OTD
Operations
Technology
Development

Geological storage of hydrogen as a large-scale energy storage solution

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80 Year History of Turning Raw Technology into Practical Energy Solutions

400+
EMPLOYEES

World-class piloting facilities headquartered in Chicago area

Collaborative Organizations and Programs

Working with utilities to address critical challenges

OTD Operations Technology Development	UTD Utilization Technology Development	ETP Emerging Technology Program	LCRI LOW-CARBON RESOURCES INITIATIVE

OTD Members

Serving 50 million gas consumers in the U.S., Canada and France

Research Foundation	Southern California Gas Company A Sempra Energy utility	PG&E Pacific Gas and Electric Company	ATMOS energy	SOUTHWEST GAS
Ameren FOCUSED ENERGY. For life.	conEdison	CenterPoint. Energy	Entergy	PEOPLES GAS NATURAL GAS DELIVERY
INTERMOUNTAIN GAS COMPANY A Subsidiary of MDU Resources Group, Inc.	NYSEG RG&E	National Fuel	AVISTA	NiSource
NW Natural We grew up here.	Dominion Energy	Oklahoma Natural Gas A Division of ONE Gas	ENBRIDGE	Washington Gas A WGL Company
Nicor Gas	TECO PEOPLES GAS AN EMERA COMPANY	DUKE ENERGY	spire	nationalgrid
Liberty	BH Black Hills Energy	GRDF GAZ RÉSEAU DISTRIBUTION FRANCE		

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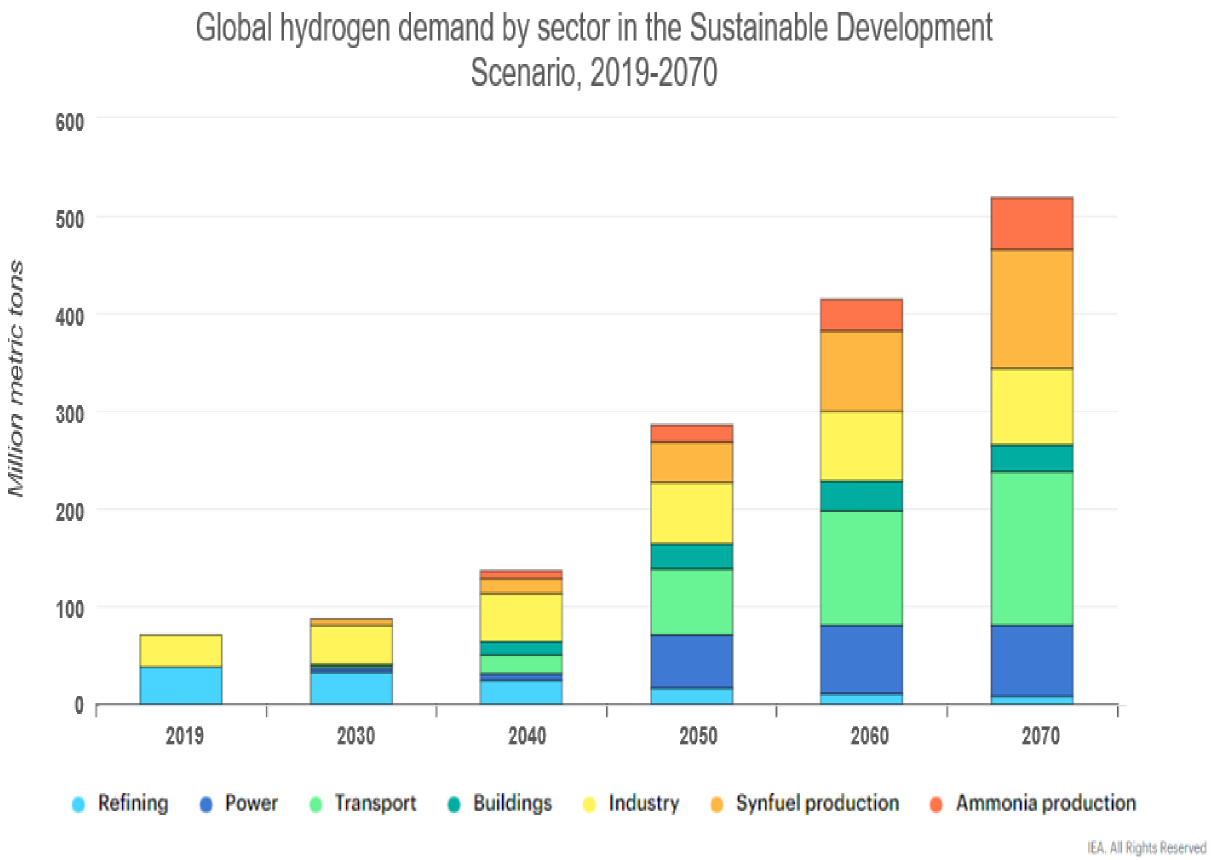
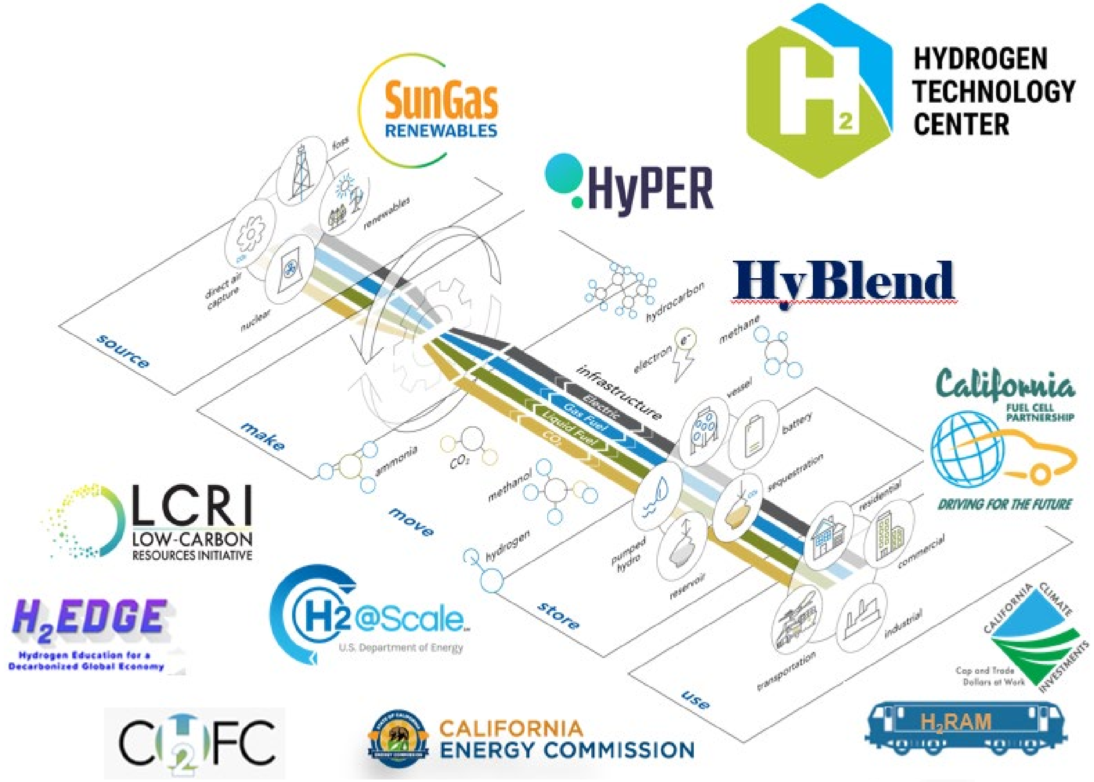
Growing demand for hydrogen



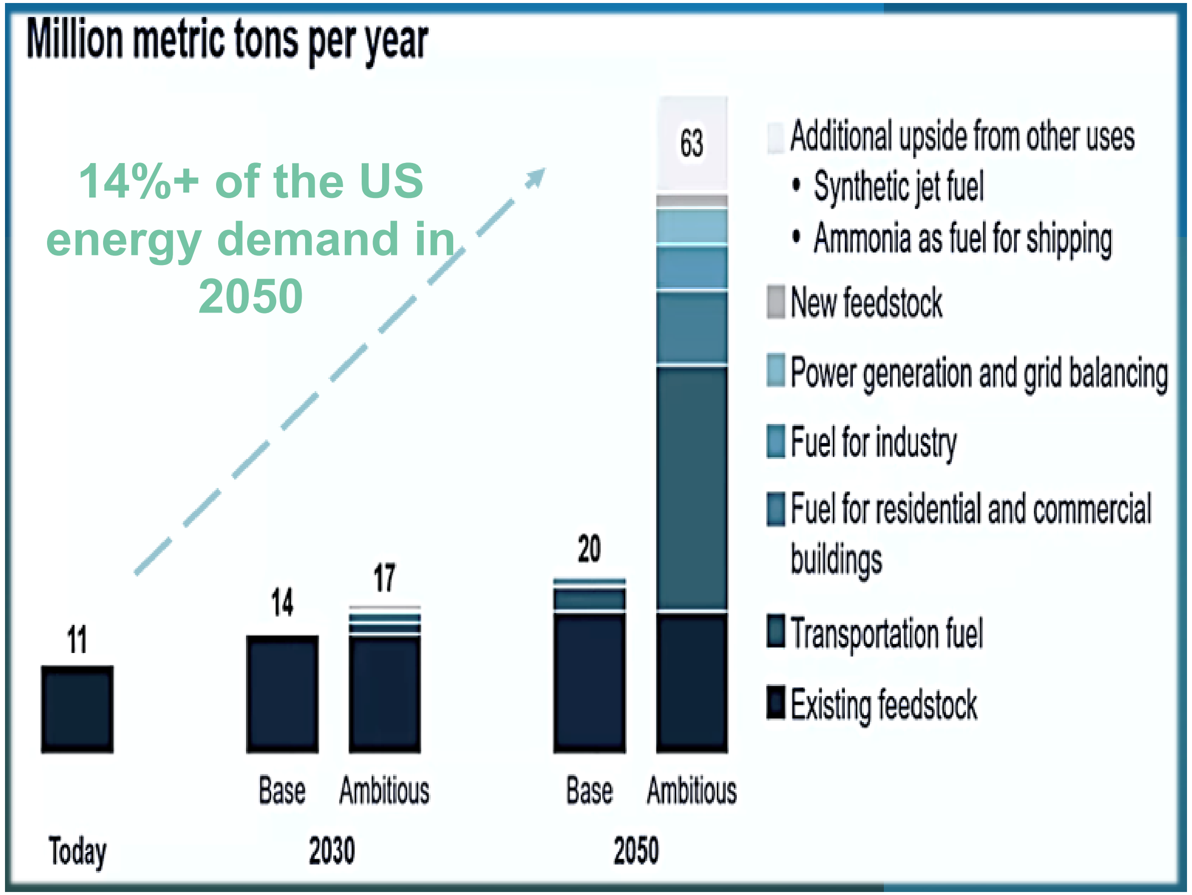
Source: [IEA Data & Statistics]

Low-Carbon, Low-Cost Hydrogen Energy Systems



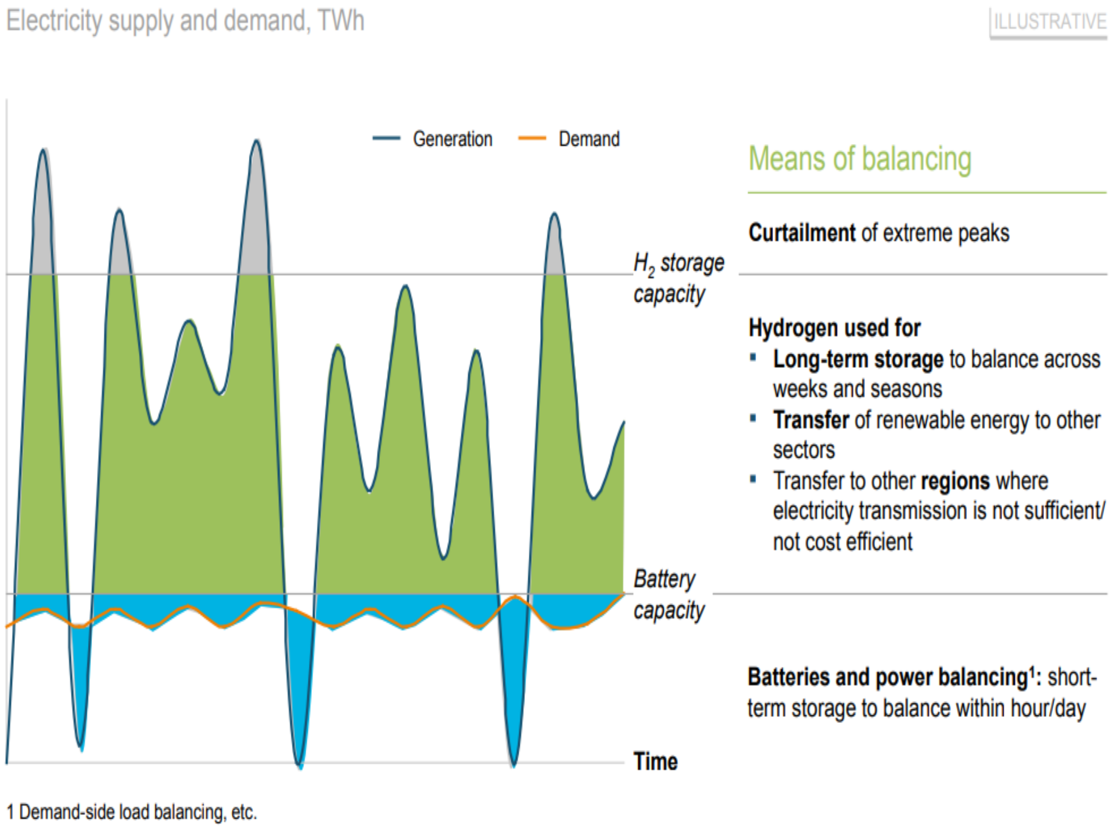
[https://www.gti.energy/hydrogen-technology-center/]

The need for storage



Source: Road Map to a US Hydrogen Economy ushydrogenstudy.org

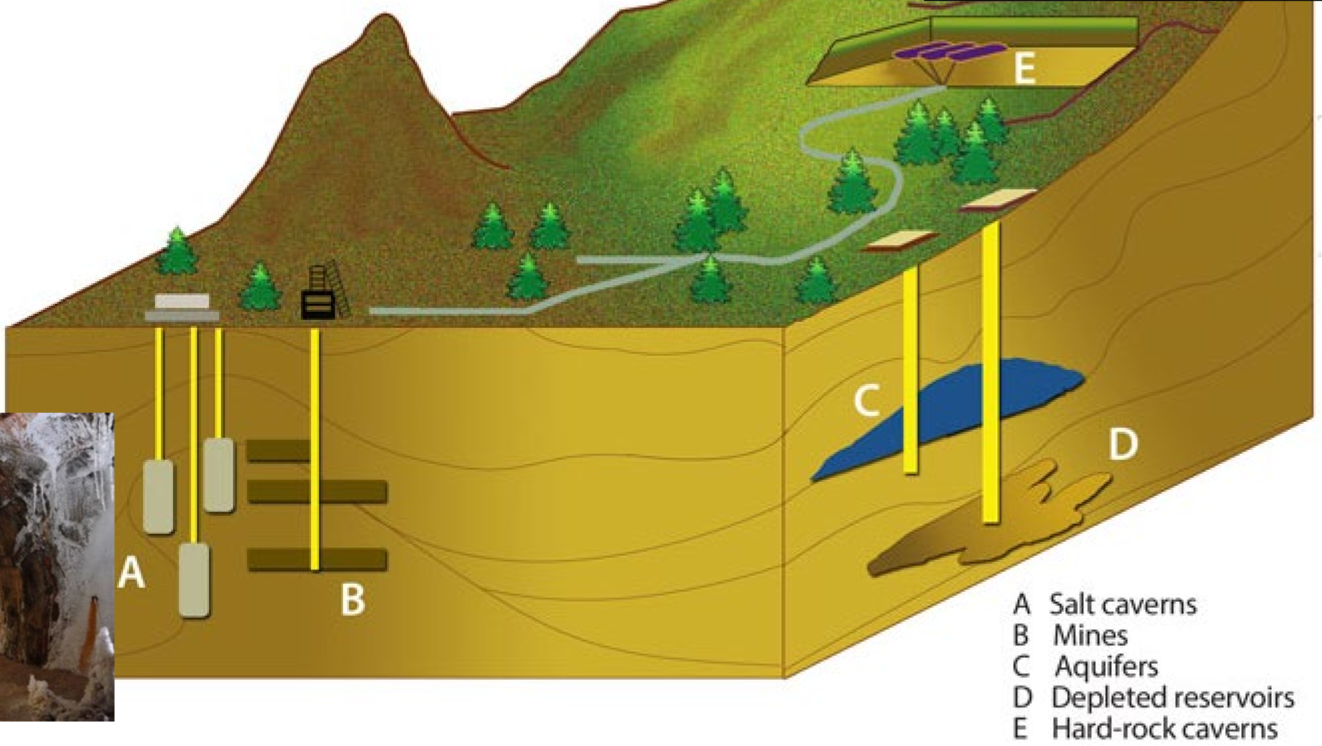
Hydrogen storage bridges gaps in supply and demand



Source: Hydrogen Council, 2017

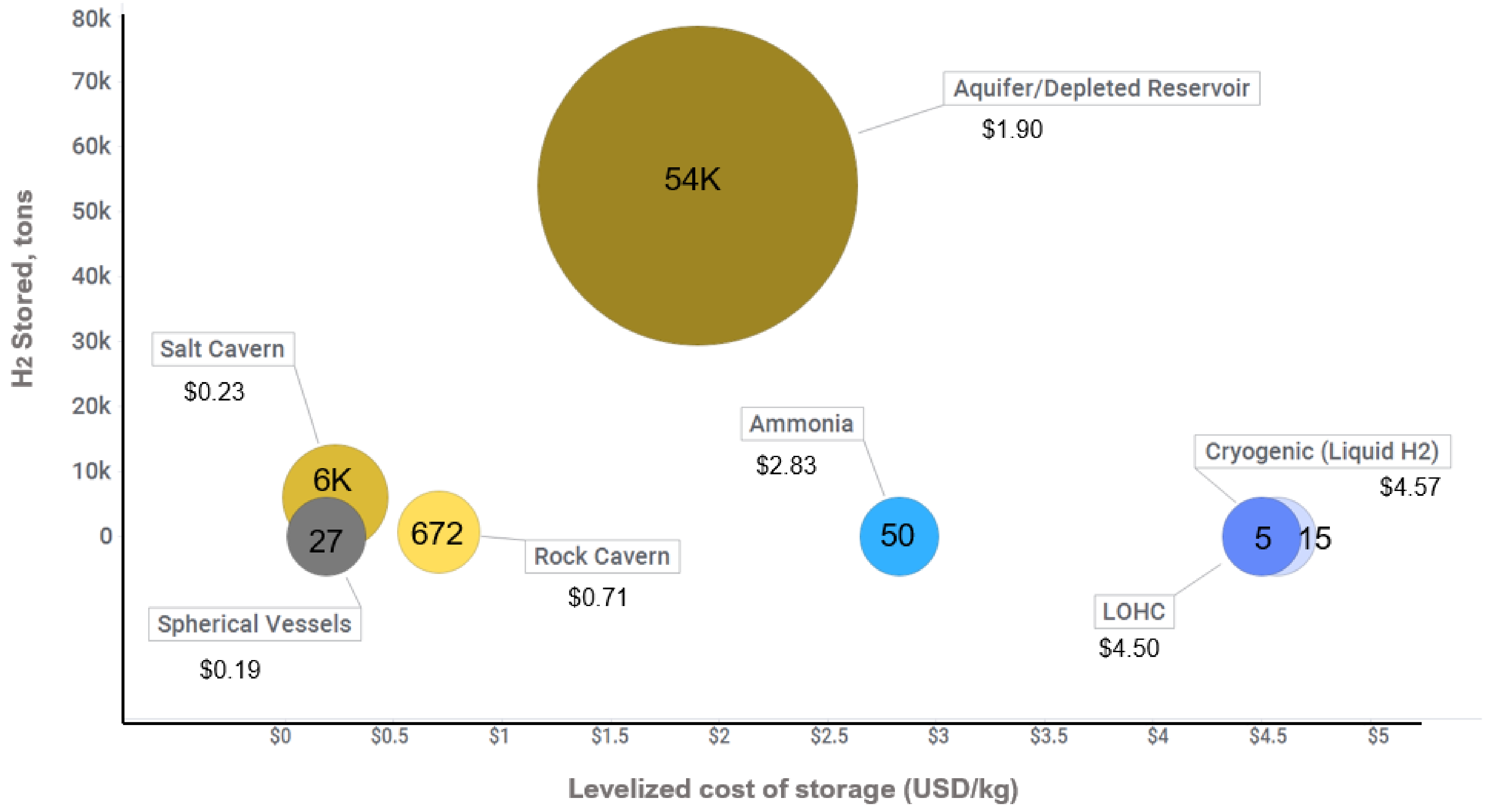
Geological storage

- Salt caverns
- Depleted reservoirs
- Deep Saline aquifers
- Mines & hard rock caverns



Source: [EIA]

Hydrogen storage options



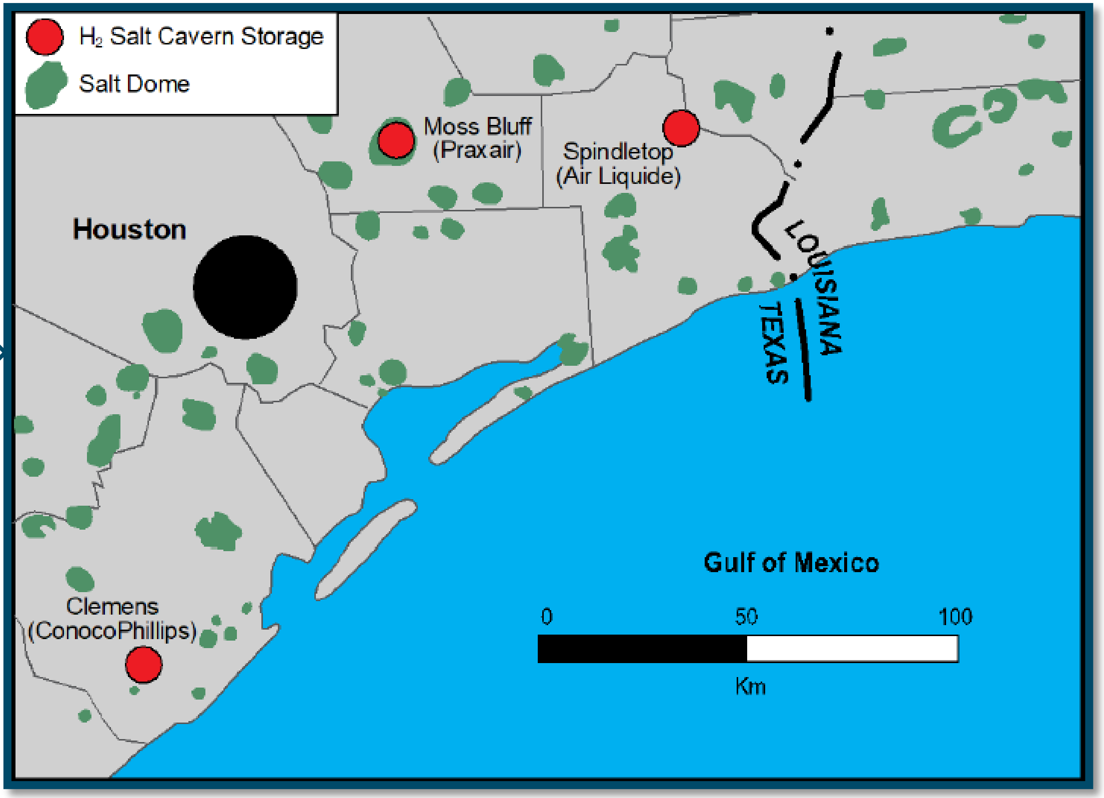
Source(s): U.S. DOE Hydrogen and Fuel Cells Program, NREL & GTI, Bloomberg New Energy Finance

Geological storage:

- salt caverns preferred method to date – efficiency, purity, high pressure operation
- Aquifers and depleted oil fields require further research

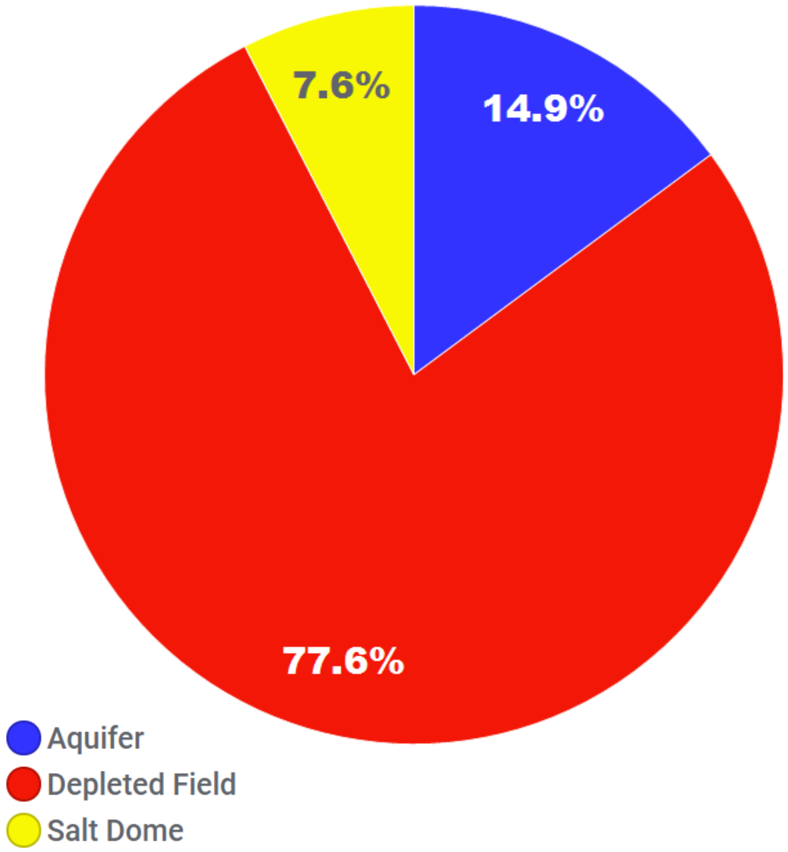
Geological storage of hydrogen- Experience

	Type	Gas (%)	p/T	Volume (m^3)	Capacity (sm^3)	Depth (m)	Start-up	Status
Germany								
Ketzin	Aquifer	CO_2 62 % H_2	-	-	-	200-250	-	closed
Kiel	Salt cavern	62 % H_2	80-100 bar	32,000	-	-	-	operating with natural gas
United Kingdom								
Teesside	Salt cavern	95 % H_2 3-4 % CO_2	50 bar	-	1.000.000	400	1959	operating
USA								
Spindletop	Salt cavern	95 % H_2	-	-	-	-	-	operating
Clemens Dome	Salt cavern	95 % H_2	70-135 bar	580,000	30.000.000	850	1980s	operating
Moss Bluff	Salt cavern	-	-	-	-	-	-	operating
France								
Beynes	Aquifer	50 % H_2	-	-	385.000.000	430	1956 - 1972	operating with natural gas
Czech Republic								
Lobodice	Aquifer	50 % H_2 25 % CH_4	90 bar / 34°C	-	-	430	1965	operating
Argentina								
Diadema (Hychico)	Depleted gas reservoir	10 % H_2	10 bar / 50°C	-	-	600	2009	-
Austria								
Underground Sun Storage	Depleted gas reservoir	10% H2	78 bar / 40 °C		1.150.000	1000	2015 - 2017	operating

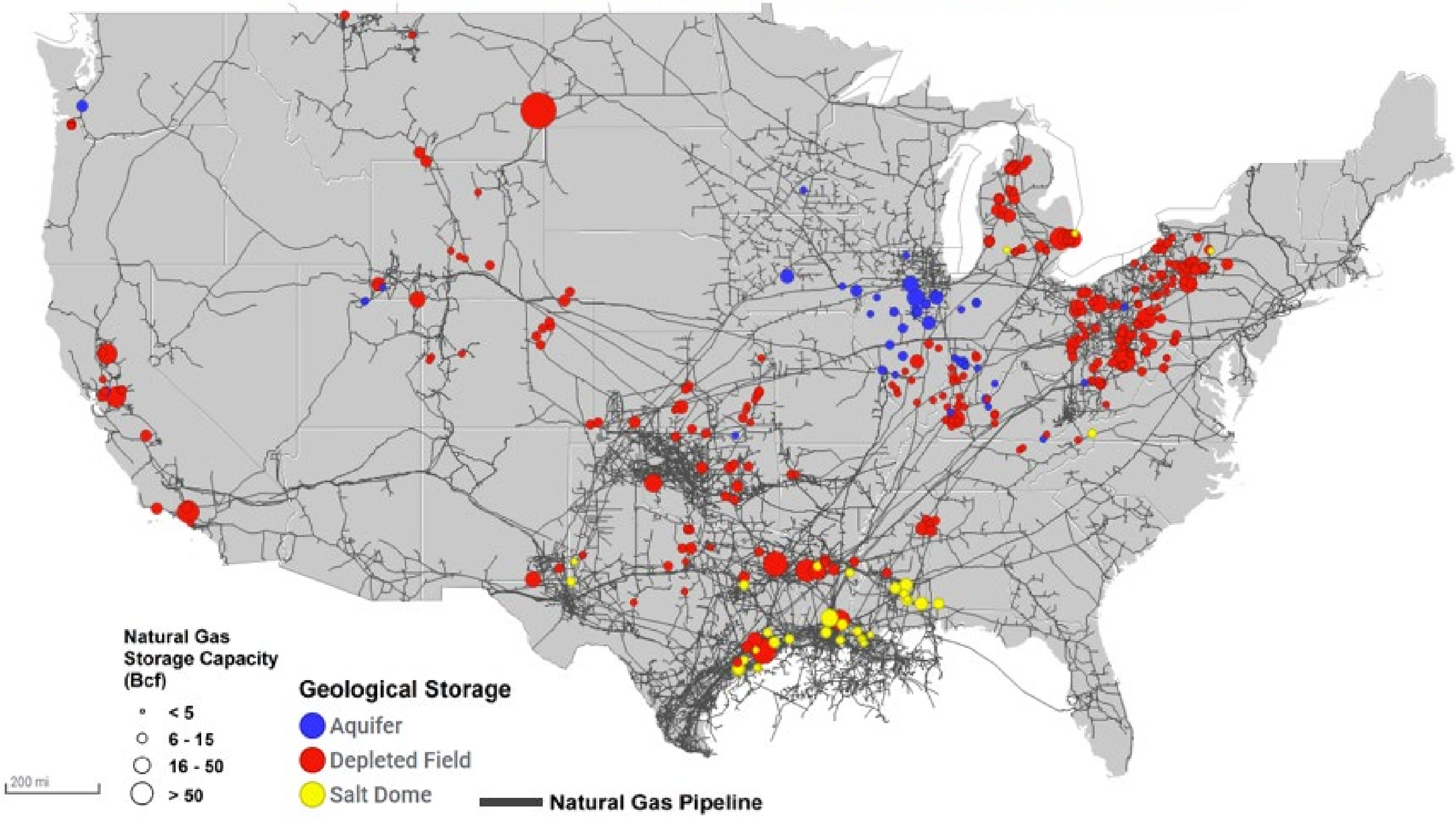


Natural Gas storage- The United States

Total storage capacity distribution



US natural gas pipeline and underground storage sites



Source: EIA

Comparison

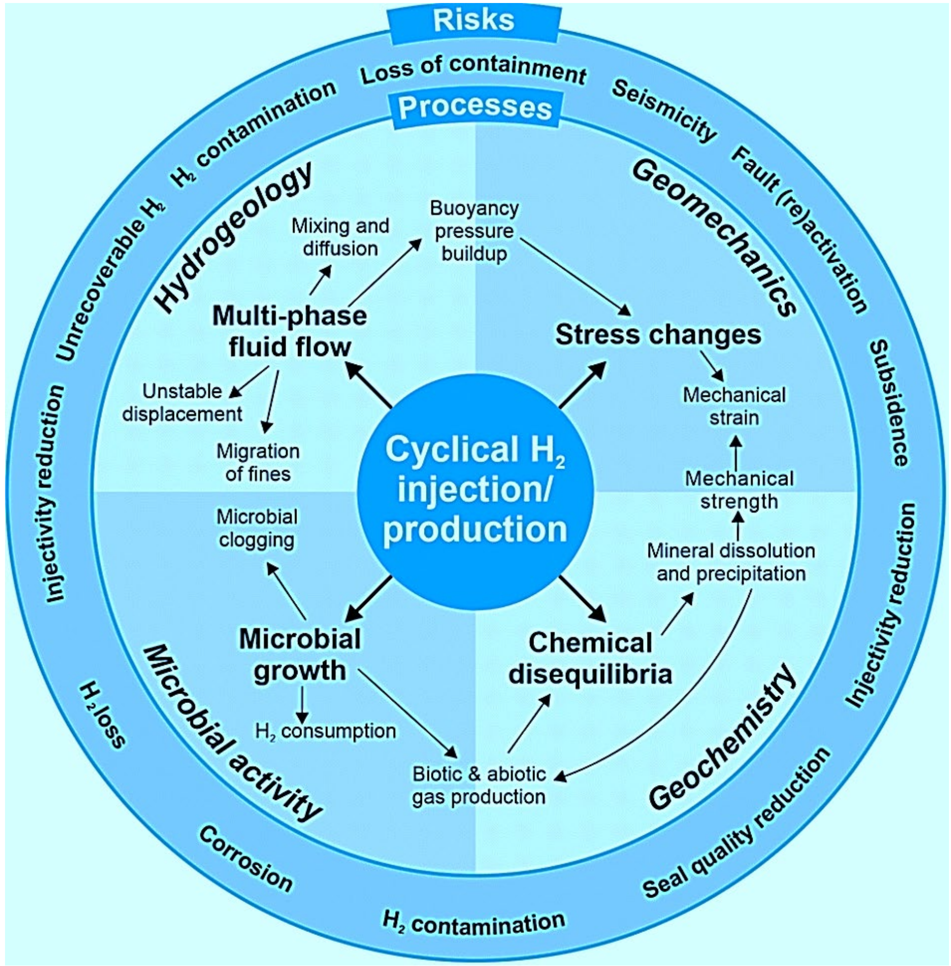
Natural Gas Storage Experience

Advantages	Disadvantages
Depleted Reservoirs	
Use of existing reservoir	**Low deliverability per well**
Geographical availability, knowledge of reservoir (geology, performance)	Maximum (0.5–1)% daily withdrawal of total capacity
Low investment costs for conversion	Maximum 1–2 turnovers per year. low deliverability and injectivity
Possibility of reusing existing wells	High percentage of cushion gas
Aquifer	
Use of existing reservoirs	**Need extensive, costly, and time-consuming exploration phase**
No hydrocarbon residues in reservoir to cause contamination	Low deliverability per well
	Maximum (0.5–1)% daily withdrawal of total capacity
	Maximum 1–2 turnovers per year
	Low deliverability and injectivity
	High percentage of cushion gas
Salt Caverns	
High safety due to only one well per storage cavern	Need for exploration phase
Low geological risk	**Limited geography, limited volume**
High flexibility, maximum 10–12 turnovers per year	Several years construction time
High deliverability and injectivity/high rates	Need to dispose large quantities of salt brine
Low percentage of cushion gas	
No reactions between storage gas and rock salt	

Research needs

- ➢ Caprock sealing and containments
- ➢ Geochemical reactions
- ➢ Biological reactions
- ➢ Multi-phase flow/Geomechanical

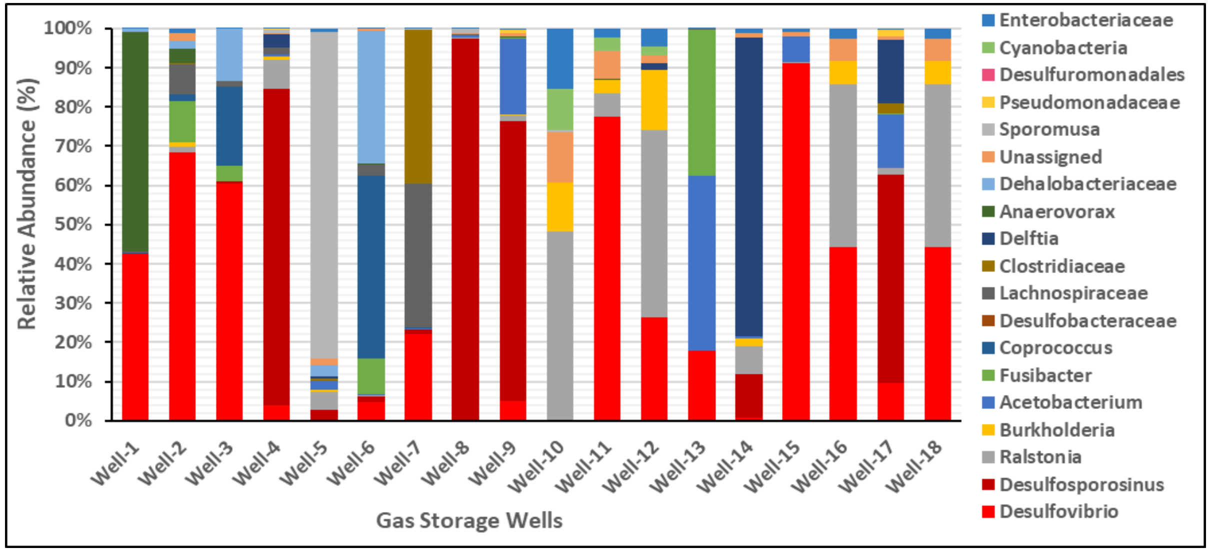
Site Screening Workflow



Source: Heinemann et al., 2021

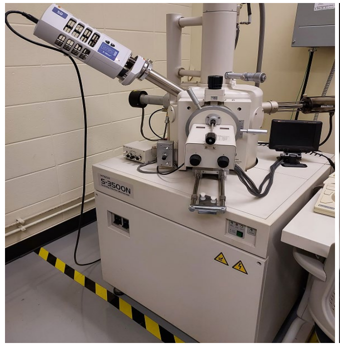
Ongoing Research and Development

1. Select best environments with undesirable conditions for microbial activities and analyze injected fluids
2. Regular monitoring of changes in microbial composition
3. Microbial inhibitory compounds
   - ➢ Metabolic inhibitors (nitrate application)
   - ➢ Biocides (needs to be screened based on reservoir characteristics)



Distribution of microbial communities in different gas storage wells: source GTI's OTD report (22227)


Geochemical analysis
- Gas analysis
- Hydrocarbon analysis
- Fluid/wet chemistry
- Fuels analysis



Biological analysis
- qPCR
- 16S sequencing
- Metagenome sequencing
- Microscopic counting


Biocorrosion analysis
- Bioreactors(high temperature and pressure)
- Coupon weight loss
- Microscopic analysis
- Biofilm analysis

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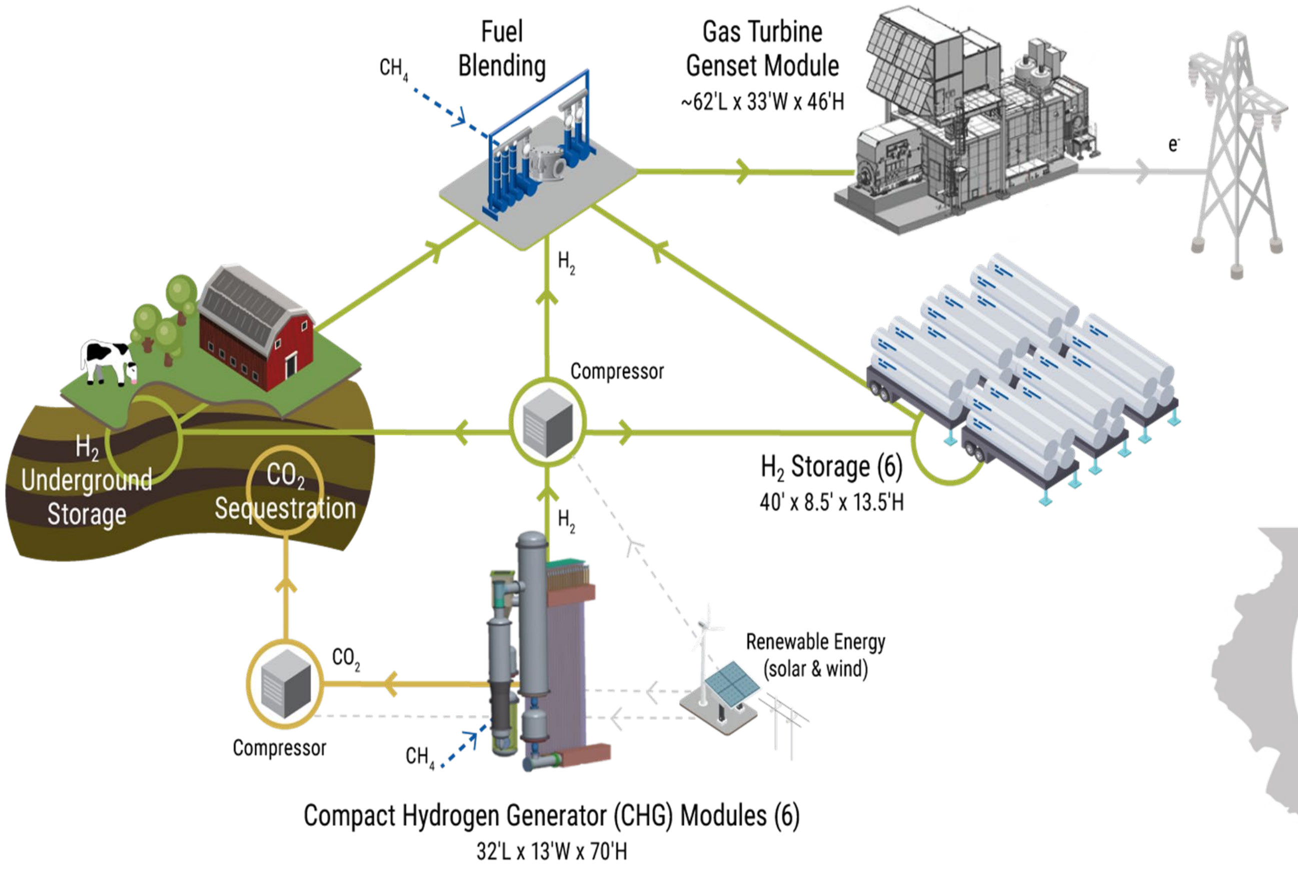
Non-salt storage pilot

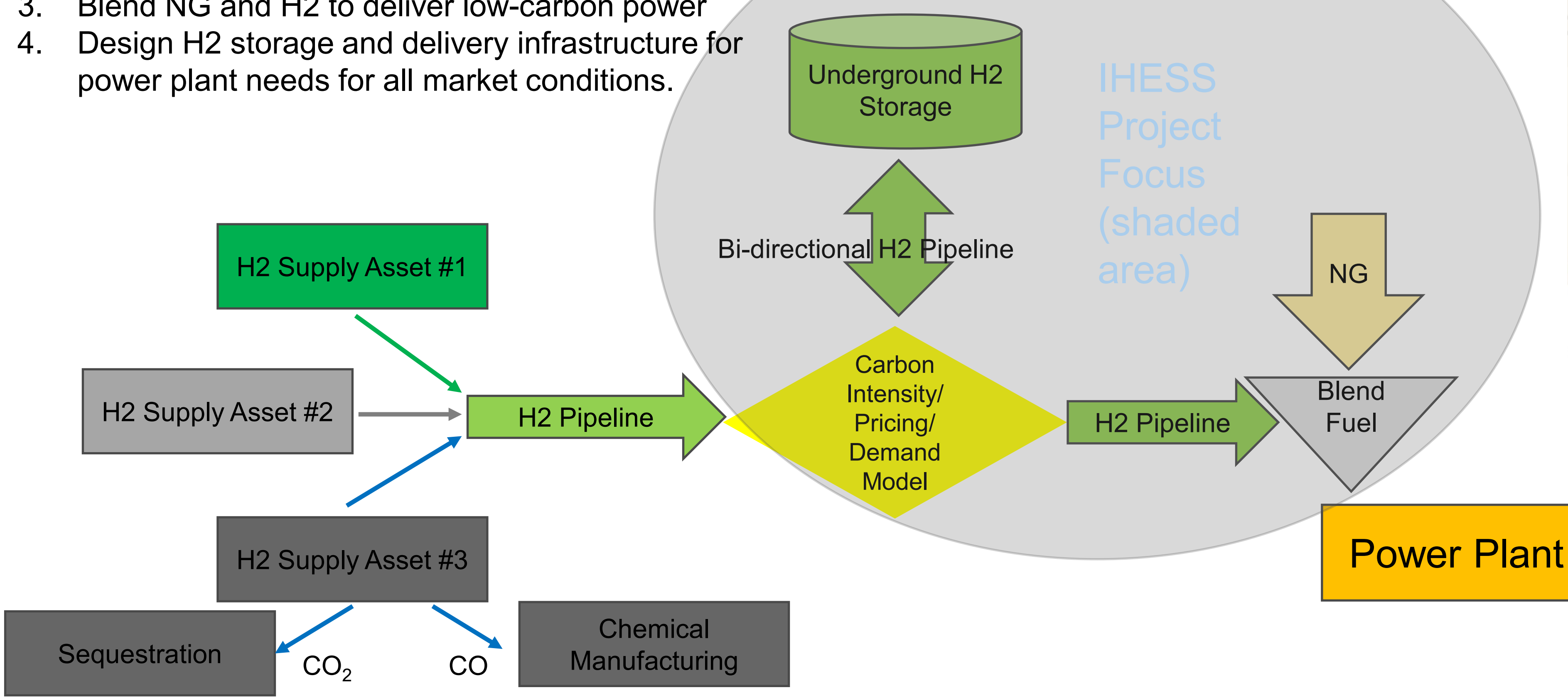


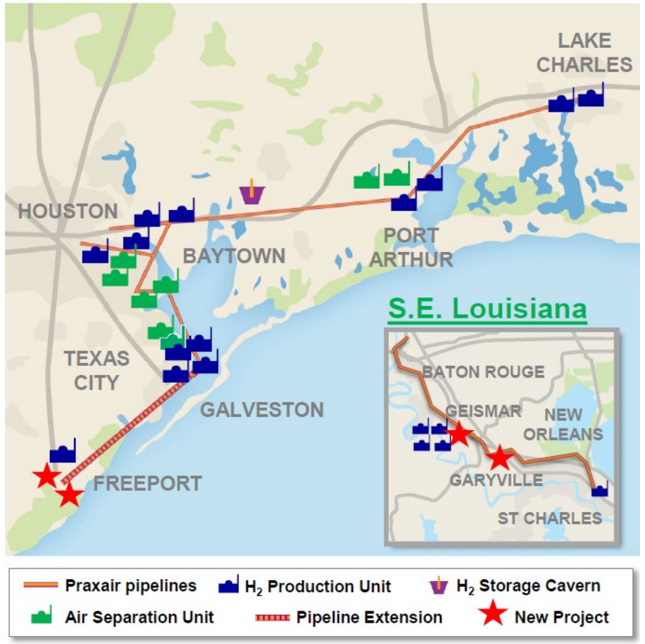
The energy storage and production system provides the platform to further test, perfect and integrate the components for larger commercial deployment in support of zero-carbon, centralized power production

OTD Operations Technology Development

Integrated Hydrogen Energy Storage System (IHESS)

1. Leverage existing/planned H2 production, distribution and power generation assets
2. Create carbon intensity optimization model with inputs from energy demand, power prices, and H2 pricing
3. Blend NG and H2 to deliver low-carbon power
4. Design H2 storage and delivery infrastructure for power plant needs for all market conditions.





Concluding remarks

✓ How can underground gas storage reservoirs adapt or evolve to meet 2050 Net Zero goals?
✓ How could existing infrastructure be retrofitted to enable the energy transition at low costs?

- ❑ Fundamental research
- ❑ Capabilities establishment
- ❑ Recommended practices
- ❑ **Field demonstrations**

Thank you!

Contact

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