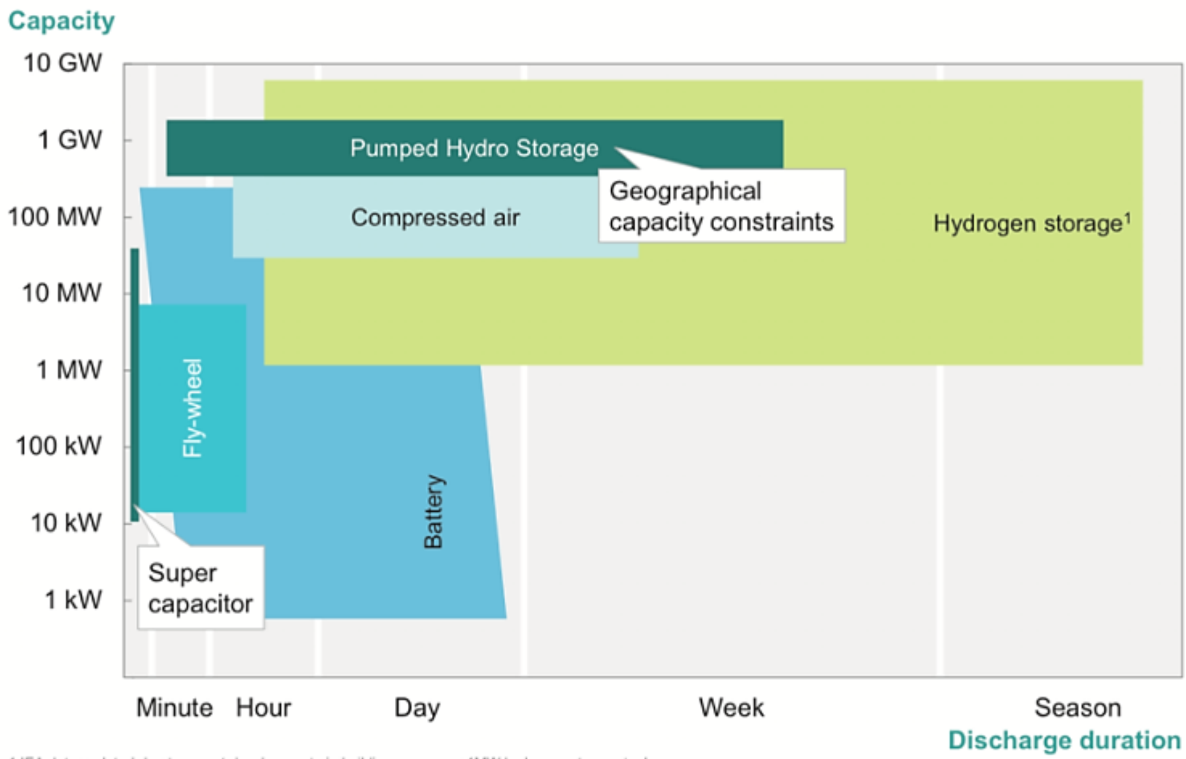
HYDROGEN EUROPE – TECH [Overview]

Hydrogen Storage

Batteries are not suitable in storing large amounts of electricity over time. A major advantage of hydrogen is that it can be produced from (surplus) renewable energies, and unlike electricity it can also be stored in large amounts for extended periods of time. For that reason, hydrogen produced on an industrial scale could play an important part in the energy transition.

However, hydrogen can complement batteries in the transport sector. The optimal energy storage system for vehicles lies in hydrogen and battery systems. The hydrogen system would provide the bulk energy storage, while a relatively small energy capacity battery would allow regenerative braking, meet peak power demands, and generally buffer the fuel cell against load changes to extend its lifetime. This complementary use of hydrogen and battery storage is precisely the arrangement employed by Honda in its FCX Clarity hydrogen car that is now available commercially in limited numbers.

Alongside other demand and supply measures, energy storage can play an important part in improved system integration. Short-term electricity storage in batteries for small plants is developing dynamically, however, longer-term storage of larger surplus amounts of electricity requires new types of storage, such as chemical storage in the form of hydrogen.



1 IEA data updated due to recent developments in building numerous 1MW hydrogen storage tanks

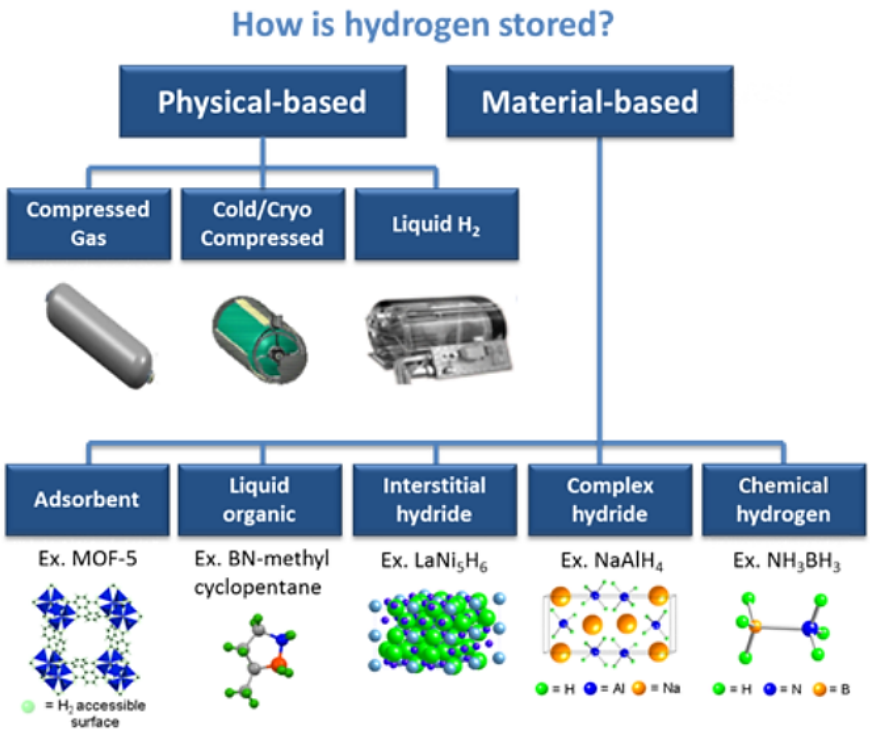
Source: IEA Energy Technology Roadmap Hydrogen and Fuel Cells, JRC Scientific and Policy Report 2013

Hydrogen can be obtained by electrolysis from electricity produced with surplus renewables. If there is a corresponding energy demand, the hydrogen can fulfil it directly. However, it can also be stored in bulk tanks as pressurised gas and retrieved when supplies are low.

Hydrogen can be utilized several ways as an energy carrier, such as feeding it in small amounts into the natural gas network, converting it to CH4 and introduce the obtained methane into the natural gas network, or the stored hydrogen can be directly converted back into electricity via fuel cells.

Hydrogen as an energy carrier has by far the highest gravimetric energy density. The mass-based energy density of hydrogen is thus almost three times higher than that of liquid hydrocarbons, however, the volumetric energy density of hydrogen is comparatively low. Therefore, for practical handling purposes, the density of hydrogen must be increased significantly for storage purposes.

The most important hydrogen storage methods, which have been tried and tested over lengthy periods of time, include physical storage methods based on either compression or cooling or a combination of the two (hybrid storage). In addition, a large number of other new hydrogen storage technologies are being pursued or investigated. These technologies can be grouped together under the name materials-based storage technologies. These can include solids, liquids, or surfaces.



Liquefied hydrogen

As well as storing gaseous hydrogen under pressure, it is also possible to store cryogenic hydrogen in the liquid state. Liquid hydrogen (LH2) is in demand today in applications requiring high levels of purity, such as in the chip industry for example. As an energy carrier, LH2 has a higher energy density than gaseous hydrogen, but it requires liquefaction at –253 °C, which involves a complex technical plant and an extra economic cost. When storing liquid hydrogen, the tanks and storage facilities have to be insulated in order to keep in check the evaporation that occurs if heat is carried over into the stored content, due to conduction, radiation or convection. Tanks for LH2 are used today primarily in space travel.

Cold- and cryo-compressed hydrogen

In addition to separate compression or cooling, the two storage methods can be combined. The cooled hydrogen is then compressed, which results in a further development of hydrogen storage for mobility purposes. The first field installations are already in operation. The advantage of cold or cryogenic compression is a higher energy density in comparison to compressed hydrogen. However, cooling requires an additional energy input.

Currently it takes in the region of 9 to 12 % of the final energy made available in the form of H2 to compress hydrogen from 1 to 350 or 700 bar. By contrast, the energy input for liquefaction (cooling) is much higher, currently around 30 %. The energy input is subject to large spreads, depending on the method, quantity and external conditions. Work is currently in progress to find more economic methods with a significantly lower energy input.

Materials-based H2 storage

An alternative to physical storage methods is provided by hydrogen storage in solids and liquids and on surfaces. Most of these storage methods are still in development, however. Moreover, the storage densities that have been achieved are still not adequate, the cost and time involved in charging and discharging hydrogen are too high, and/or the process costs are too expensive. Materials-based hydrogen storage media can be divided into three classes: first, hydride storage systems; second, liquid hydrogen carriers; and third, surface storage systems, which take up hydrogen by adsorption, i.e., attachment to the surface.

Hydride storage systems

In metal hydride storage systems, the hydrogen forms interstitial compounds with metals. Here molecular hydrogen is first adsorbed on the metal surface and then incorporated in elemental form (H) into the metallic lattice with heat output and released again with heat input. Metal hydrides are based on elemental metals such as palladium, magnesium and lanthanum, intermetallic compounds, light metals such as aluminium, or certain alloys. Palladium, for example, can absorb a hydrogen gas volume up to 900 times its own volume.

Liquid organic hydrogen carriers

Liquid organic hydrogen carriers represent another option for binding hydrogen chemically. They are chemical compounds with high hydrogen absorption capacities. They currently include the carbazole derivative N-ethylcarbazole, but also toluene.

Surface storage systems (sorbents)

Finally, hydrogen can be stored as a sorbate by attachment (adsorption) on materials with high specific surface areas. Such sorption materials include, among others, microporous organometallic framework compounds (metal-organic frameworks (MOFs)), microporous crystalline aluminosilicates (zeolites) or microscopically small carbon nanotubes. Adsorption materials in powder form can achieve high volumetric storage densities.

Underground Storage

When it comes to the industrial storage of hydrogen, salt caverns, exhausted oil and gas fields or aquifers can be used as underground stores. Although being more expensive, cavern storage facilities are most suitable for hydrogen storage. Underground stores have been used for many years for natural gas and crude oil/oil products, which are stored in bulk to balance seasonal supply/demand fluctuations or for crisis preparedness.

To date, operational experience of hydrogen storage caverns exists only on a in a few locations in the USA and Europe. In particular, the underground natural gas stores in Europe and North America could potentially be used as large reservoirs for hydrogen generated from surplus renewable energies. However, only a relatively small proportion of these are storage caverns; the most prominent and common form of underground storage consists of depleted gas reservoirs. In addition, the natural gas stores are unevenly distributed at a regional level.

Gas Grid

Another possibility for storing surplus renewable energy in the form of hydrogen is to feed it into the public natural gas network (Hydrogen Enriched Natural Gas or HENG).

Until well into the 20th century, hydrogen-rich town gas or coke-oven gas with a hydrogen content above 50 vol% was distributed to households in Germany, the USA and England, for example, via gas pipelines – although not over long distances, for which as yet no experience is available.

Infrastructure elements that were installed at the time, such as pipelines, gas installations, seals, gas appliances etc., were designed for the hydrogen-rich gas and were later modified with the switch to natural gas. Many countries have looked at adding hydrogen into the existing natural gas networks. For the USA, it would be possible to introduce amounts from 5 vol% to 15 vol% hydrogen without substantial negative impact on end users or the pipeline infrastructure. At the same time, the larger additions of hydrogen would in some cases require expensive conversions of appliances. In Germany this limit has been set somewhat lower, at up to 10 vol%. In principle, gas at concentrations of up to 10 vol% hydrogen can be transported in the existing natural gas network without the risk of damage to gas installations, distribution infrastructure, etc. However, a number of components have been listed that are still considered to be critical and to be generally unsuitable for operation with these hydrogen concentrations. For CNG vehicles, the currently authorized limit value for the proportion of hydrogen used is only 2 vol%, depending on the materials built in (UNECE 2013).

It can be assumed that many of the gas transport networks, distribution lines and storage facilities that were operated in the past are still in use today. In Leeds (UK), for instance, the possibility has been explored of converting the existing natural gas network in the region (used primarily for municipal heating supply) entirely to hydrogen. Given their length, the large gas networks in many industrial countries could store considerable amounts of hydrogen.