Making our world more productive


## Expert Insights from Linde

# Increase Hydrogen Supply Availability with Cavern Storage

For bulk storage of very large amounts of gaseous hydrogen, underground salt caverns are an option. Pure hydrogen can be compressed and injected into a hydrogen cavern, and be withdrawn at a later time as pure, but saturated, hydrogen. Hydrogen-filled cavities can act as a backup for a pipeline network.

Linde has been operating the world's first commercial hydrogen high-purity cavern since 2007 and we supply some of our pipeline hydrogen customers out of this hydrogen storage facility in Texas and Louisiana. The underground storage cavern is designed to provide our customers with hydrogen during periods of planned and unplanned peak demand. The storage facility is integrated into Linde's 340-mile (545 km) hydrogen pipeline that serves more than 50 refineries and chemical plants from Sweeny, Texas, to Lake Charles, Louisiana.

In this article, we will address the most common questions about hydrogen storage in caverns.

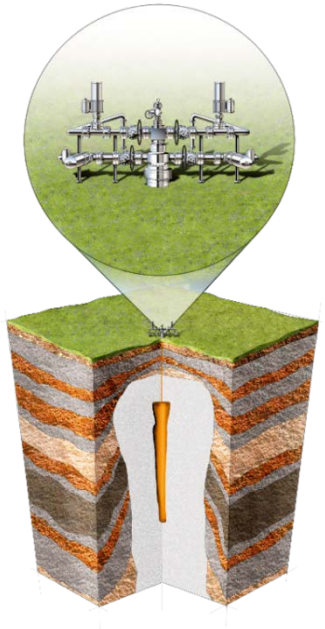

Image 1. Hydrogen Storage Cavern

## Hydrogen Storage Cavern

- 15+ years of successful operation
- 2 years to solution mine: geophysical and execution expertise is key
- Total capacity of approx. 6,000 MT
- Working capacity equivalent to over 14 days production from a world-scale SMR
- Surface infrastructure comprises:
  - 170 bar compression with ancillary equipment
  - Hydrogen product drying & conditioning
  - Metering & control equipment
  - Unmanned & remotely operated
- Essential for storing off-peak energy and ensure supply reliability

## Benefits of Hydrogen Cavern Storage

**Q. What was the impetus for the development of Linde's $H_2$ on-line storage cavern?**

A. The impetus was to offer our customers with instantaneous, back-up hydrogen supply and to also increase hydrogen availability from Linde's Gulf Coast hydrogen system. Hydrogen has become more than just a selective additive to the oil refining process. Heavier crudes and mandated ultra-low sulfur transportation fuels make hydrogen absolutely vital to the 24/7/365 operations of a refinery. Today we are focusing on the transition to clean energy, which relies on renewable energy. For renewable power systems to be successful at large scale, we need smart grids, intelligent load management, grid extension and energy storage to balance demand and supply in electricity systems, and this is where hydrogen and hydrogen storage play a key role.

**Q. How does the existing cavern increase hydrogen availability?**

A. By being integrated directly into the heart of Linde's 340-mile Gulf Coast hydrogen pipeline system, the cavern can meet a customer's planned or unplanned hydrogen requirement on an instantaneous basis. For example, most refiners supply a significant portion of their hydrogen needs from their own hydrogen sources and, at times, these sources become unavailable. In the past, refiners adjusted their refinery processes when hydrogen wasn't immediately available if their supply was lost. The cavern provides that on-line, back-up supply.

**Q. Why use a cavern for availability? Couldn't this be done with $H_2$ production plants?**
A. Gas pipeline systems operate with limited storage so Linde must continually match system supply to meet customer demand. In the case of our cavern in Texas, the initial driver was the fact that hydrogen production plants cannot be instantaneously brought on and offline without large inefficiencies and significant equipment wear and tear and there are times when refinery hydrogen demand goes unmet, and the refiner is forced to adjust its production process. The on-line storage cavern changes this availability paradigm. The same holds true for renewables – the sun doesn't always shine, and the wind doesn't always blow, but the demand is permanently there and we need to make sure we have a solution for matching supply with demand, reliably and economically.

## Optimizing Related Energy Needs

**Q. How does the hydrogen system and energy system integration and impact on availability work?**
A. The customer's energy system is significantly impacted by hydrogen supply decisions. Linde engineers can work with customers to model and optimize energy sources and demands to meet efficiency and sustainability targets. Reliable supplied low carbon hydrogen as an energy source can help our customers achieve their carbon reduction goals.

**Q. What other capabilities does Linde have along the hydrogen value chain?**
A. As one of the world's leading industrial gases and engineering companies, Linde covers the full spectrum of the hydrogen value chain – from production, through processing, to storage and distribution. We can help customers and industry stakeholders navigate through the complexities of the transition to a zero-carbon economy. Our engineers work with customers in identifying their path to zero emissions and provide support to design, build and operate that project, every step of the way.

Today, Linde has the largest liquid hydrogen capacity and distribution system in the world. We ensure reliable and safe delivery of hydrogen through an unrivaled pipeline network of approximately 1,000 kilometers and the largest fleet of hydrogen trailers in the world. With over 200 hydrogen refueling stations and 80 hydrogen electrolysis plants worldwide, we are at the forefront of the energy transition.

## Learn more

Visit us at www.lindehydrogen.com or contact us at hydrogen@linde.com.

# Enabling the transition to clean energy.

Linde is a leading global industrial gases and engineering company with over 140 years of experience and technology knowledge.

Our gases are used in almost every country in the world and in a variety of end markets including chemicals & refining, food, electronics, healthcare, manufacturing and primary metals. The portfolio ranges from life-saving oxygen for hospitals to high-purity & specialty gases for electronics manufacturing and hydrogen for clean fuels. It is important to us to increase our operational excellence and to optimize our portfolio through continuous improvement.

We live our mission of *making our world more productive* every day by providing high-quality solutions, technologies and services which are making our customers more successful. It is our ambition to combine this economic success with environmental protection, safety and social responsibility.
Linde helps customers worldwide improve their environmental performance and reduce their carbon footprint. At the same time, we are committed to minimizing our own environmental resource intensity, including for energy, water and waste. We manage performance through a sustainable development management system with KPIs and targets that are applicable to global operations and our value chain.

**Linde – making our world more productive.**

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