PS Exploring Underground Hydrogen Storage Options in North Dakota: A Review

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Search and Discovery Article #80738 (2023)**
Posted June 16, 2023

*Adapted from extended abstract based on oral presentation given at 2023 AAPG Rocky Mountain Section Meeting, Bismarck, North Dakota, June 4-6, 2023
 DOI:10.1306/80738Laalam2023

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Abstract

As the world shifts towards a low-carbon future, the demand for efficient, safe, and cost-effective energy storage solutions has become increasingly critical. Hydrogen has emerged as a promising energy carrier with numerous advantages, such as high energy density, zero emission combustion, and versatile applications. Nevertheless, the challenge of effective hydrogen storage remains. This study examines the potential of underground hydrogen storage (UHS) in North Dakota, assessing its opportunities and challenges in supporting the region's renewable energy objectives.

North Dakota's unique geological features, abundant renewable energy resources, and growing energy demands make it an ideal location for UHS implementation. This review explores various UHS technologies, including salt caverns, depleted oil and gas reservoirs, and aquifers, emphasizing their technical feasibility, environmental impacts, and economic viability within the North Dakota context. Salt caverns, created in subsurface salt formations, are well-suited for UHS due to their impermeability, structural integrity, and rapid cycling capacity. North Dakota's plentiful salt deposits, especially in the Williston Basin, present significant opportunities for large-scale hydrogen storage. Depleted oil and gas reservoirs offer another feasible option, leveraging existing infrastructure and reservoir knowledge. The state's long history of oil and gas production yields numerous depleted reservoir candidates for potential UHS projects. Aquifers, naturally occurring underground water-bearing formations, constitute a third alternative. Although less investigated than salt caverns and depleted reservoirs, aquifers show promise for UHS in North Dakota due to their extensive distribution and potential for substantial storage capacities. Additionally, we emphasize key economic factors and benefits for the state.

In conclusion, this study provides a comprehensive assessment of the opportunities and challenges linked to implementing underground hydrogen storage in North Dakota. By conducting a detailed analysis of the region's geological characteristics, economic factors, and environmental concerns, we aim to offer valuable insights for policymakers, industry stakeholders, and researchers. This information can help inform future UHS projects and support the state's transition towards a sustainable energy future.

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Introduction

Hydrogen has immense potential as an energy carrier for a sustainable future, but the challenge of long-term storage hinders its widespread adoption (Rosen & Koohi-Fayegh, 2016). However, North Dakota, with its abundant renewable energy resources and geological formations, is well-positioned to become a significant hub for hydrogen storage. The state's capacity for renewable energy production, particularly in wind and solar power, can be effectively utilized to produce green hydrogen through electrolysis. Moreover, North Dakota's salt caverns and saline aquifers provide suitable conditions for large-scale, long-term hydrogen storage (DOE,2022). By leveraging its unique combination of renewable energy resources and geological formations, North Dakota could play a pivotal role in advancing hydrogen storage and contributing to a sustainable future. Thorough modeling and optimization studies are crucial to fully capitalize on these advantages and establish North Dakota as a key player in the widespread adoption of hydrogen-based technologies

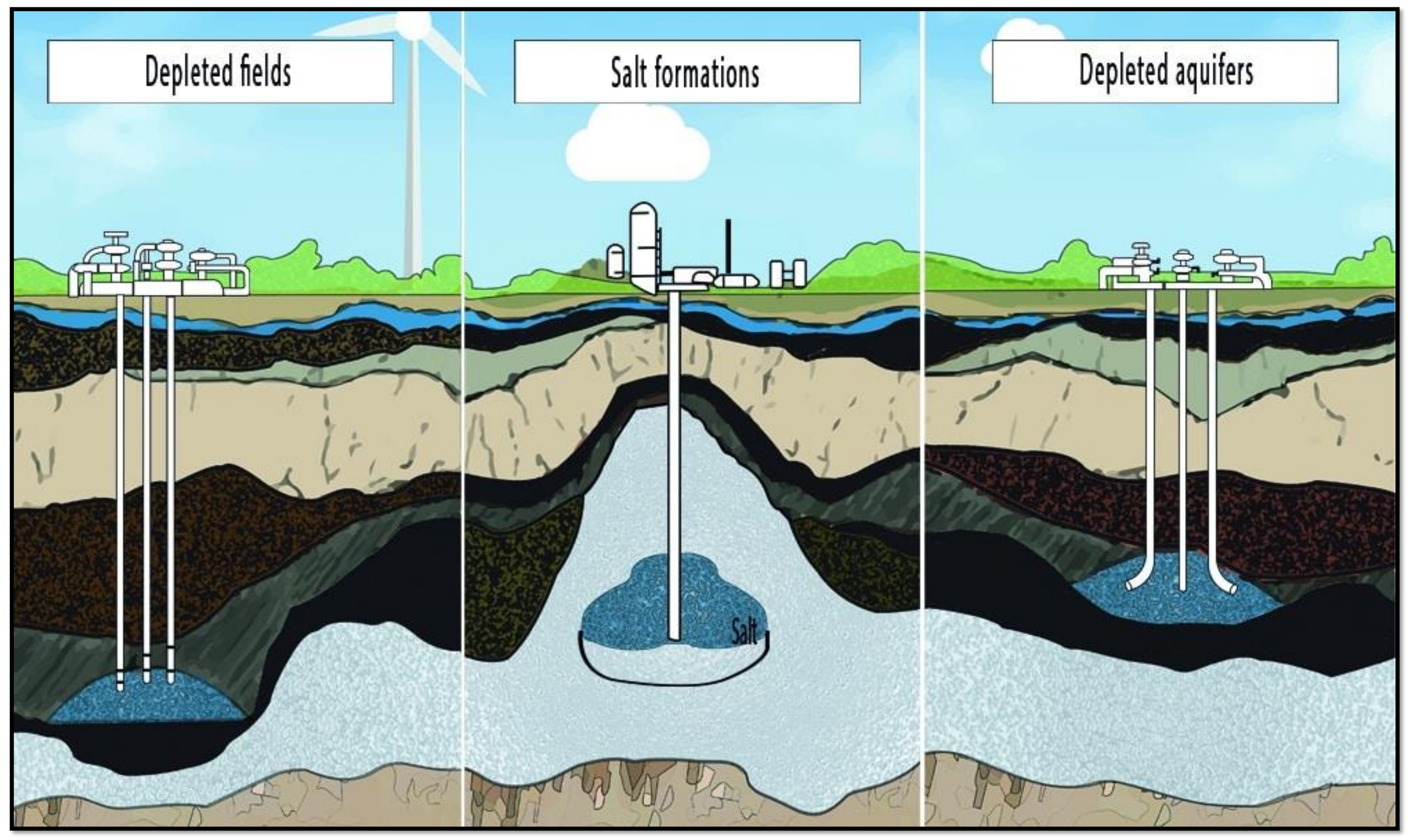

Figure [1]: Different Storage Options for Underground Hydrogen Storage (Heine, 2022)

Objectives

This review examines the potential of salt caverns and saline aquifers as storage options for hydrogen in North Dakota. By analyzing the advantages, limitations, and challenges of each storage medium, this study aims to provide valuable insights for stakeholders considering hydrogen storage projects. Understanding the characteristics of these storage options will support informed decision-making and contribute to the state's transition to a sustainable energy future

Salt Cavern Storage Potential in North Dakota

In western North Dakota, there are a total of seven salt layers that span across an extensive region, with each layer covering an area of over 5,000 square miles. These salt layers have an average thickness exceeding 40 feet and are positioned above the Bakken Formation (Nesheim & LeFever).

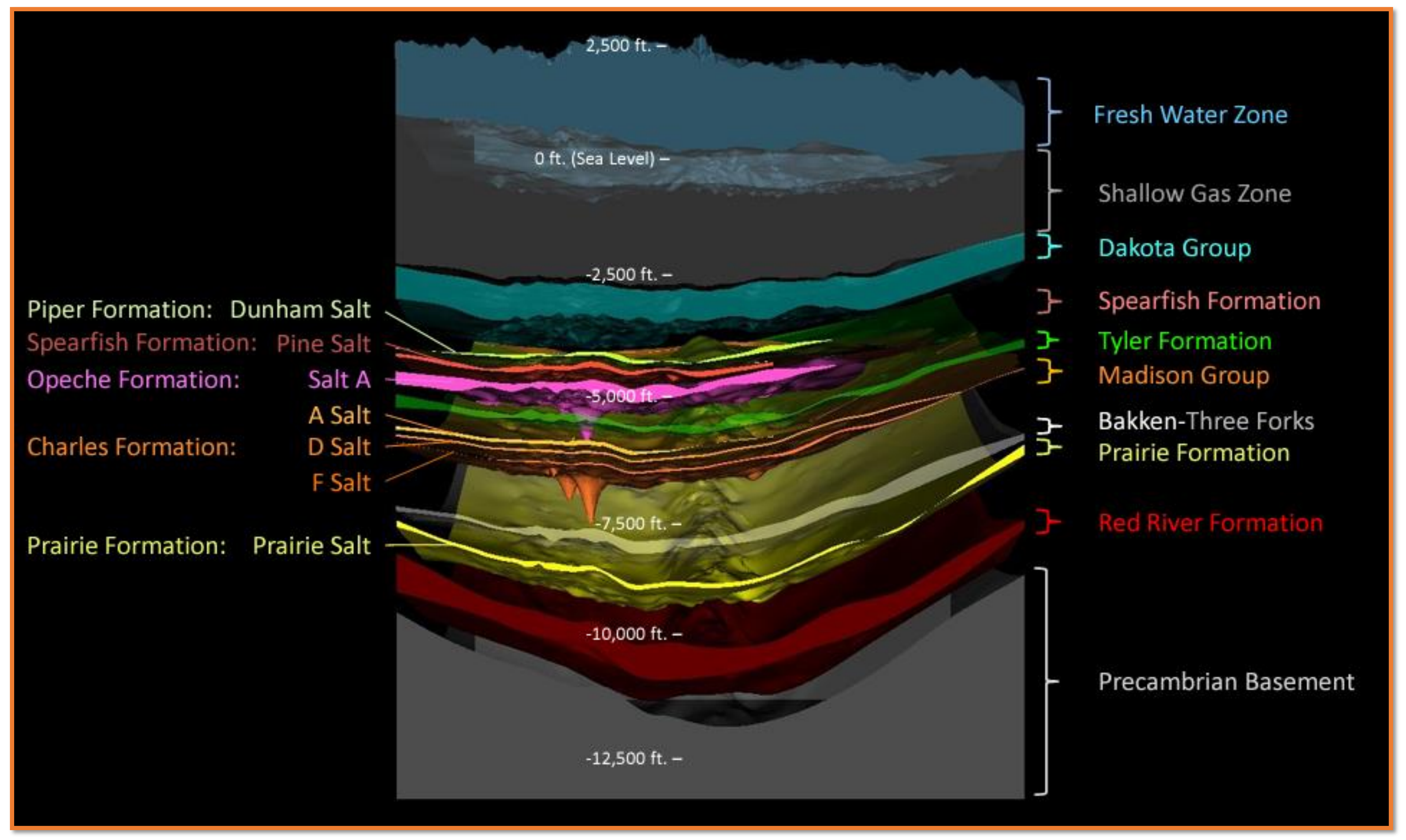

Figure [2]: Main Salt deposits in Western North Dakota [North Dakota Department of Mineral Resources]

Additionally, there are three more salt layers in the same region, also covering an area of over 5,000 square miles each. However, these three salt layers have a relatively thinner average thickness of less than 40 feet and are situated above the Bakken Formation as well (Nesheim & LeFever).

Saline Aquifer Storage Potential in North Dakota

Three primary saline aquifers in western North Dakota show promise for hydrogen storage. Among them, the Inyan Kara formation stands out with its substantial storage capacity, although it has also been used for saltwater disposal. Another viable option is the Broom Creek formation, which has shown potential for CO_2 storage. Similarly, the Deadwood formation has demonstrated promise for CO_2 storage and could be considered for hydrogen storage as well.

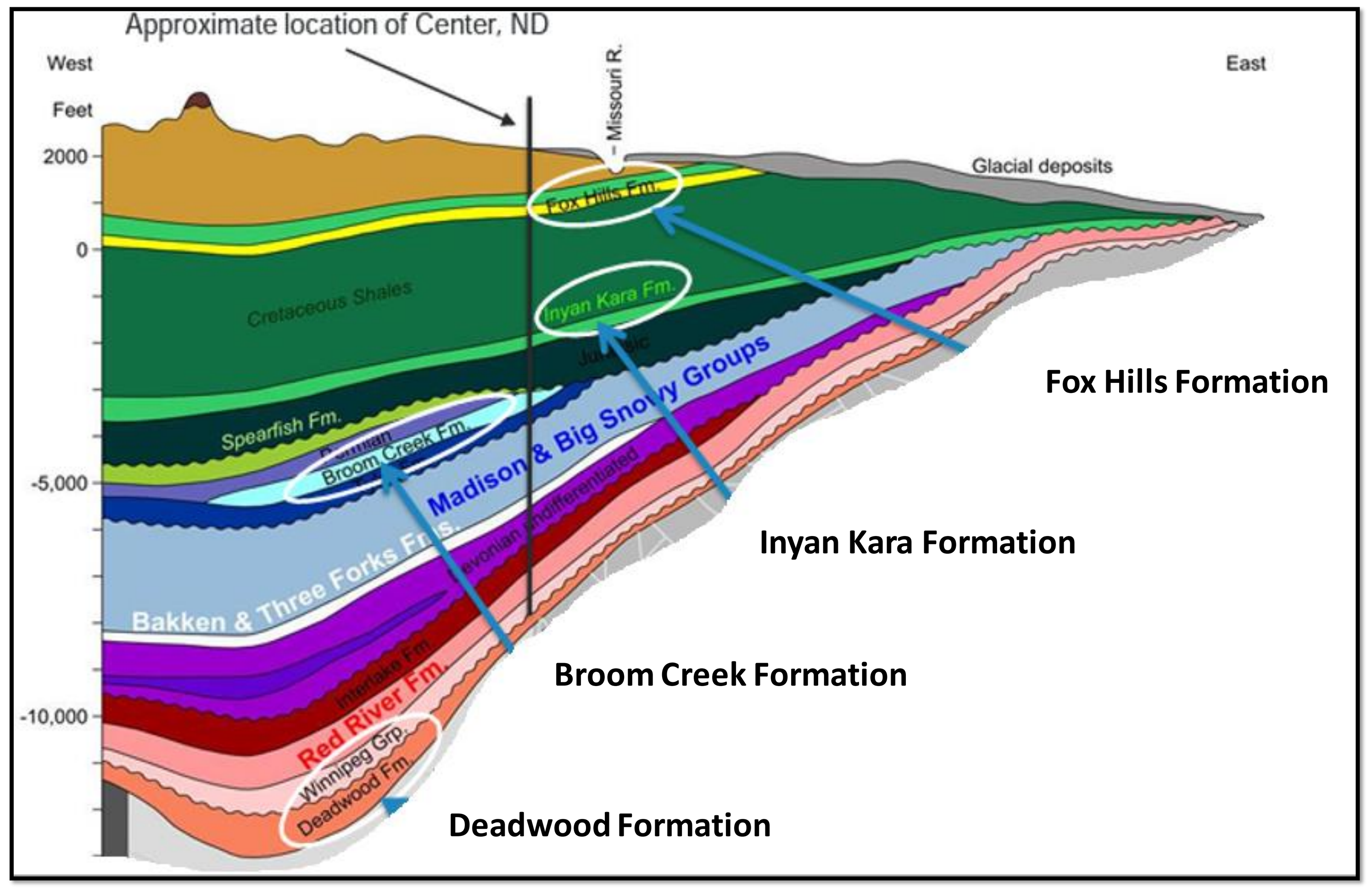

Figure [3]: Saline Aquifer Formations in North Dakota (Adapted from EERC Report, 2022)

Comparison Between Storage Options (Adapted from Raad et al., 2022)

Comparing Metrics	Salt Caverns	Saline Aquifers
Geologic Features	Underground cavities created by leaching salt formations, providing excellent structural integrity and impermeability.	Underground porous rock formations saturated with saline water, offering storage capacity within the pore spaces.
Suitability for Storage	Excellent for hydrogen storage due to their impermeability and structural stability.	Good potential for hydrogen storage with proper site selection, characterization, and injection techniques.
Storage Capacity	Can provide large-scale storage capacity due to the spacious nature of caverns.	Generally offers substantial storage capacity due to the extensive network of interconnected pores.
Technical Maturity	Salt cavern storage has been extensively used for natural gas storage, indicating a high level of technical maturity.	Saline aquifers have been utilized for carbon dioxide storage, but hydrogen storage projects are still in the research and pilot phase.
Development Costs	Initial development costs can be high due to the need for solution mining and cavern creation.	Development costs are moderate, typically involving drilling wells and implementing injection and extraction infrastructure.
Environmental Concerns	Potential for the release of saltwater during cavern formation. Proper management and monitoring are crucial to prevent environmental impacts.	Possible challenges related to the injection and extraction of hydrogen into and from aquifers, including ensuring long-term integrity and avoiding water contamination.

Conclusion

North Dakota's geologic setup presents promising opportunities for hydrogen storage, with extensive salt layers and saline aquifers. However, further investigations are required to assess the suitability of each storage medium considering the complex behavior of hydrogen storage. Factors such as geomechanics, geochemical reactions, microbial processes, and operational challenges must be considered. Drawing lessons from CO_2 sequestration and adapting them to hydrogen storage can expedite progress. Continued research, collaboration, and knowledge-sharing are crucial to unlock the full potential of North Dakota's geologic resources for safe and efficient hydrogen storage. By embracing hydrogen as a clean energy carrier, North Dakota can drive economic growth and environmental sustainability.

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RMS-AAPG 2023 Annual Meeting, June 04- June 06, Bismarck, ND