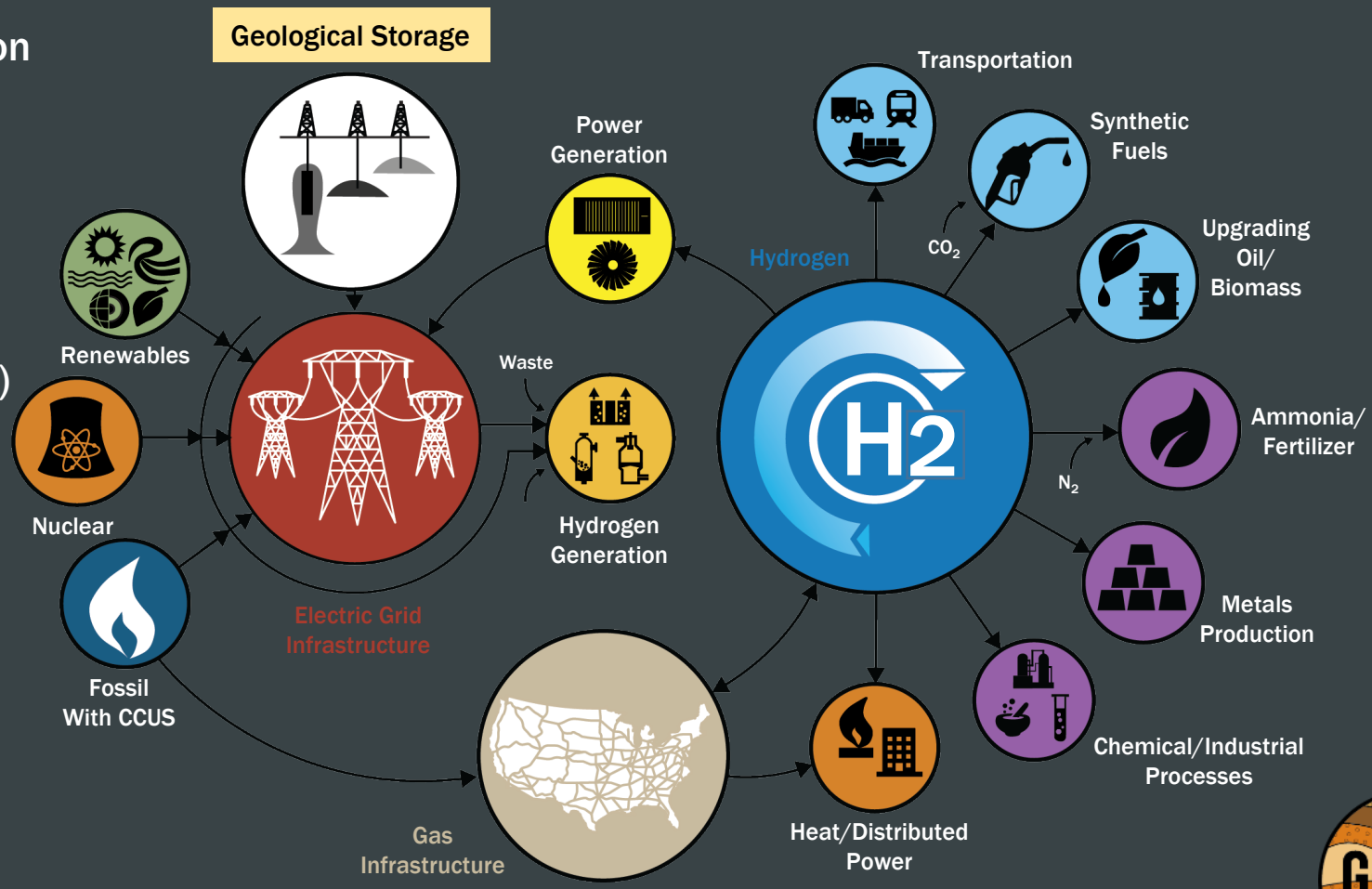
Hydrogen as Part of a Low Carbon Economy

- <u>Low carbon emissions</u>
  - From fossil fuels combined with carbon capture and storage (CCS)
  - From electrolysis (hydro, solar, wind, nuclear, geothermal) without CO_2
- Transportable
  - Pipeline gas
  - Liquified
  - Derivative compounds (e.g. ammonia)
- Store-able
  - Large capacity (geological)
  - Indefinite storage duration
- Multiple sources
  - Electrolysis
  - Natural gas reforming
  - Coal gasification



Source: DOE, Office of Fossil Energy, 2020

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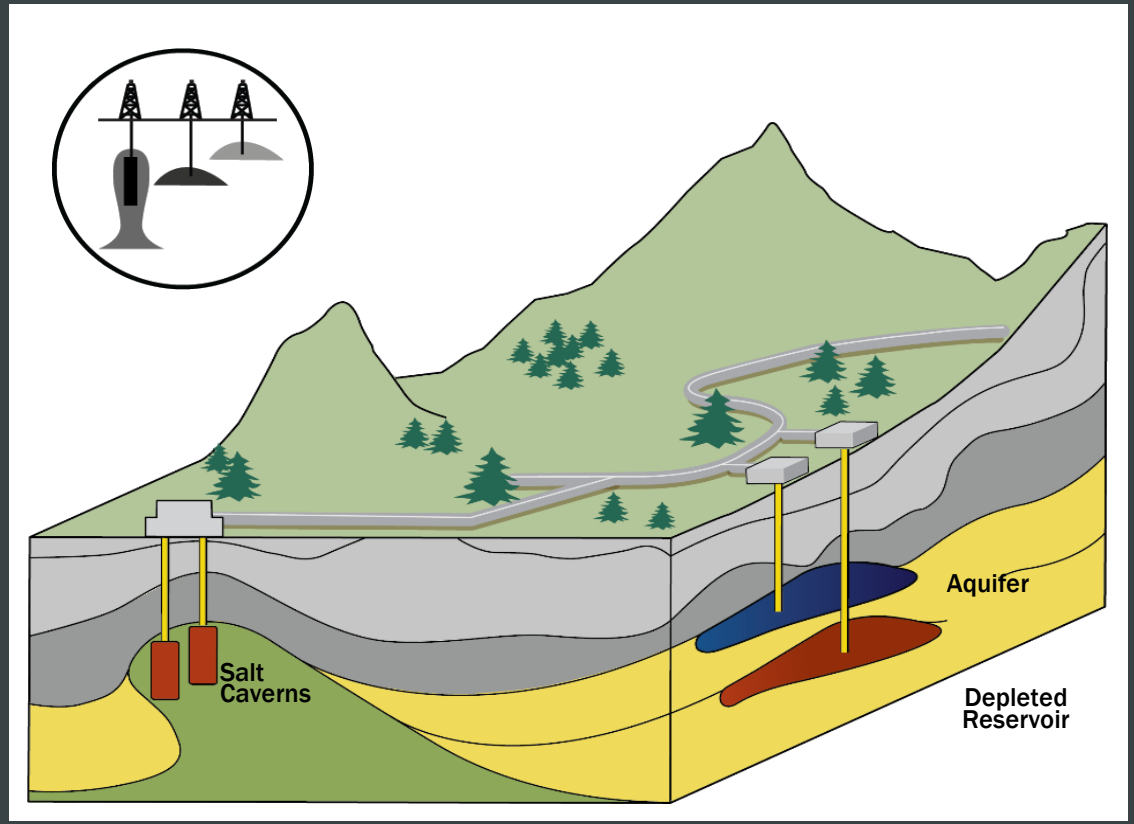
Low Carbon Intensity Hydrogen Value Chain

- Storage is a key component of the LCI hydrogen value chain
- Offers ability to manage intermittency in supply and demand and provide uninterrupted supply for uses across sectors

Feedstock	H_2 Production	Transportation	Storage	Potential Markets
• Natural Gas • Solar • Wind • Water	• Methane Reforming w/ CCS • Electrolysis	• Pipeline • Trucked	• Geologic (e.g salt caverns) • Line pack • Surface containers	• Industry • Power • Transportation • Res/Com

Geological Storage

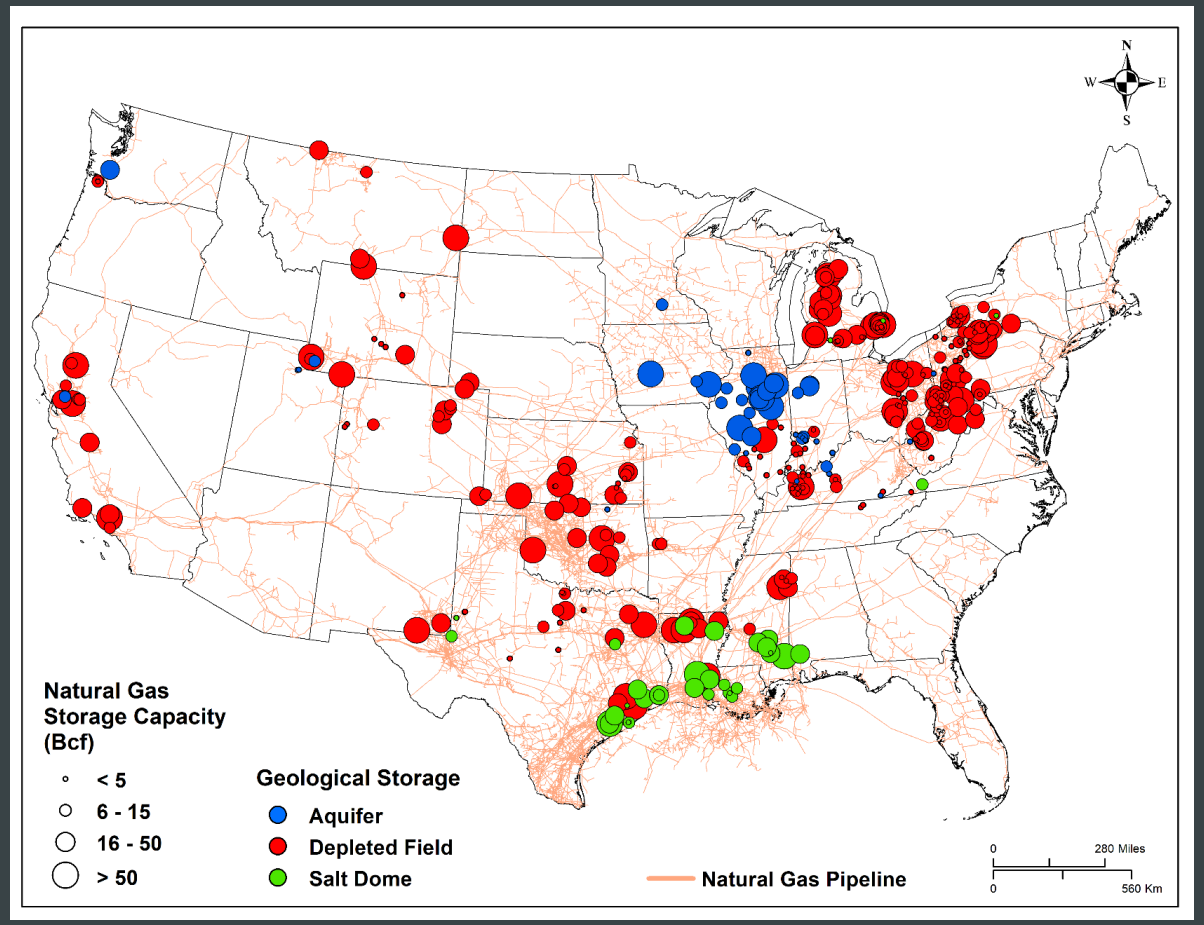
- Geological storage options
  - Dissolution caverns in salt
  - Depleted oil & gas fields
  - Saline aquifers
  - Lined caverns
- Geographic coverage important
  - Links supply to demand
    - Production sites
    - End-use sites



US Natural Gas Infrastructure and Geological Storage

Geological storage provides large capacity gas storage across the US

- ~ 400 underground storage sites in US
- U.S. natural gas storage (working gas) capacity is 4.25 Trillion cubic feet
- Storage ~ 13 % of annual consumption



Source: EIA, 2021

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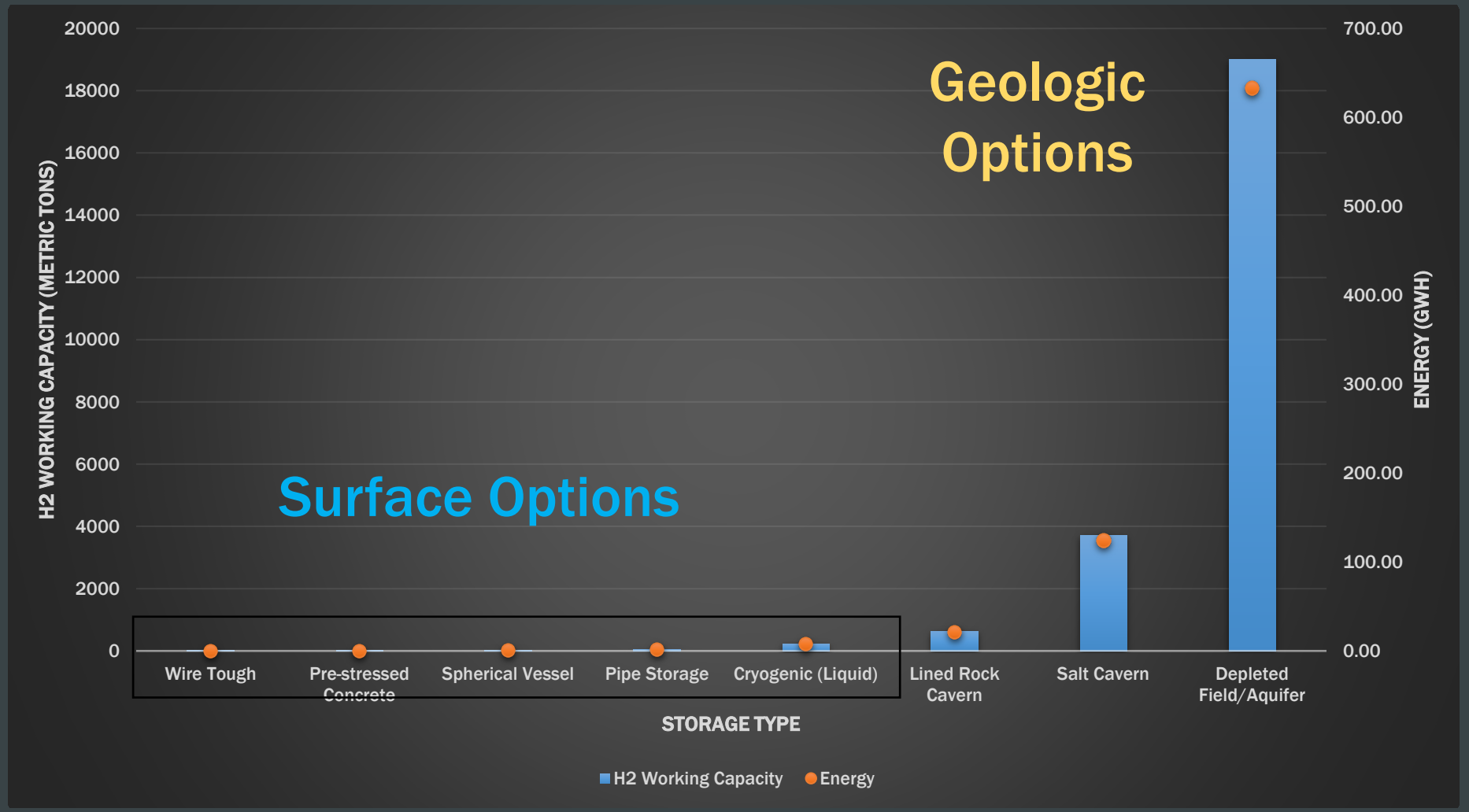
Indicative H_2 Storage Options by Unit Capacity



Data from Ahluwalia et al, 2019

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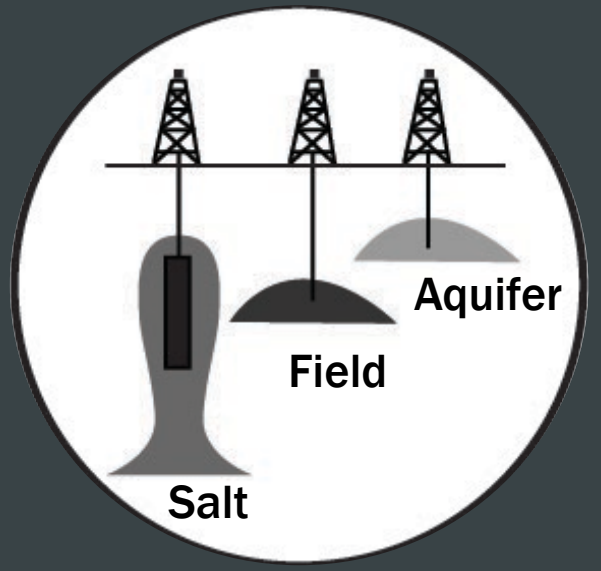
Geo-storage Offers Long-term, High-capacity Energy Storage

Vistra Energy's Lithium-ion battery system Moss Landing, CA

1.2 GWh (300 MW);
4 hour storage duration

One (small) Geological Hydrogen Site (~1.3 Bcf)



100 GWh
Seasonal (months) storage duration

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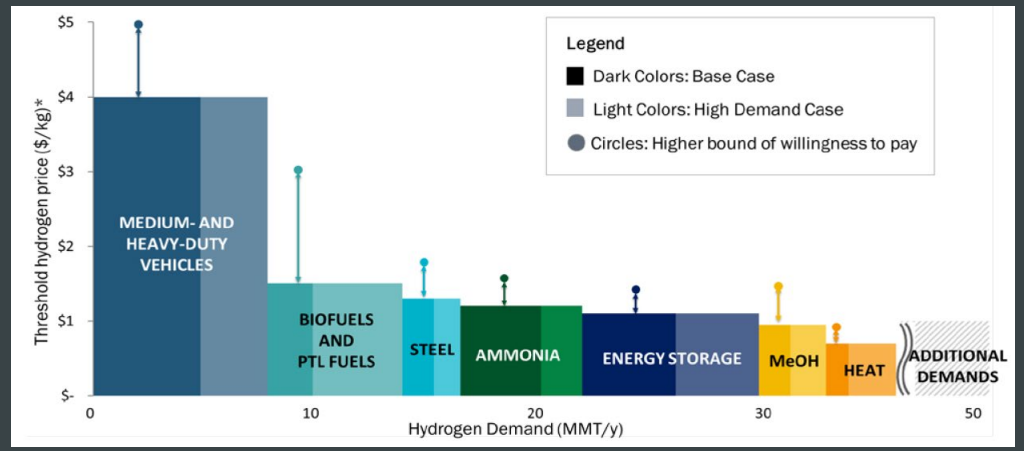
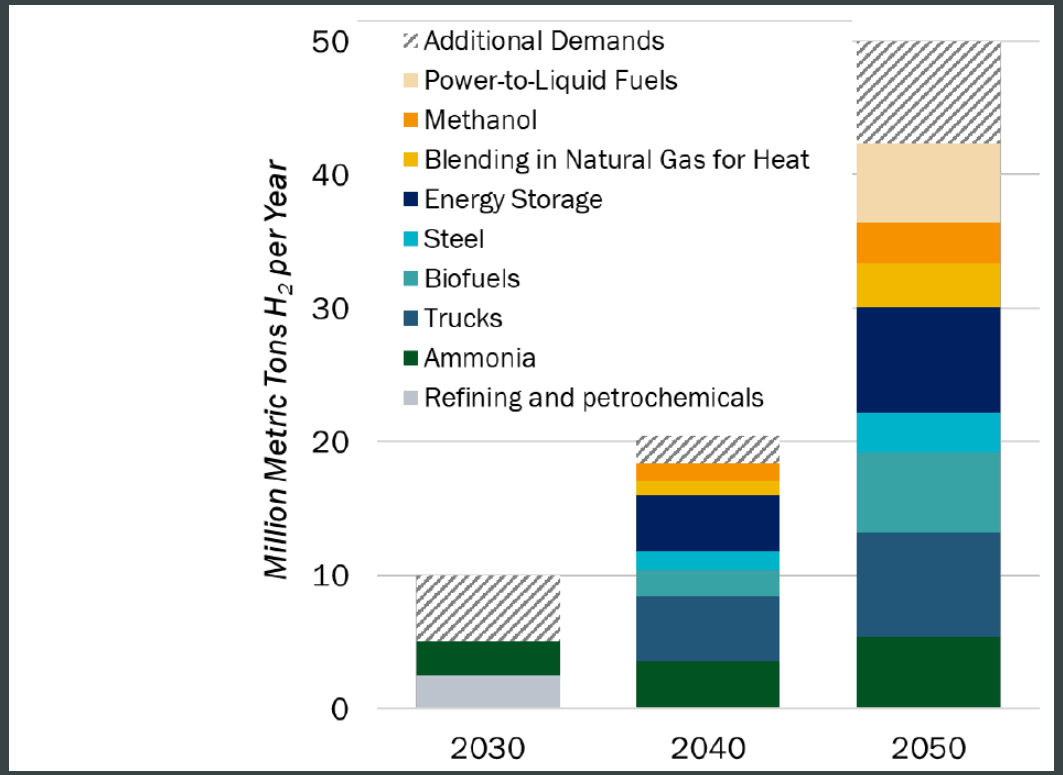
US DOE Clean H_2 Demand Projection

- 50 MMT/year by 2050
- Mix of sectors
- Price thresholds vary by sector





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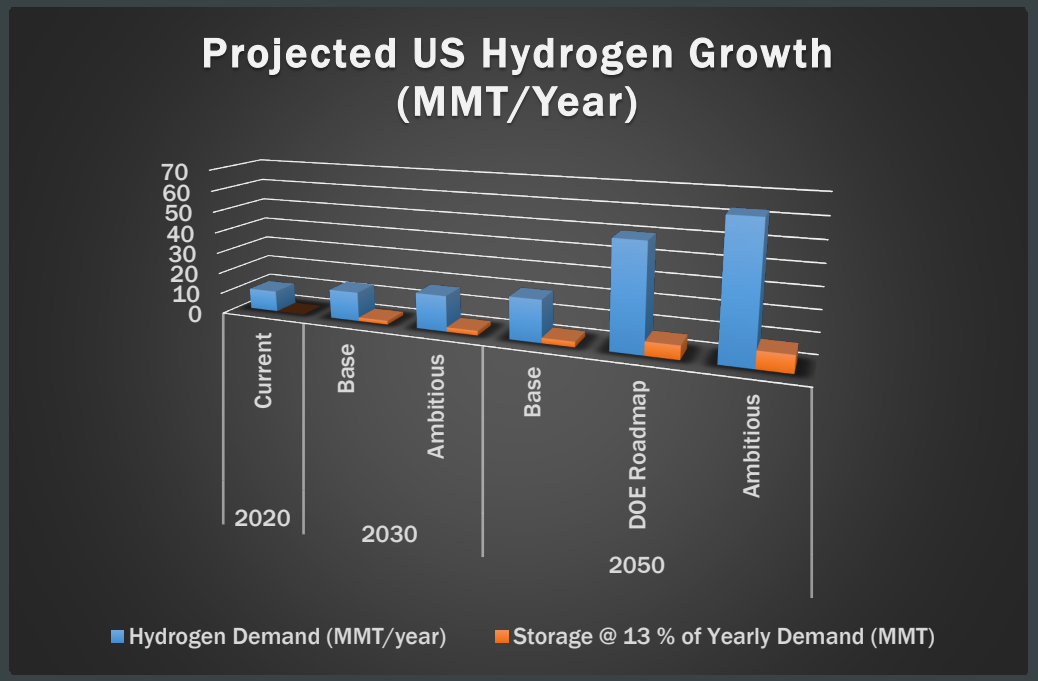
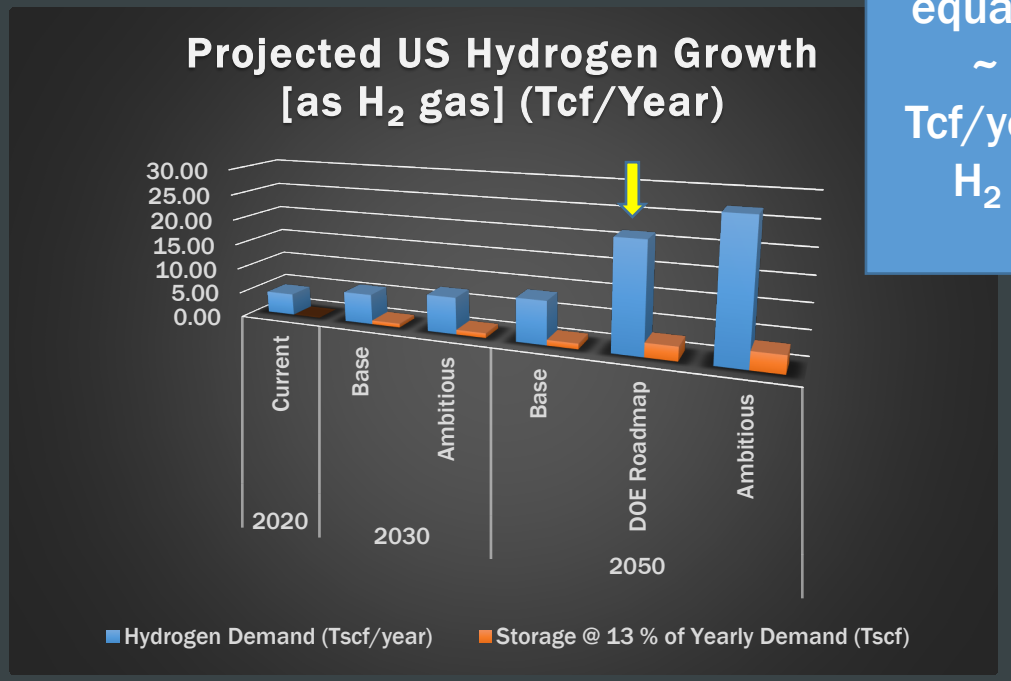
https://www.hydrogen.energy.gov/pdfs/clean-hydrogen-strategy-roadmap.pdf

Future H_2 Demand Growth Scenarios

- DOE Roadmap (2050) and FCHEA (Base & Ambitious) Scenario Projections
- 2050 range: 20 - 50 - 63 MMT/year





DOE 2050 Projection equates to ~ 22 Tcf/year as H_2 gas

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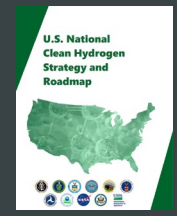
"Base & Ambitious"
https://www.fchea.org/us-hydrogen-study
[Fuel Cell & Hydrogen Energy Association]

Department of Energy Roadmap 2050
https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/us-national-clean-hydrogen-strategy-roadmap.pdf



Future of H_2 Geo-Storage

- Need for large-scale storage of hydrogen driven by expected growth of a hydrogen economy: Industry, Heavy Transportation, Power

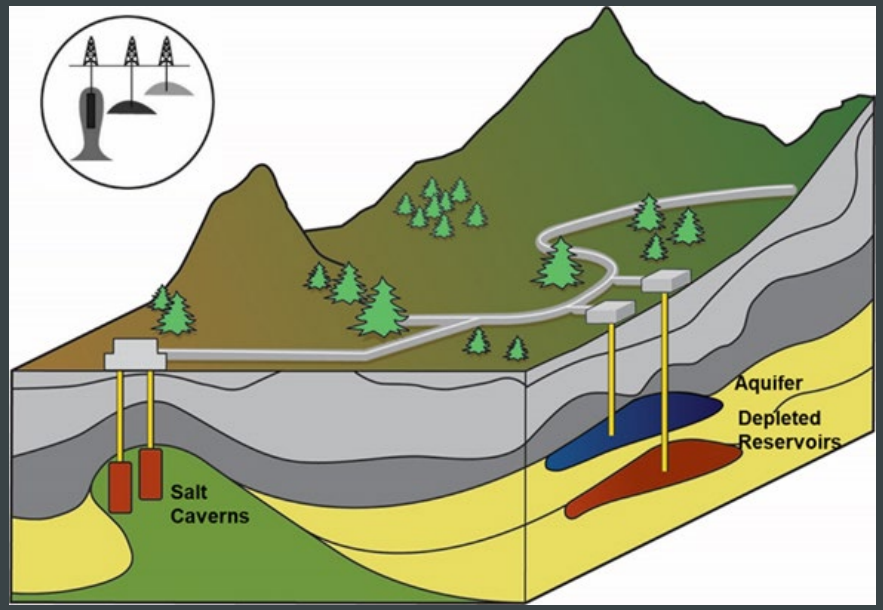
- Some technologies (e.g. salt caverns) are in use but many technologies and application are immature (e.g. depleted fields, saline aquifers)

- <u>Research is needed</u>:
  - Understand behavior of H_2 in subsurface (laboratory, modeling, field tests)
  - Techno-economic analysis to optimize storage for given pathways
  - Identify risks and develop mitigations (e.g. leakage)

$GeoH_2$ – Hydrogen Consortium

Conduct geoscience, reservoir engineering, & economic research to facilitate and advance the development of a hydrogen economy *at scale*

- Geological Storage
- Techno-economics and Value Chain Analysis
- Novel concepts: In Situ Generation and Native Hydrogen



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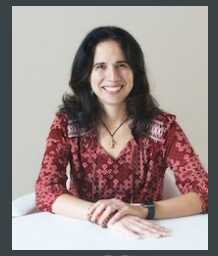
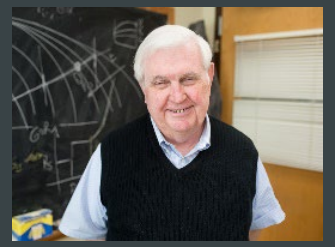
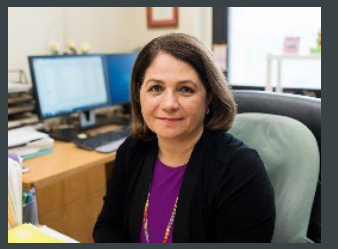

Lorena Moscardelli

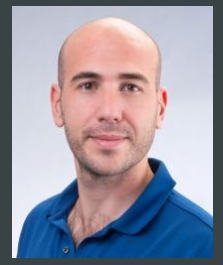

Larry Lake

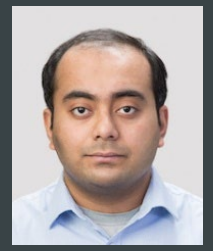

Mojdeh Delshad


Ian Duncan


Tongwei Zhang


Jay Kipper


Leo Ruiz Maraggi

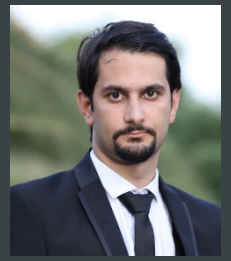

Shuvajit Bhattacharya


Toti Larson

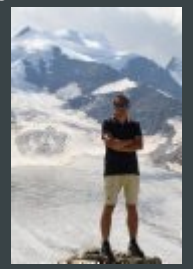

Mark Shuster


Sobhan Razm

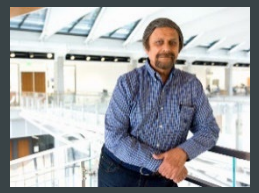

Ander Martinez-Donate


Reza Ershadnia


Nur Schuba


Xiaoqiang Li


Ali Cherif


Kamy Sepehrnoori

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Examples of Recent Publications

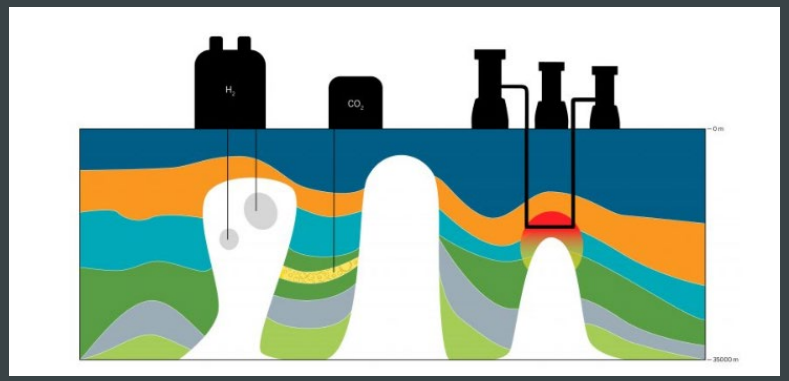
The Role of Salt Tectonics in the Energy Transition: An Overview and Future Challenges

Oliver B. Duffy [*1], Michael R. Hudec [1], Frank Peel [1], Gillian Apps [1], Alex Bump [1], Lorena Moscardelli [1], Tim P. Dooley [1], Naiara Fernandez [1,2], Shuvajit Bhattacharya [1], Ken Wisian [1], Mark W. Shuster [1]

[1]Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin, University Station, Box X, Austin, Texas, 78713-8924, USA | [2]Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences, Potsdam, Germany

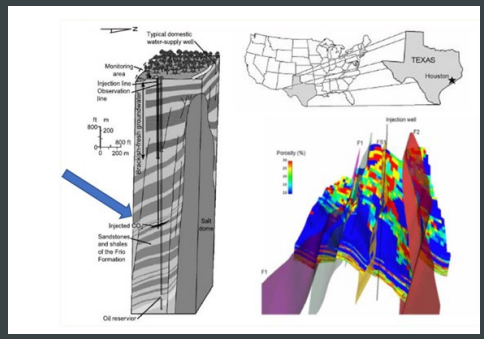
Hydrogen Storage Assessment in Depleted Oil Reservoir and Saline Aquifer

by Mojdeh Delshad [1,*], Yelnur Umurzakov [1], Kamy Sepehrnoori [1], Peter Eichhubl [2] and Bruno Ramon Batista Fernandes [3]



ENERGY TRANSITION

Digging Into the US Gulf Coast's 'Salt Real Estate' for Hydrogen Storage



PIPELINES & TRANSPORTATION

Hydrogen infrastructure expansion requires realistic framework

May 3, 2021

Pros and Cons of Saline Aquifers Against Depleted Hydrocarbon Reservoirs for Hydrogen Energy Storage

Mojdeh Delshad; Muhammad Alhotan; Bruno Ramon Batista Fernandes; Yelnur Umurzakov; Kamy Sepehrnoori

Paper presented at the SPE Annual Technical Conference and Exhibition, Houston, Texas, USA, October 2022.
Paper Number: SPE-210351-MS
https://doi.org/10.2118/210351-MS

Panel Session

• Energy & hydrogen storage	Dr. Peter Eichhubl (BEG)
• Subsurface hydrogen storage in Texas	Dr. Lorena Moscardelli (BEG)
• Leakage risk and impact	Dr. Tianyi Sun (EDF)