Hydrogen Storage Subsurface Research

Mark W. Shuster

Hydrogen Working Group, Bureau of Economic Geology

$GeoH_2$

- $GeoH_2$ is a new consortium at the University of Texas to conduct geoscience & economic research to facilitate and advance the development of a hydrogen economy *at scale*
- Research focus:
  - Geological storage of hydrogen
  - Techno-economics of integrated value chains and market analysis
  - Novel subsurface concepts (e.g. in-situ generation)
- World-class research capability with proven track-record of high-value research and impact
- Multi-company consortium-approach offers cost-effective means of R&D and knowledge transfer
  - Members steer research
  - Leverage multi-member participation
  - Focus on applied research

Bureau of Economic Geology

The University of Texas at Austin
Center for Subsurface Energy and the Environment
Cockrell School of Engineering

$GeoH_2$

Team GeoH$_2$

Resource Characterization, Geology, Geophysics, Petrophysics, Geomechanics, Reservoir Engineering, Energy Economics

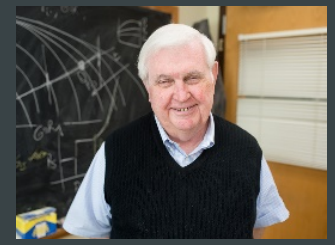

JP Nicot

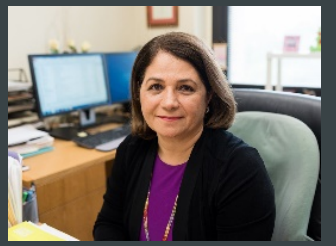

Ning Lin


Seyyed Hosseini


Peter Eichhubl


Lorena Moscardelli

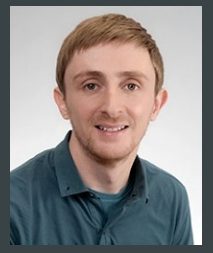

Larry Lake

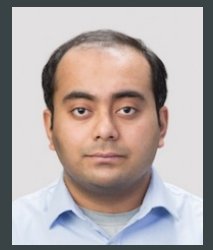

Mojdeh Delshad


Ian Duncan


Bo Ren


Farzam Javadpour


Oliver Duffy


Shuvajit Bhattacharya

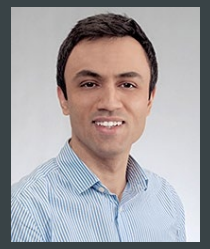

Kamy Sepehrnoori


Mehran Mehrabi


Mark Shuster


Jay Kipper


Aura Araque


Reza Ganjdanesh

The University of Texas at Austin
Center for Subsurface Energy and the Environment
Cockrell School of Engineering

Bureau of Economic Geology

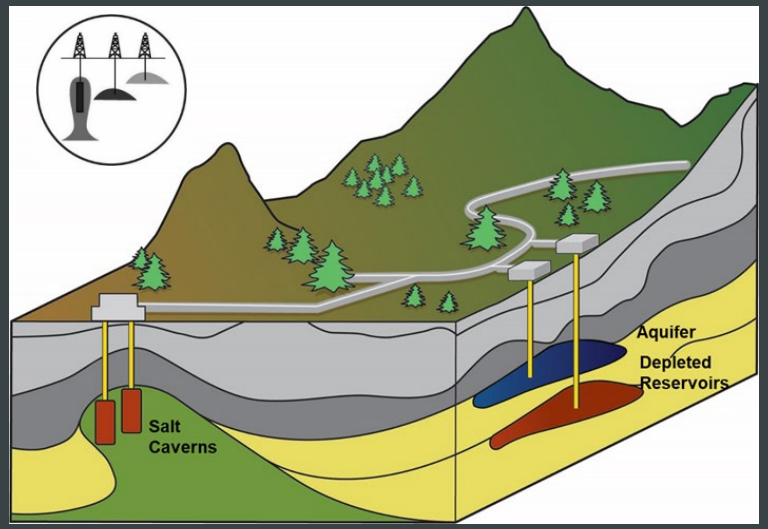
GeoH$_2$

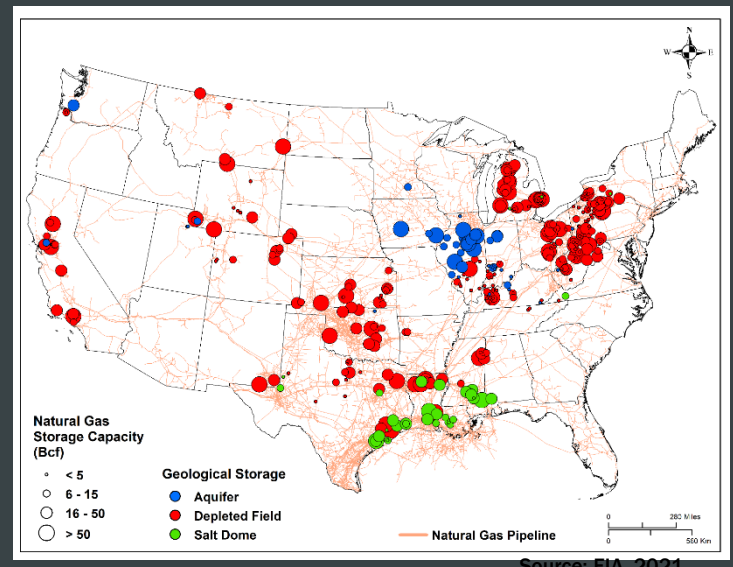
Geological Storage

- Geological storage provides best options for large capacity storage

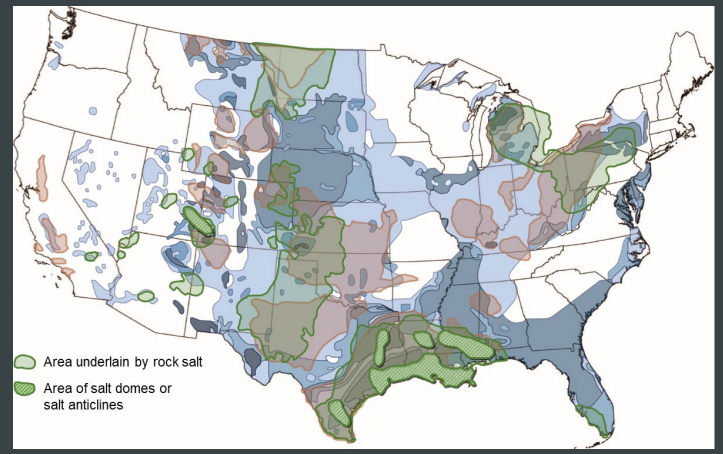
- Viable geological storage
  - Dissolution caverns in salt domes
  - Depleted oil & gas fields
  - Saline aquifers
  - Lined caverns

- Geographic coverage important
  - Generation sites
  - End-use sites
  - Infrastructure





Source: EIA, 2021



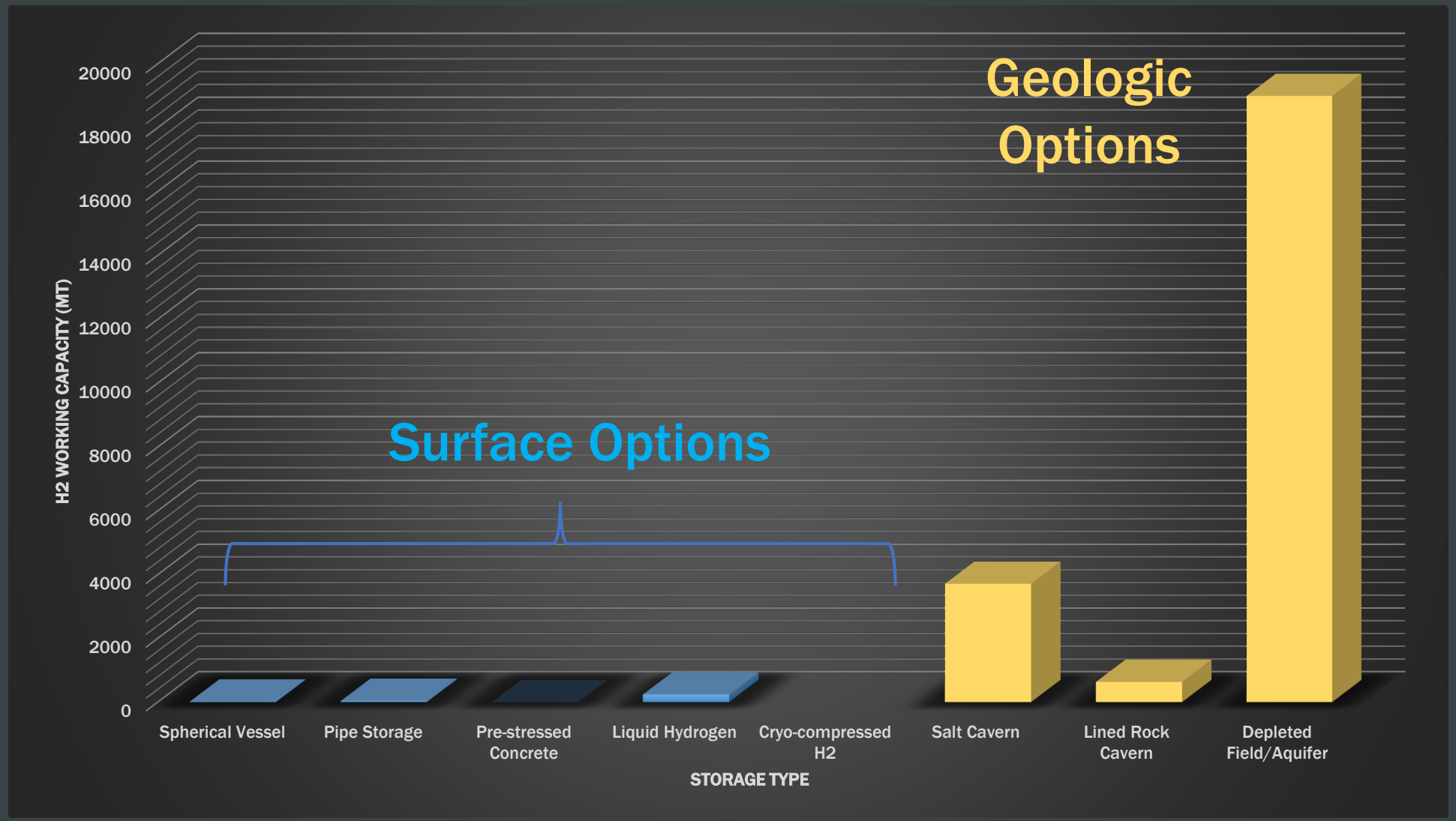
Bureau of Economic Geology

The University of Texas at Austin
Center for Subsurface Energy and the Environment
Cockrell School of Engineering

GeoH2

Sources: Alley, 2003; Johnson and Gonzales, 1978, Lord et al, 2014

Indicative H_2 Storage Options by Unit Capacity



Bureau of Economic Geology

Data from Ahluwalia et al, 2019

GeoH2

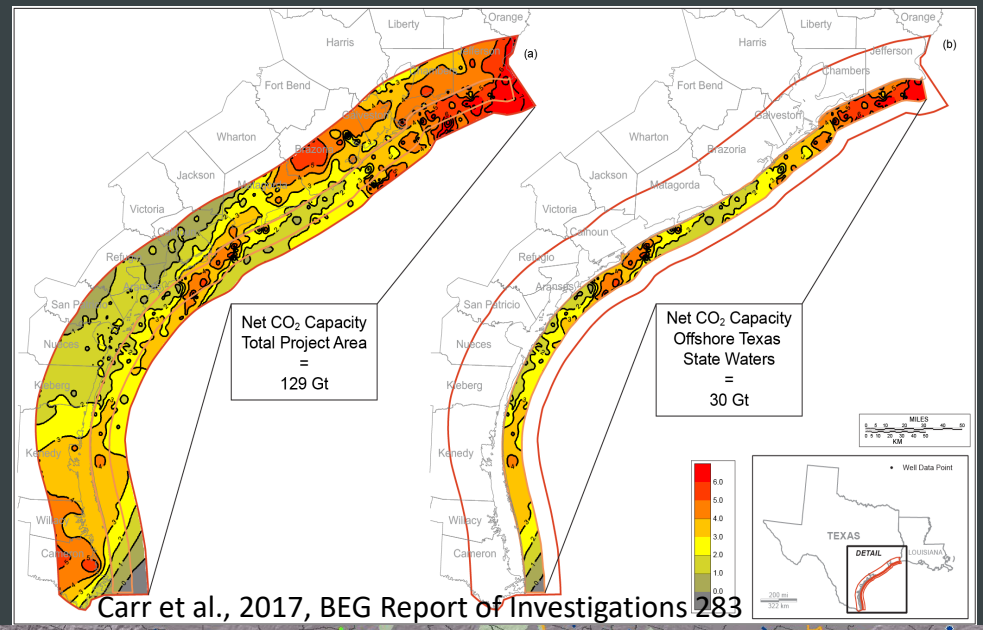
Bulk Geological Storage of H_2

Type	Status	Pros	Cons	Research Needs
Salt (dissolution) caverns	3 industrial H_2 storage sites in Texas; 1 in Scotland	• Lowest cost bulk storage • Proven technology • Rapid injection/production	• Limited geographic distribution of suitable salt deposits • Brine disposal • Limited size	• Resource assessment, expanded catalog of suitable sites • Screening criteria • Cost/life-cycle analysis
Depleted oil & gas fields	Untested for H_2 storage, proven for NG, natural gas/H_2 blends	• Wide geographic distribution • Suitability of sealing caprocks • Potential for stacked CCS	• H_2-reservoir interaction is not well understood • Integrity of abandoned wells • Oil/gas interaction	• Resource assessment, catalog of suitable sites • Screening criteria/best practices • Reservoir simulations • Chemical reactions • Geomechanics, risk analysis • Cost/life-cycle analysis • Pilot field tests
Aquifers	Untested for H_2 storage, proven for NG, natural gas/H_2 blends	• Widest geographic distribution • Potential for stacked CCS • Brine disposal	• H_2-reservoir interaction is not well understood • Suitability of sealing caprocks	
Lined rock cavern	Not in US, one site in Sweden	• Suitable for high-purity H_2 • Soft limestone in TX ideal	• Limited size • High CAPEX	• Cost/life-cycle analysis • Site characterization • Geomechanics

Integrated Subsurface Evaluation

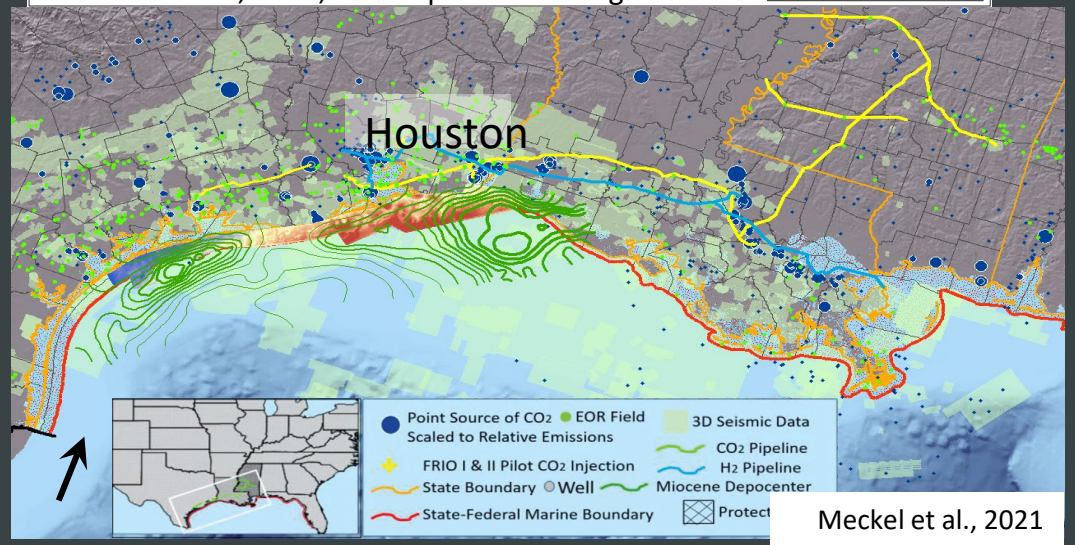
- Reservoir characterization for regional resource assessment
- Geophysics & petrophysics for trap-scale reservoir characterization
- Reservoir flow simulation—optimization of well geometry & injection/production strategy
- Seal & seismic risk analysis
- Techno-economic analysis
- Field test design
- Integrity monitoring

Storage Resource assessment – link H_2 and CCS



Carr et al., 2017, BEG Report of Investigations 283

Factoring in existing infrastructure

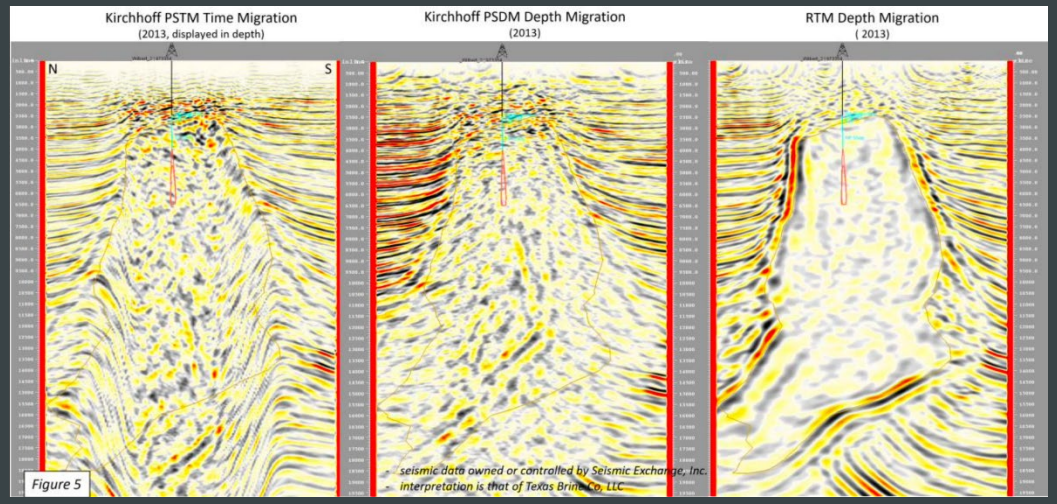


Meckel et al., 2021

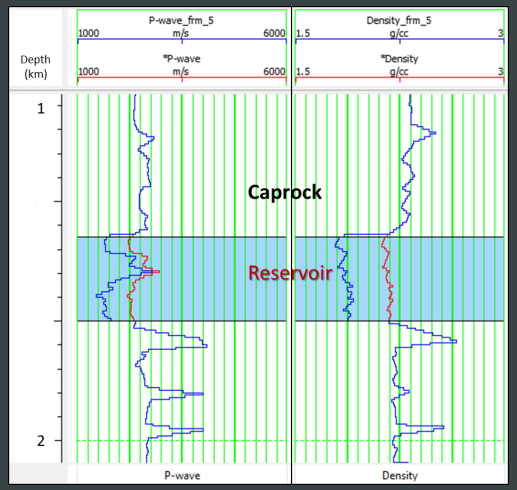
Bureau of Economic Geology

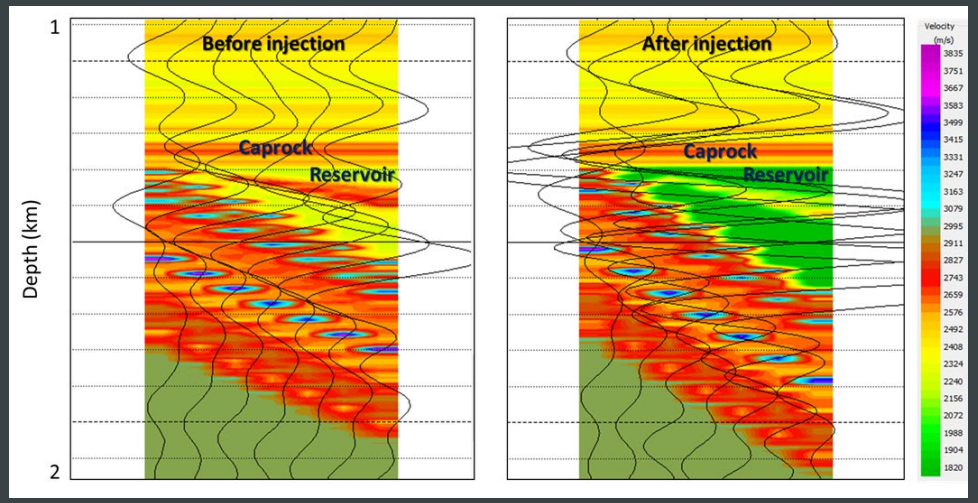
Geophysics for H_2 storage

- Use geophysical surveys and techniques to evaluate suitable reservoirs for H2 storage in the subsurface
- Integrate geology, geophysics, and reservoir engineering to estimate H2 storage capacity
- Monitor storage



Reverse Time Migration Thompson et al. (2021) SMRI





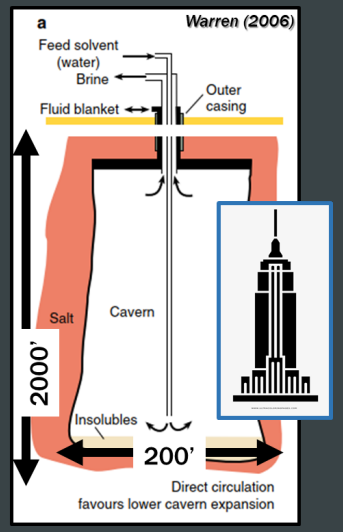
Synthetic seismic wedge model in sandstone reservoir Bhattacharya, 2021

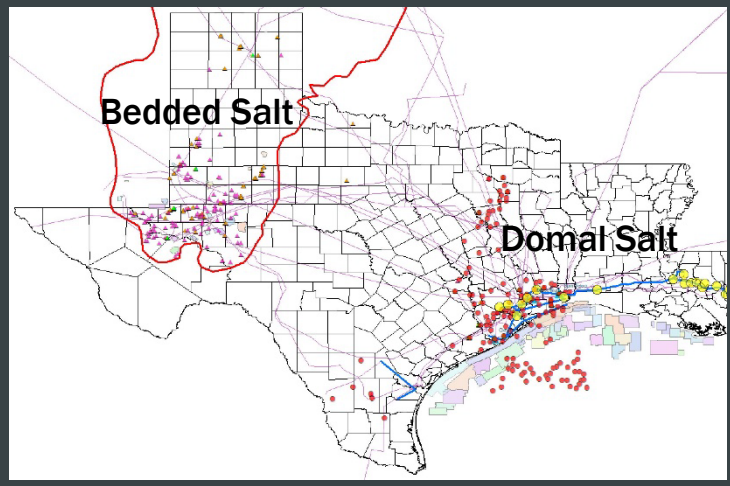
Bureau of Economic Geology

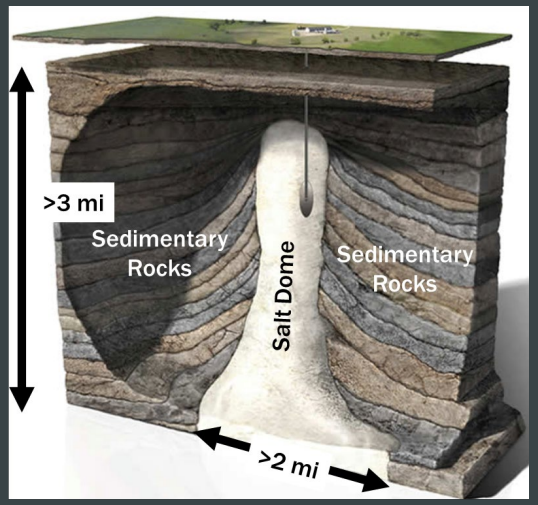
GeoH$_2$

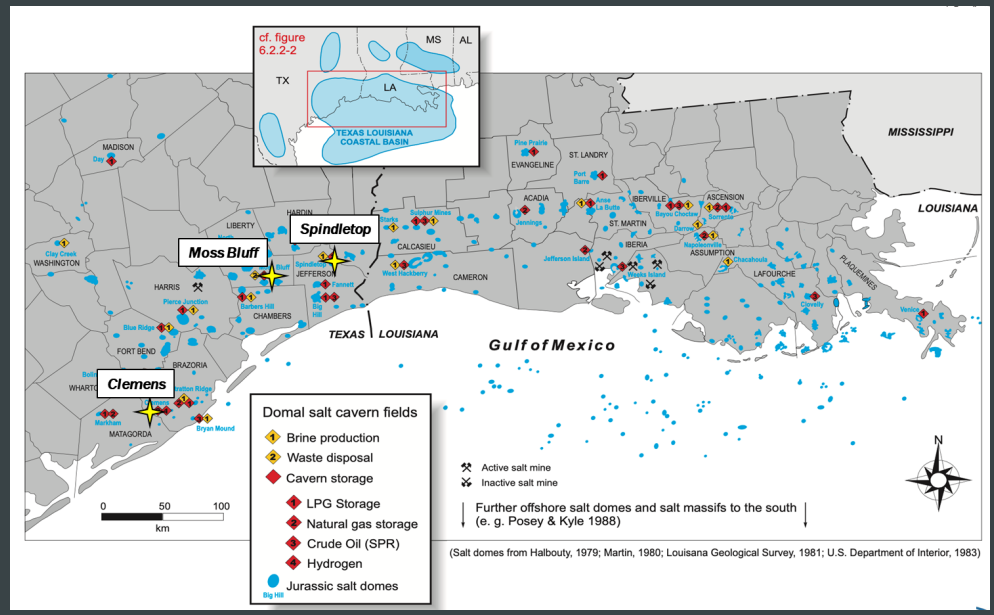
Hydrogen Storage in Salt Caverns

- Current H_2 subsurface storage method in the onshore Texas Gulf Coast
- Need to improve our ability to predict internal shear zones/impurities to maximize placement of caverns in salt domes
- Understand feasibility of H_2 storage in caverns in bedded salt





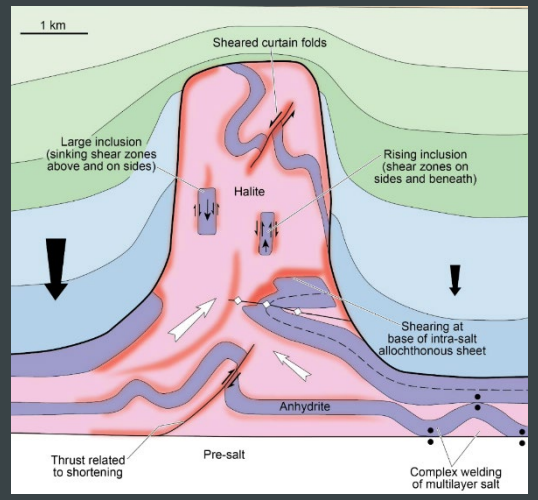




Bureau of Economic Geology

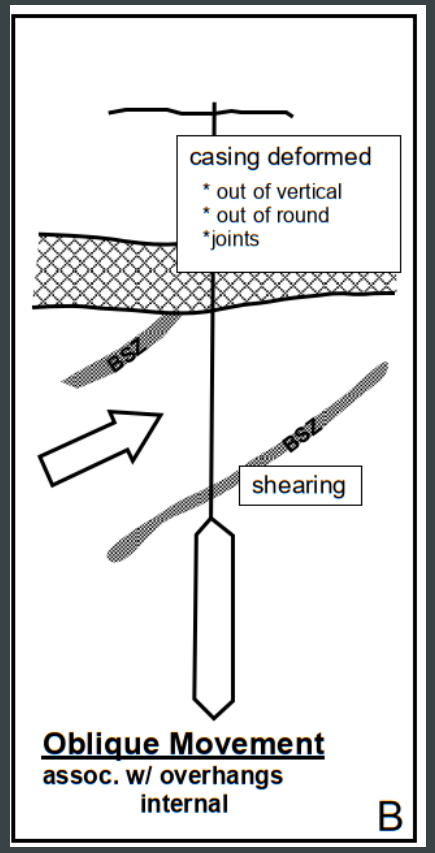
https://www.domeenergy.com/understanding-salt-domes/ *Los Angeles Department Water and Power*

Predicting Heterogeneities in Domal Salt



Duffy et al. (in prep.) BEG

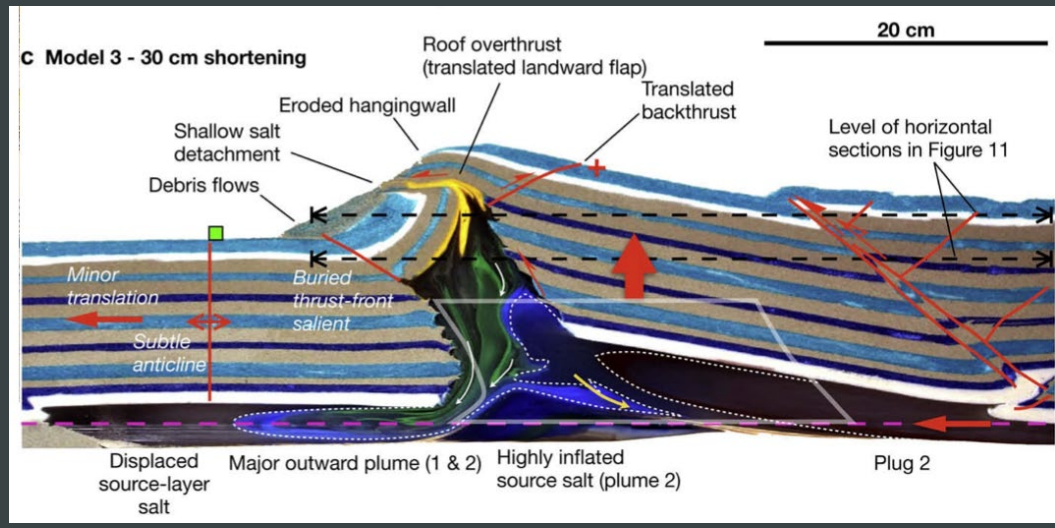
STARR
State of Texas Advanced Resource Recovery



Karl et al. (2010)

Caverns that intersect intra-salt bodies or shear zones are prone to (1) salt falls, (2) cavern failure, (3) well damage and (4) gas outbursts

(1) Physical modelling
(2) Numerical modelling
(3) Seismic-based mapping



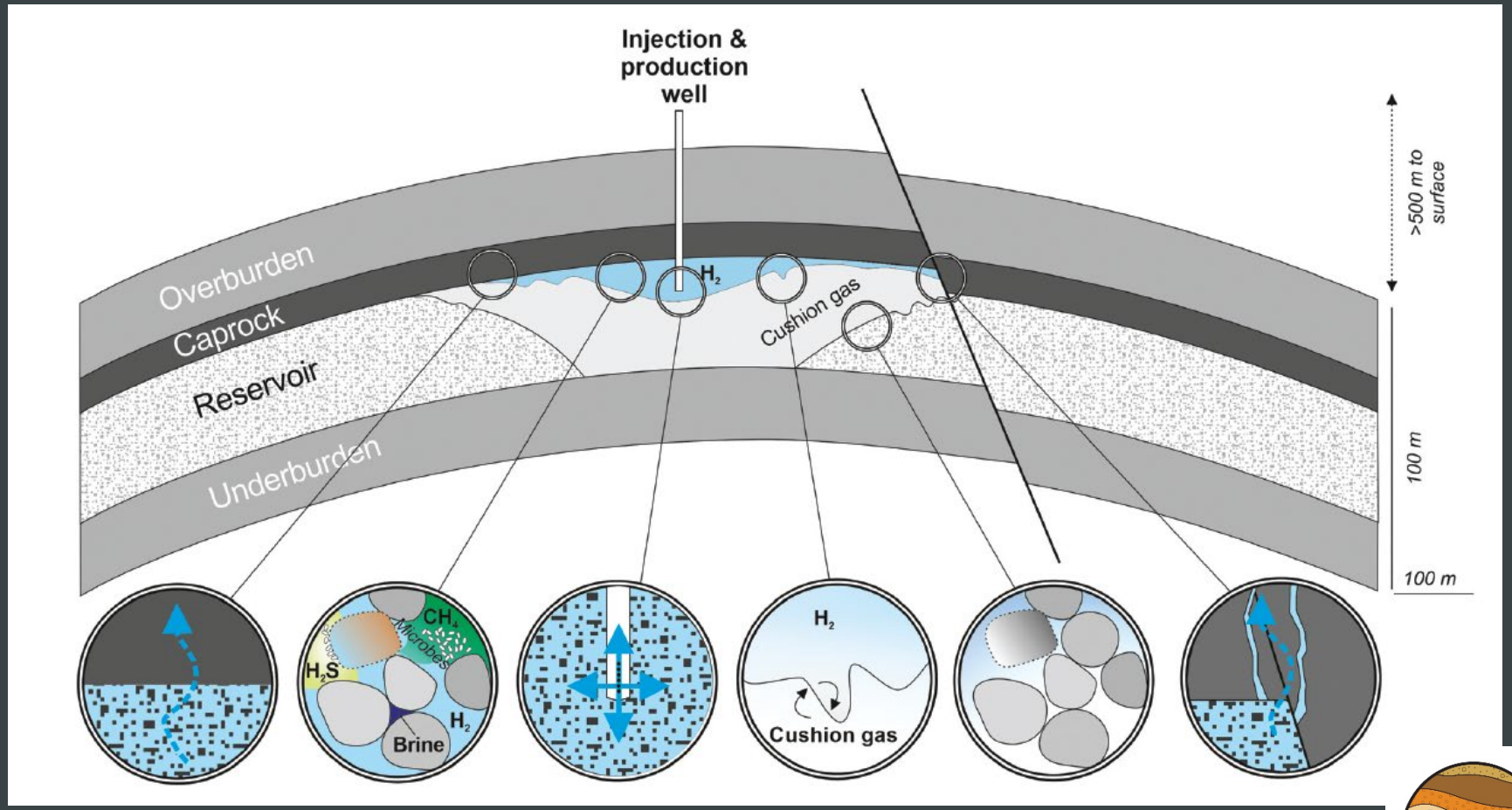
Physical model by Dooley et al. (2009) AGL

Bureau of Economic Geology

GeoH2

Hydrogen Storage in Porous-media Reservoirs (Depleted Fields and Saline Aquifers)

- Leakage
- Fluid-rock interactions
- Injection/production
- Gas-gas and gas-brine interactions



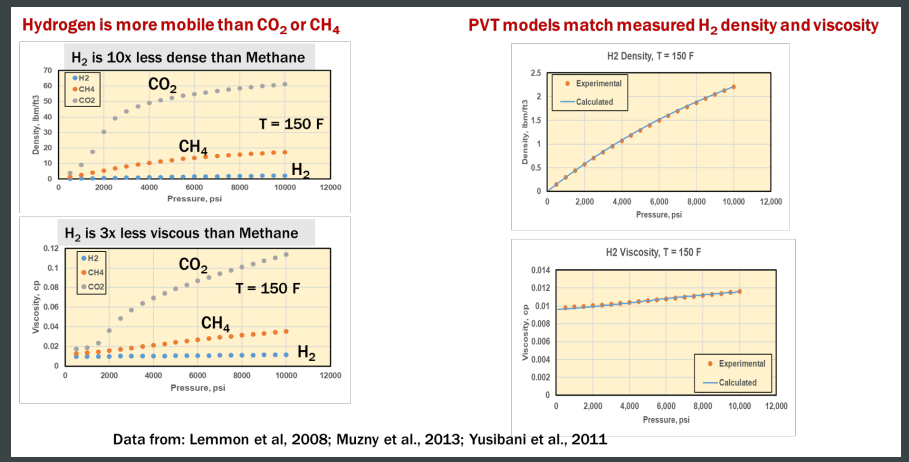
Source: Heinemann et al, 2021 Energy Environ. Sci., 2021,14, 853

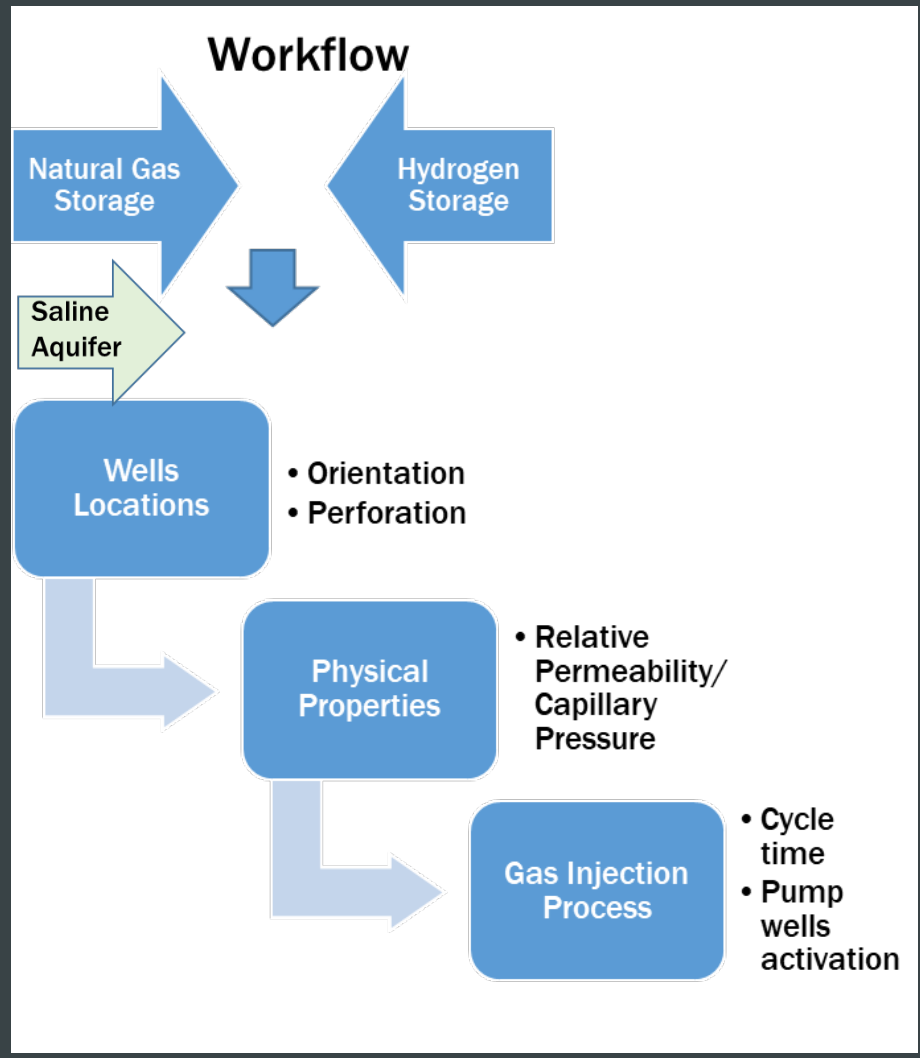
Bureau of Economic Geology

GeoH2

Reservoir Simulation Workflow

- Validate the PVT model against measured H_2 properties (density, solubility, and viscosity)
- Use calibrated history matched dynamic geological models:
- Compare storage results of H_2 with NG and CO_2
- Sensitivity cases and optimize H_2 storage

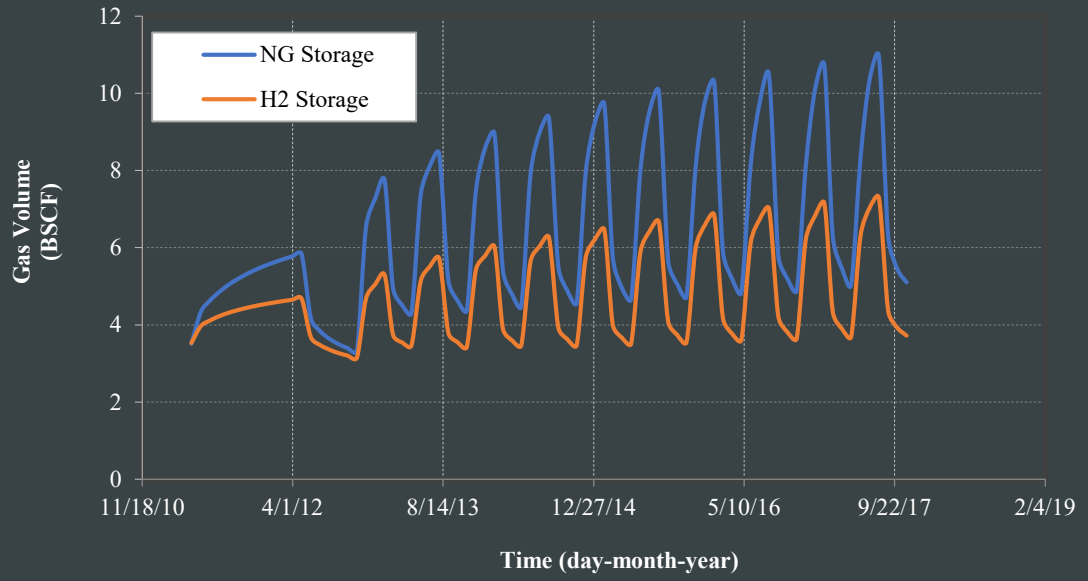




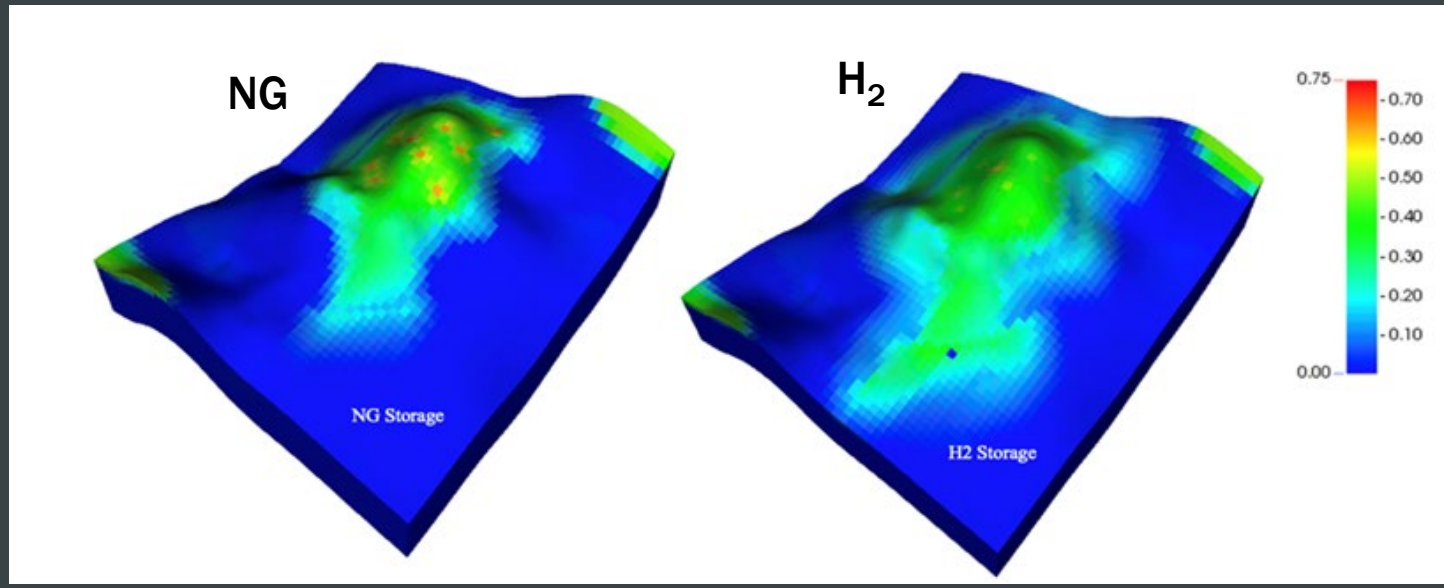
From Delshad, 2021 unpub.

Compare H_2 vs. NG Storage

Gas volumes stored in the reservoir



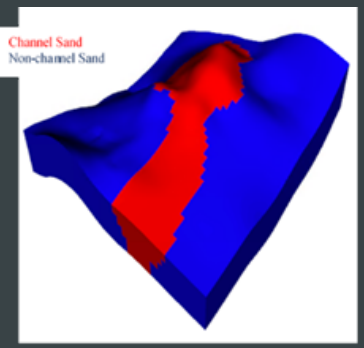
Gas saturation after the last injection cycle



Compared to NG

- 10% less H_2 volumes injected due to well constraints (H_2 higher insitu pressure)
- 32% less working gas capacity
- 3% higher average H_2 saturation in the top layer

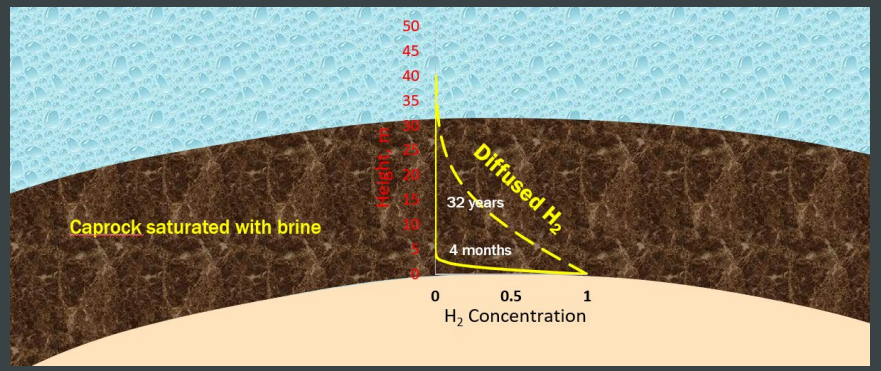
Need to optimize storage for H_2 due to its different properties



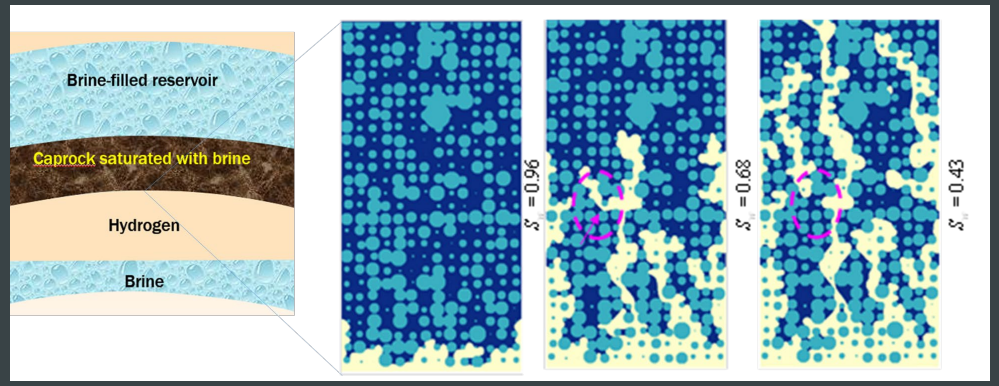
From Delshad, 2021 unpub.

Risk analysis: Leakage potential, top seal integrity & induced seismicity

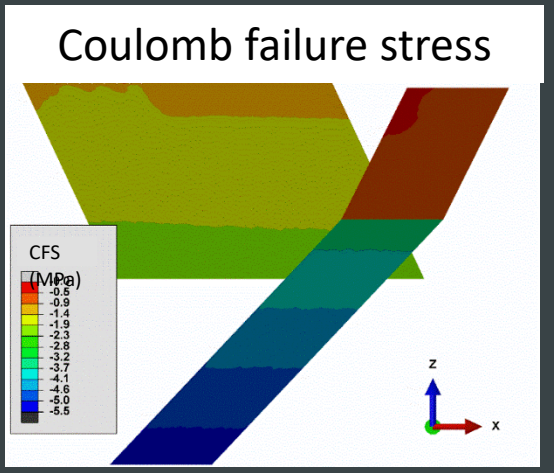
- Diffusion into seal/caprock
- Two-phase flow into seal
- Chemical interaction with top seal may affect chemically aided fracture growth & fault reactivation
- Risk of seal failure by fracture growth & fault reactivation



Diffusion modeling



Two-phase flow modeling



Calculation of fault failure stress

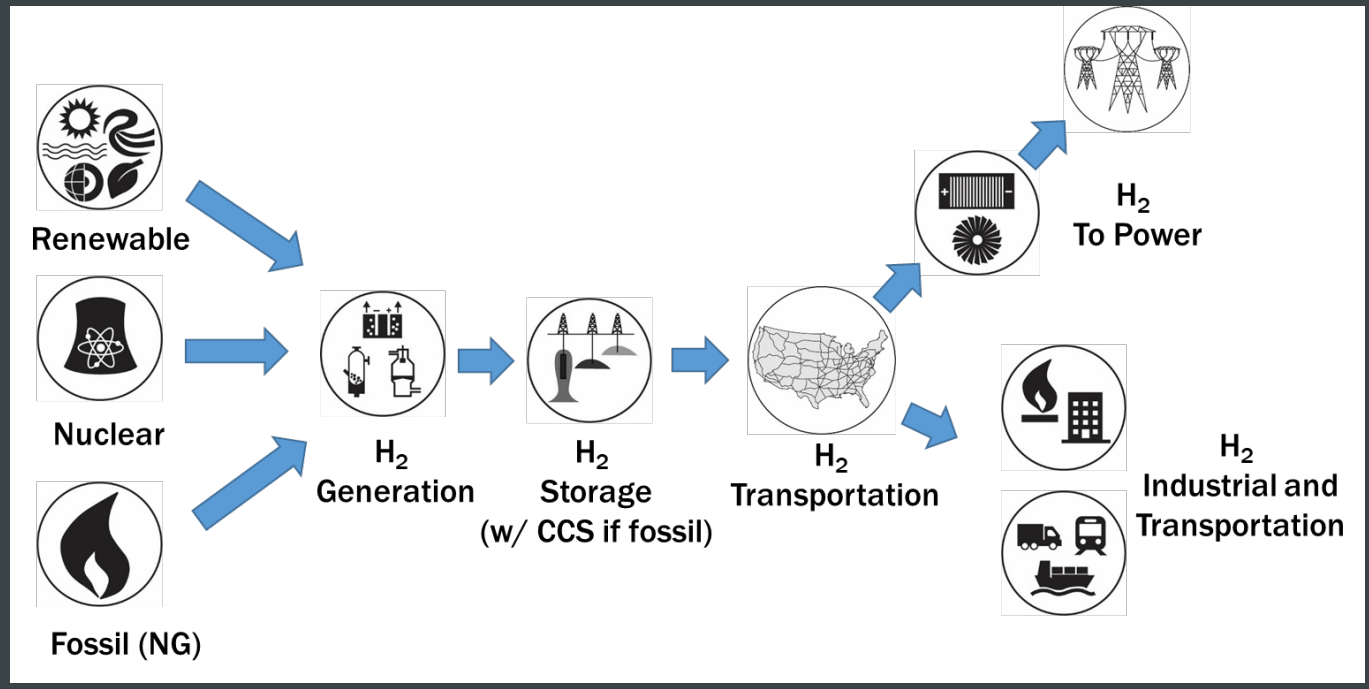
Hydrogen Value Chain Analysis

What is the optimized infrastructure buildout for scaling up a hydrogen sector as part of the energy system?

- *What are the optimum storage and transportation options for various market scenarios ?*
- *Interconnection and tradeoff of the new technologies versus existing options?*
- *Opportunities for conversion of oil and gas infrastructure to hydrogen*

Supply ?
Location?

Demand ?
Usage ?



- Many scenarios…many questions

Infrastructure ?
Storage ?
Salt cavern ? Depleted Field ? Saline Aquifer ?

Bureau of Economic Geology

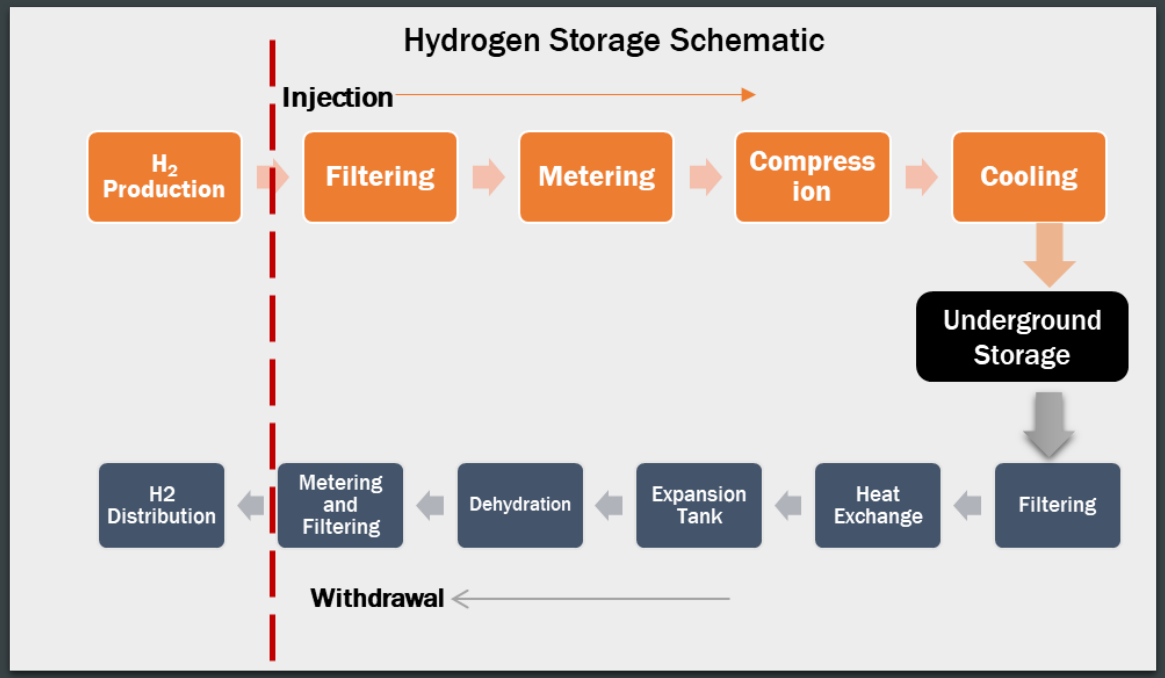
The University of Texas at Austin
Center for Subsurface Energy and the Environment
Cockrell School of Engineering

GeoH$_2$

Techno-economic analysis
Storage value and cost modeling

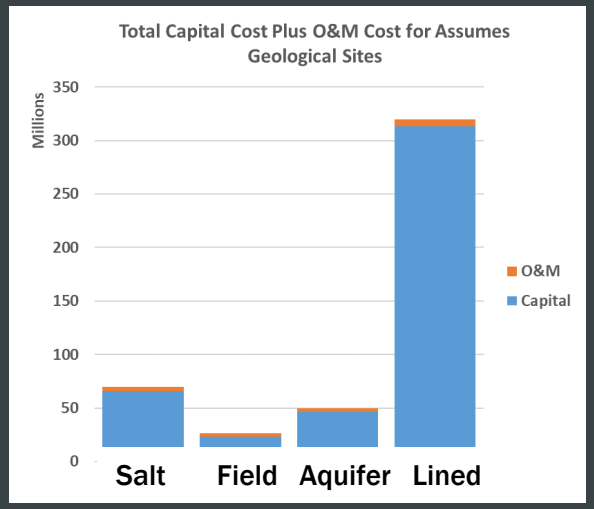
Estimate total demand for H_2 as energy carrier and investment cost and return for H_2 storage using demand scenarios.

- *Input: Storage process cost and capacity parameters / Demand assessment (prices and demand quantity)*
- *Output: Cost estimates of H_2 storage / Valuation of H_2 storage project (Net Present Value, Internal Rate of Return)*

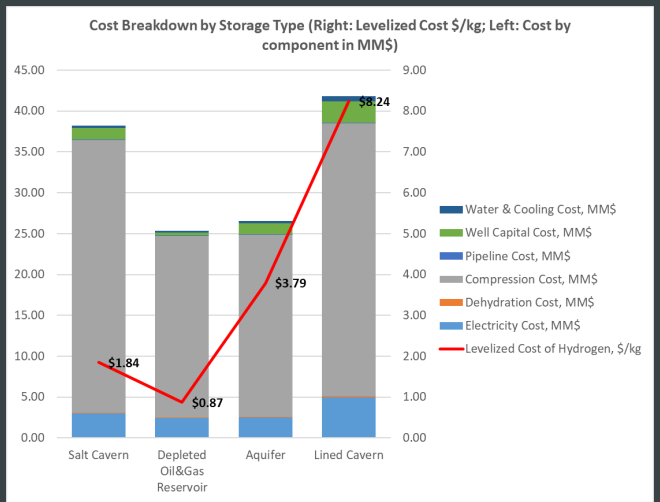


Calculations for West Texas
Araque & Lin, unpublished

Total Cost by Site



Cost Breakdown by Storage Type



Bureau of Economic Geology

Thank You !

Contact:

Mark Shuster
Deputy Director
PI, $GeoH_2$
mark.shuster@beg.utexas.edu

Peter Eichhubl
Senior Research Scientist
Co-PI, $GeoH_2$
peter.eichhubl@beg.utexas.edu