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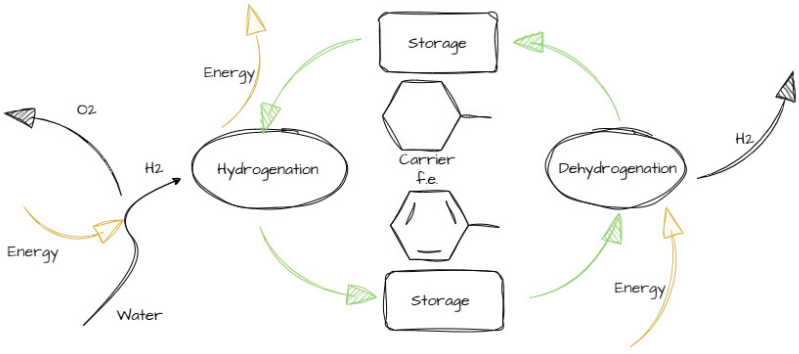
Liquid Organic Hydrogen Carriers

Seasonal energy carrier – Power-to-X technology

A Liquid Organic Hydrogen Carrier (LOHC) is a specific type of chemical compound or substance (carrier material) that serves as a medium for safe and efficient storage and transport of hydrogen. LOHCs are composed of organic molecules that can chemically bond with hydrogen and release hydrogen reversibly. This allows for the secure storage of hydrogen in a liquid form at moderate temperatures and pressures, mitigating the challenges associated with handling gaseous hydrogen. The Power-to-H_2-LOHC system is a promising technology with a high energy density.



Simplified LOHC principles

Hydrogen is produced through the process of water splitting via electrolysis. The details of hydrogen production via electrolysis can be found in the corresponding factsheet. The produced hydrogen is bonded to an organic liquid carrier material. In principle, any unsaturated compound (organic molecules with C-C double or triple bonds) can adsorb hydrogen during hydrogenation. But for the LOHC mostly aromatic compounds are used [2].
The bonding of hydrogen is called hydrogenation. It is an exothermic process that takes place between 30 and 50 bar. On the contrary, heat needs to be applied to release the hydrogen (dehydrogenation step). For both reaction steps, a catalyst is needed to get the reaction running.

When using LOHC, no CO_2 is released, and the carrier material is kept in circulation. The degradation of the carrier per cycle is around 0.1% but may vary depending on the type of carrier [5].

As shown on the left, the concept of LOHC production utilizes water as an input which is split into hydrogen and oxygen. The hydrogen is then combined with the carrier medium, this hydrogenation step releases heat. To retrieve hydrogen, a dehydration step is required. This step requires heat. The hydrogen is then introduced into a fuel cell to generate energy. The carrier is kept in the circuit and may be hydrogenated several times.

Several projects located worldwide are investing in the LOHC technology. The biggest plant is in Germany and its commissioning is planned in 2027 with an overall hydrogen storage capacity of 1800 tons. This amount is loaded in 40 000 m^3 of carrier material [1].

The efficiency of Power-to-LOHC-to-H_2 is around 49% [2]. The technology readiness level (TRL) of LOHC systems is estimated at 5–6 [8], indicating pilot to early demonstration stage.

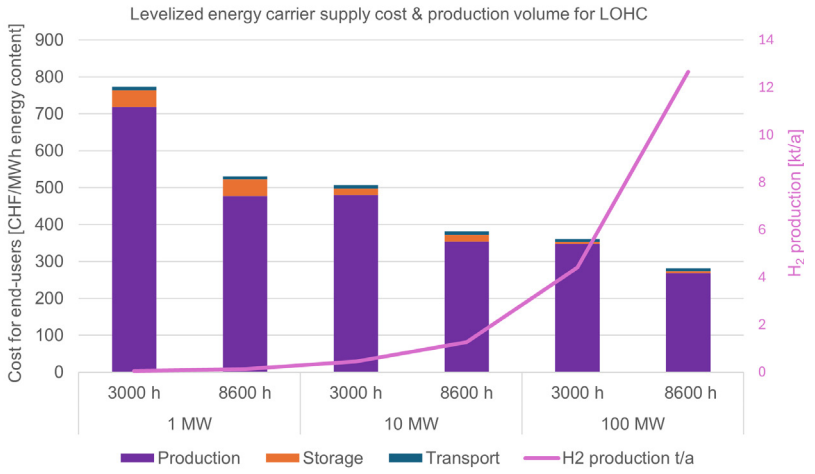
Availability

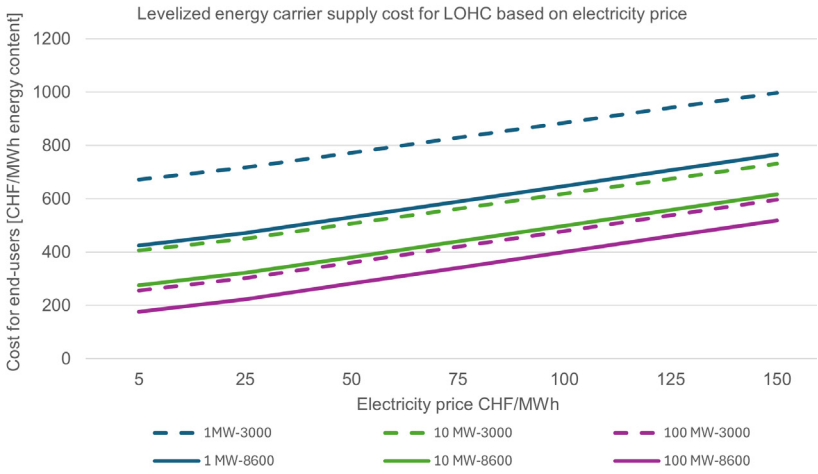
Global production of LOHC	38 000 tonne [3]
CH production of LOHC	0

Chemical properties (aromatic compounds)

Volumetric energy density	1700-2 200 kWh/m³ [9]
Gravimetric energy density	1.7-1.9 kWh/kg [9]
Flammability/air	Depending on the carrier used, it could be flammable or a combustible material which will not ignite readily.
Health safety	Depending on the carrier used, from aspiration hazards to toxic

Cost analysis





The upper left graph shows the cost distribution for installed capacities of 1 MW, 10 MW, and 100 MW under two operational modes (3000 h and 8600 h), with the pink line indicating annual production volume in kilotons.

The lower left graph illustrates the dependency of the overall carrier price on electricity, showing steep increases for smaller, low-utilization plants (e.g., 1 MW at 3000 h: 618 to 943 CHF/MWh as electricity rises from 5 to 150 CHF/MWh) and significantly lower, flatter costs for larger plants with high utilization (e.g., 100 MW at 8600 h: 162 to 505 CHF/MWh). Overall, production cost is the main driver, ranging between 160 and 950 CHF/MWh depending on the electricity price, while transport and logistics add only 8 to 26 CHF/MWh for truck deliveries over 50 to 150 km. Storage needs are assumed to be covered by existing methanol or oil tank infrastructure. The cost driver in production is the hydrogen electrolyser, hydrogenation, and dehydrogenation plant. [5].

For detailed cost information on hydrogen, refer to the corresponding Power-to-Hydrogen factsheet.
The cost calculation assumes an economic lifetime of 25 years, maintenance costs at 2% of investment, a 5% discount rate, an electricity price of 50 CHF/MWh, and a carrier price of 2–4 CHF/kg.

Sources / additional information

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