors per rate of withdrawal would be required than for retrofitting an aquifer or depleted oil and gas reservoir facility.
- The most economical new-build hydrogen storage type may be depleted oil and gas reservoir due to the low site preparation costs. At larger sizes, salt caverns may be the most expensive due to the cost of solution mining which scales with storage capacity.

Why This Matters

Availability of underground storage is a key determining factor in the economic viability of hydrogen as an energy carrier, as regions without favorable geology for underground storage would need to import hydrogen by pipeline from other regions, increasing the delivered cost. Geographically differentiated assumptions for the availability and capital costs of underground hydrogen storage will allow for better modeling analysis and resource planning.

How to Apply Results

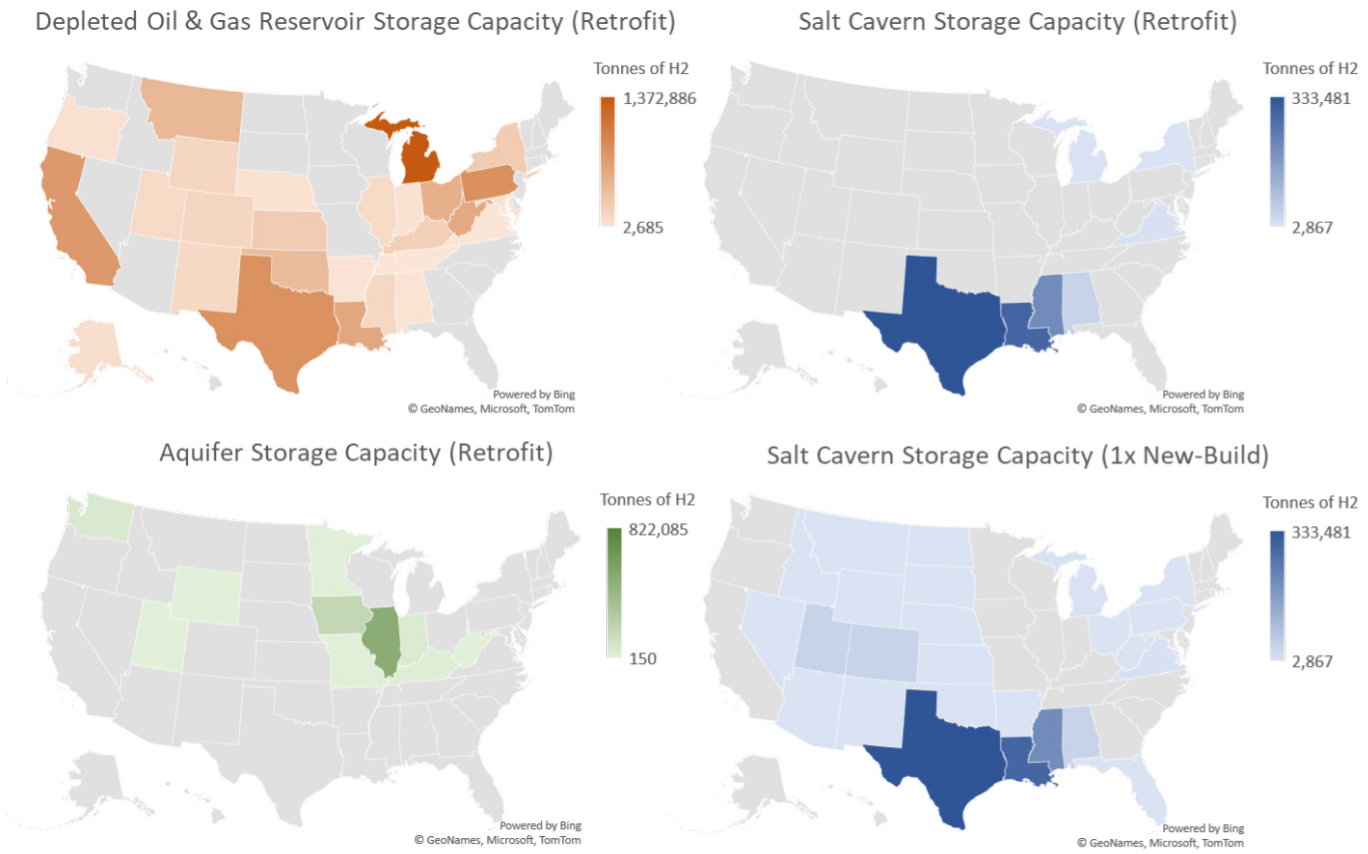
These results will primarily serve as inputs to the US-REGEN model. These results will more generally be applicable to utility resource planners considering the viability of hydrogen as an energy carrier in a particular region.

Learning and Engagement Opportunities

- This study builds on previous EPRI LCRI report *Review of Hydrogen Geologic Storage Options in the U.S.: Existing Facilities and Potential for Future Storage Expansion*, 3002026653.
- Compressor costs were taken from EPRI LCRI report *Economic Cost, Limitations, Challenges, and Opportunities of Utilizing Existing Natural Gas Compressor Systems for Transport of Hydrogen and Hydrogen Blends*, 3002028177.
- More information on the LCRI US-REGEN model can be found at the website: lcri-vision.epri.com/content/portfolio-modeling-analysis.html

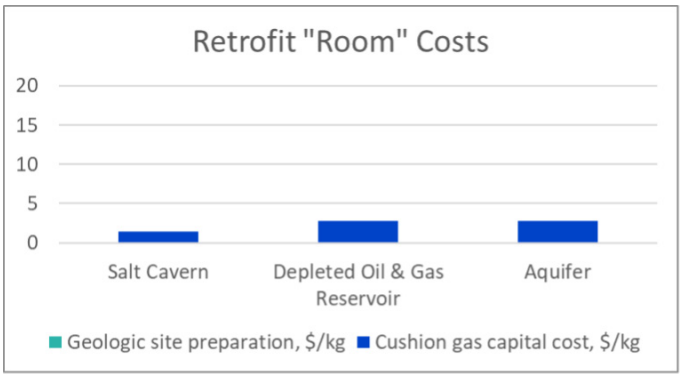
The following maps depict the regional hydrogen storage capacity calculated in this study. These values represent hydrogen storage in existing underground natural gas storage facilities if they were retrofitted to store hydrogen. Different scenarios of future new-build facilities can be calculated by multiplying the existing storage capacity by an assumed multiplier. LCRI report *Review of Hydrogen Geologic Storage Options in the U.S.* 3002026653 identified several states which do not have any existing underground natural gas storage in salt formations but have salt formations that could

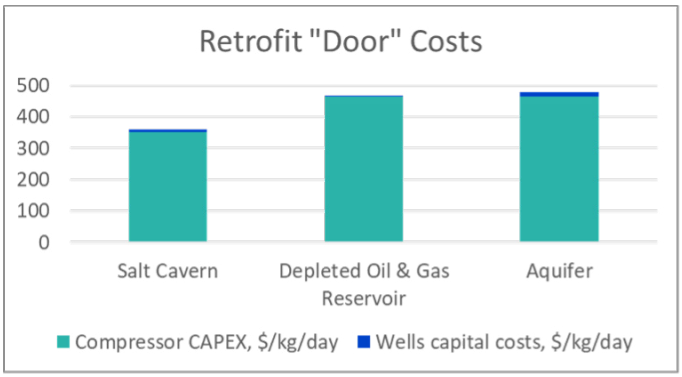
potentially be used for future hydrogen storage if investigated further. This study manually added potential for such states, so the salt cavern potential for new-build capacity (assuming a multiplier of 1) is greater than the potential for retrofitted natural gas storage facilities.

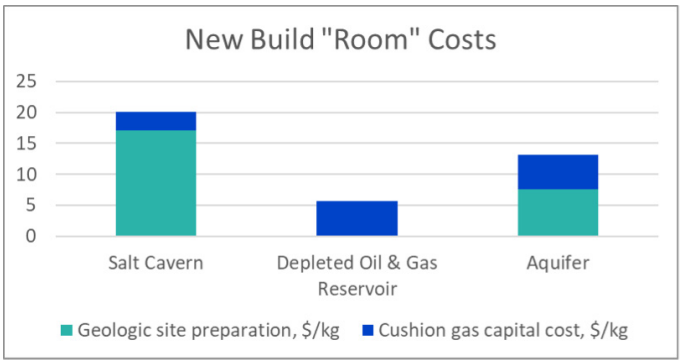


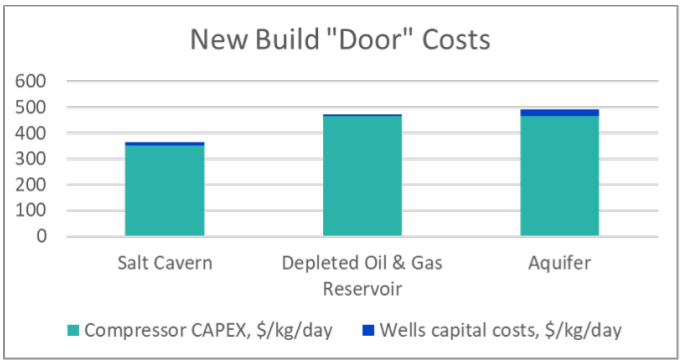
The non-regionalized capital costs calculated for this study are shown in the tables and graphs below.

Underground Hydrogen Storage Capital Costs		"Room" ($/kg)	"Door" ($/kg/day)
Retrofit	Aquifer	2.81	479
	Depleted Oil & Gas Reservoir	2.81	469
	Salt Cavern	1.47	360
New Build	Aquifer	13.2	493
	Depleted Oil & Gas Reservoir	5.62	472
	Salt Cavern	20.0	367









The full report contains greater detail on the methodology and the full final data set of regional availability and costs.

The Low-Carbon Resources Initiative

This report was published under the Low-Carbon Resources Initiative (LCRI), a joint effort of EPRI and GTI Energy addressing the need to accelerate development and deployment of low- and zero-carbon energy technologies. The LCRI is targeting advances in the production, distribution, and application of low-carbon energy carriers and the cross-cutting technologies that enable their integration at scale. These energy carriers, which include hydrogen, ammonia, synthetic fuels, and biofuels, are needed to enable affordable pathways to economy-wide decarbonization by mid-century. For more information, visit www.LowCarbonLCRI.com.

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