



# Liquid Hydrogen

STORAGE SOLUTIONS

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## Harnessing Hydrogen Energy

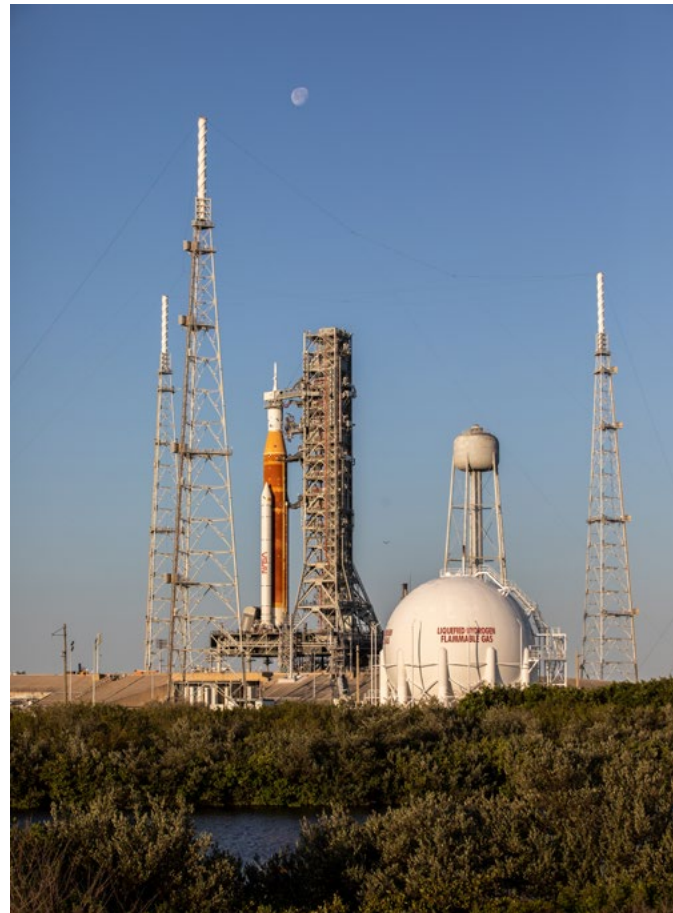
As the global economy pursues opportunities to decarbonize, hydrogen has taken center stage due to its abundance, versatility and potential carbon-free footprint. However, viable storage solutions are necessary to implement the infrastructure required for a large-scale hydrogen economy.

CB&I built the first liquid hydrogen storage sphere in 1960 and continues to scale up liquid hydrogen solutions beyond what was previously thought possible to accommodate growing hydrogen demand.

## Proven Project Execution

We built the world's first liquid hydrogen (LH<sub>2</sub>) sphere for NASA with the capacity to store 170 cubic meters of liquid and have expanded that threshold over the last sixty years by almost 30-fold to reach 5,000 cubic meters.

There's no other company with the longevity of experience, proven project execution model and in-house team of cryogenic pressure vessel experts to deliver your next liquid hydrogen project. Moreover, CB&I provides a truly turnkey solution, following a project from concept to completion and everything in between.



**130+**

Vessels Built

**5,000 m<sup>3</sup>**

Largest Net Capacity

**10,650+**

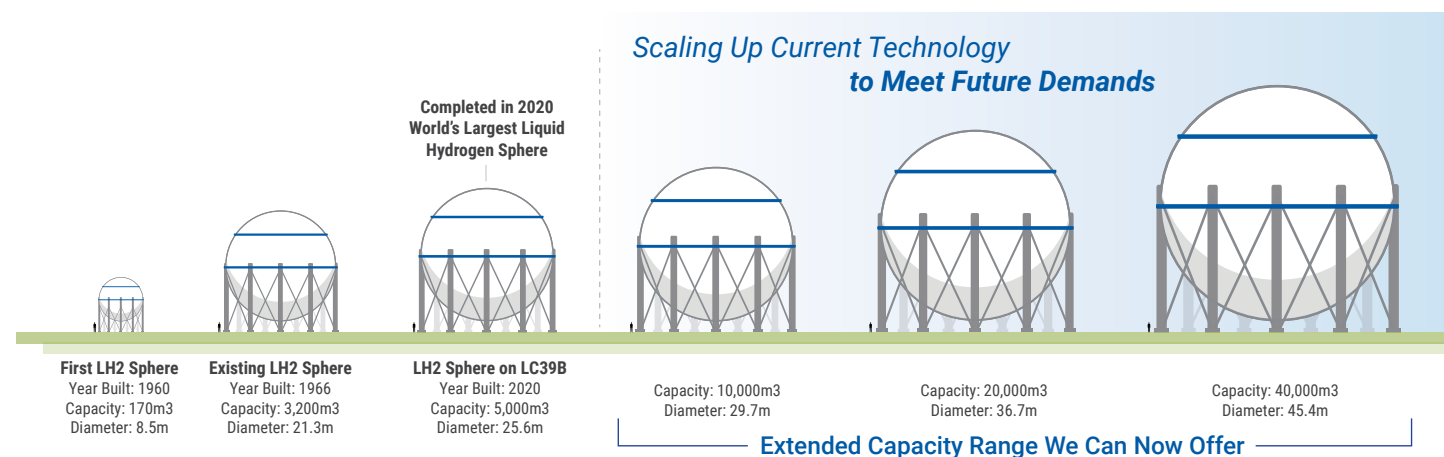
Total Tonnes of Capacity

**150,000+ m<sup>3</sup>**

Total Storage Volume

## Scaling Up Capacity Thresholds

The capacity limitations of today won't enable the carbon-free aspirations of tomorrow. Through ongoing research and development, CB&I continues to expand our portfolio of engineering technologies to exponentially scale-up safe liquid hydrogen capacity thresholds.



Knowledge sharing and collaboration is also key to progress the global commercialization of hydrogen, which is why CB&I and a Shell-led consortium of public, private and academic experts were awarded funding from the U.S. Department of Energy to demonstrate that large-scale LH<sub>2</sub> storage, with capacities up to 100,000 cubic meters, is both feasible and cost competitive. This three year project is scheduled for completion in 2024.

## Solid, Liquid or Gaseous Storage?

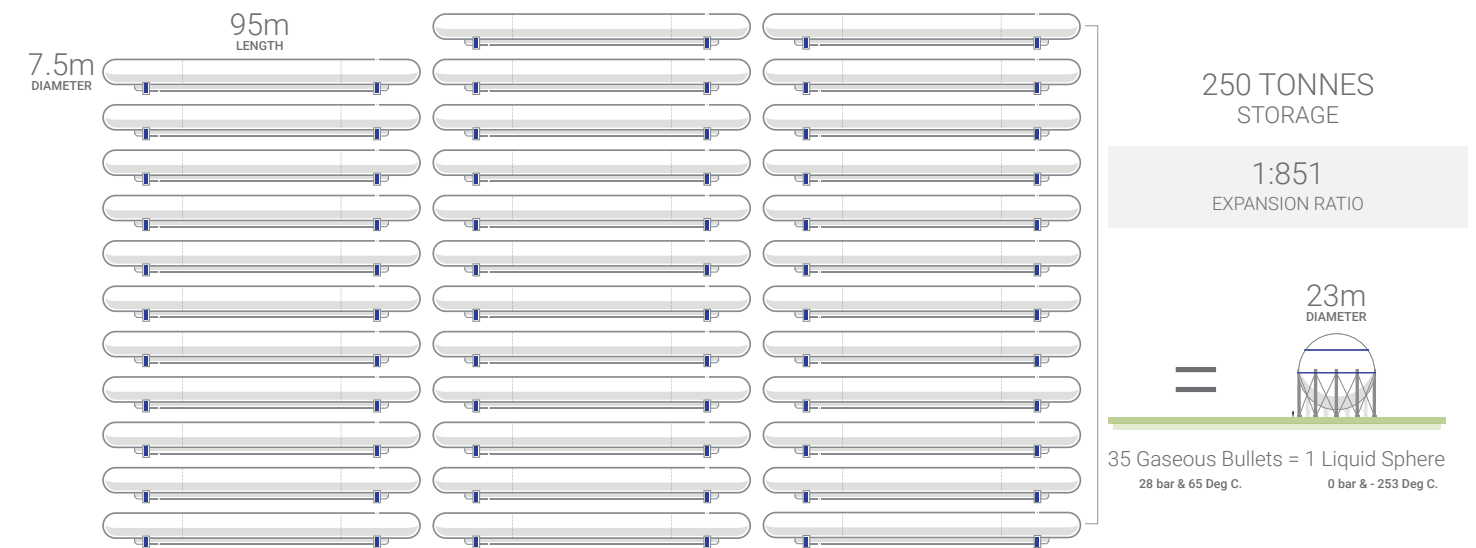
Hydrogen occupies a substantial volume under standard conditions, i.e., atmospheric pressure. In order to store and transport hydrogen efficiently, its volume must be significantly reduced using one of the following techniques:

- High-pressure storage in gaseous form
- Cryogenic storage in liquid form

Efficiently storing the maximum amount of hydrogen in the smallest overall volume is the goal of many hydrogen producers and liquefying hydrogen achieves this goal without changing the molecule through a chemical reaction.

As an example, 250 tonnes of gaseous hydrogen storage with a design pressure of 28 bar and design temperature of 65 degrees Celsius would require 35 bullets (7.5 m diameter x 95 m length) for storage. The same amount of hydrogen can be stored in one LH<sub>2</sub> sphere (23 m diameter).

Liquid hydrogen also increases the transportation payload, which is critical for hydrogen produced at a distance from where it is consumed.



## Large-Scale Storage of Liquid Hydrogen

As storage volumes increase, spheres quickly become the most economical storage solution when compared to bullets by providing the following advantages:

- Lower capital costs achieved through overall reduction in land requirements, foundations, insulation, piping and associated components
- Decreased operations and maintenance costs as a result of less surface area, piping and associated equipment
- Minimize product loss with boil-off rates of 0.1% per day or less

## Importance of Insulation

Insulation is a critical component of any cryogenic storage system. CB&I is one of the only companies in the industry with an in-house Insulation Betterment Center dedicated to researching, developing and achieving the best designs for the quality and longevity of any insulation system, particularly cryogenic insulation.

Our insulation technology experts are involved from the start of any liquid hydrogen storage project and CB&I self-performs large-scale bulk fill perlite and glass bubble installations to ensure that these cryogenic insulation systems achieve optimal thermal performance.

## Services Beyond the Flange

CB&I also provides balance of plant systems beyond just the storage vessel, including truck loading and unloading, liquefaction, vaporization, mechanical systems, instrumentation and controls, civil work, and more, reducing interfaces and increasing project execution efficiency.

## Testing Protocols

Our success rate and breadth of experience performing helium mass spectrometry and vacuum retention testing for large-scale storage structures is second to none. Our portfolio of work includes liquid hydrogen spheres, thermal vacuum chambers and signature projects for the National Aeronautics and Space Administration (NASA).



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