Zeroing Out Losses: Efficient Liquid Hydrogen Storage for a Greener Future

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A Green Infrastructure: Hydrogen as an Energy Carrier

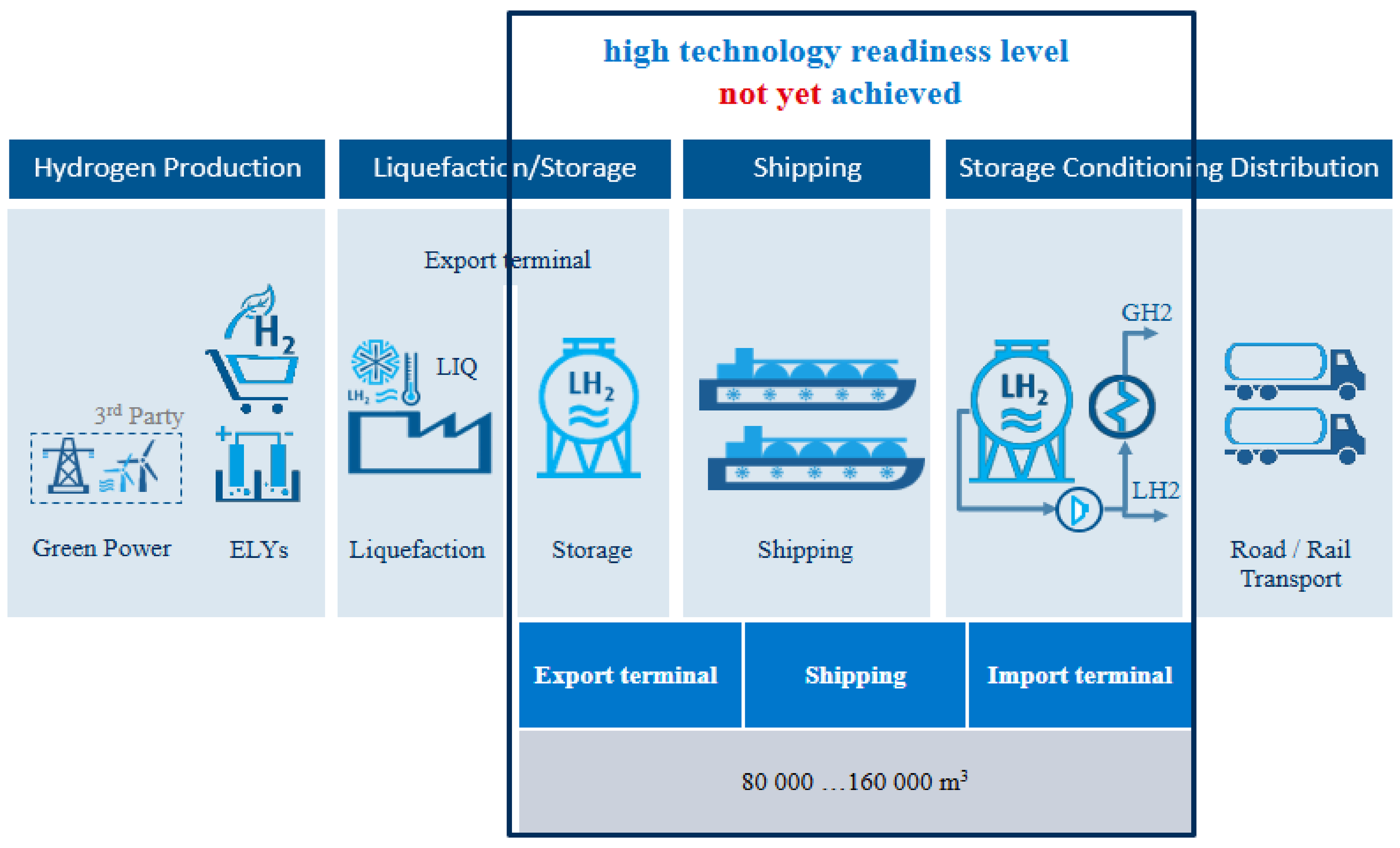
With conventional energy sources depleting and its impact on the climate increasing, the need for a sustainable energy supply and infrastructure is evident. When it comes to developing such an infrastructure, hydrogen (H_2) is perhaps the most promising energy carrier. For proper compatibility with renewable sources, the hydrogen infrastructure must be able to store hydrogen on a large scale, in terminals. These act as buffers to counter-act the fluctuations in energy-supply inherent to e.g. solar and wind power [1]. Developing commercially viable hydrogen transport and storage technologies is crucial for the Netherlands. To address this, **GroenvermogenNL** has launched the **HyTROS** project - a consortium of 32 research and industry partners - focused on developing 'the infrastructure for hydrogen transport and storage, both offshore and onshore'.

The Current Hydrogen Chain

The hydrogen chain consists of several key components: power generated by renewables are used in the electrolysis to produce hydrogen. This hydrogen in turn is liquefied in an energy-intensive process. The liquefied hydrogen is then (temporarily) stored in large terminals at the production site.

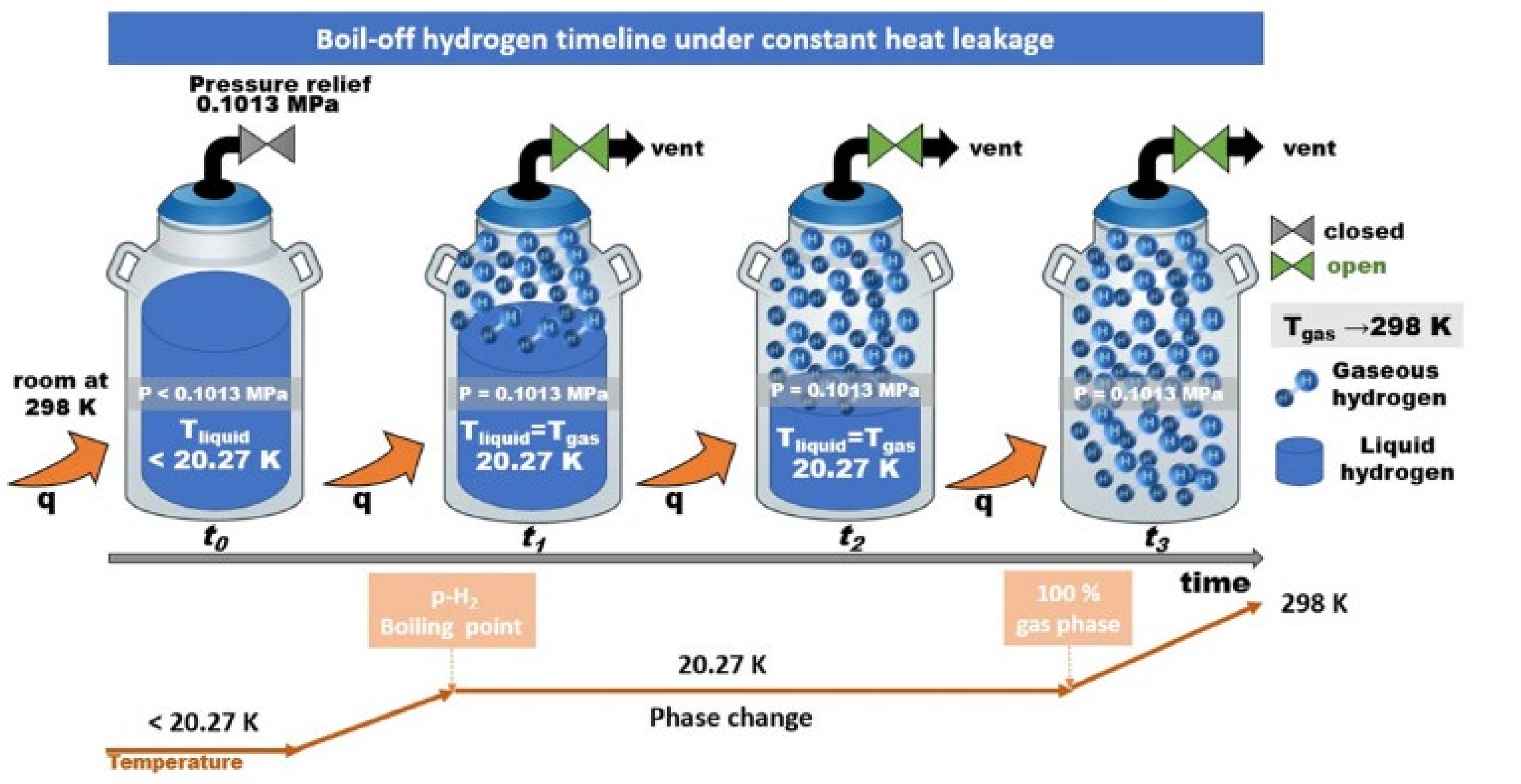
- As a storage method, liquid hydrogen (LH_2) is the most promising technology compared to other technologies, such as ammonia (NH_3) and liquid organic H2 carriers (LOHCs), because of its high gravimetric and volumetric energy density. Additionally, no extra energy is required to extract H_2 like for NH_3 and LOHCs [2].

Next, the hydrogen is shipped to regions that lack hydrogen production sites where it again is stored in terminals. From these terminals the hydrogen is further locally distributed for end use in applications. Currently, liquid hydrogen storage and shipping technology is not yet at sufficient TRL for wide-spread commercial implementation: there are several challenges to overcome.



Problem: Boil-Off Hydrogen

Perhaps the major challenge in large-scale LH_2 storage is boil-off, which is a significant loss mechanism. This phenomenon occurs due to the heat leak from the ambient surroundings (at 20°C) into the storage tank to the LH_2 (at -253°C), which causes the LH_2 to evaporate. Klell et al. reported that most of the current LH_2 storage tanks have BOH rates of 0.3-3% per day [3].



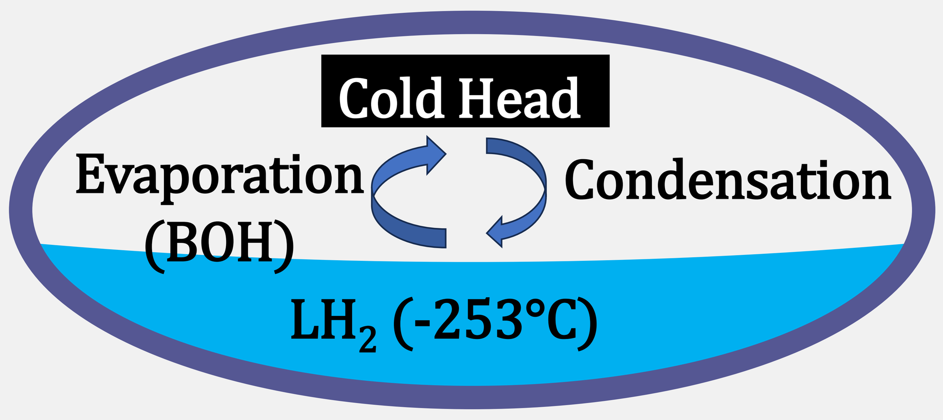
Boil-Off Hydrogen (BOH) is highly undesired for several reasons:

- safety: leakages into rooms without ventilation or potential hazards, accidents during transport, loading, off-loading,
- environmental: contributes to climate change by increasing the amounts of other greenhouse gases such as methane, ozone and water vapor
- economic: loss of fuel and cost of safety equipment

Problem: Excessive boil-off rates and the accompanying safety, environmental and economic concerns, severely limit liquid hydrogen storage as a feasible option in the hydrogen chain.

Research: Efficient & Cost Competitive ZBO System

Solution: Zero Boil-Off Cooling System



Key idea: small latent heat hydrogen (4.61 kJ/kg [4]) → minimal cooling power needed to recondense BOH.
Cooling system inside tank to **minimize** BOH → achieve zero boil-off (ZBO)

NASA ZBO cooling system

Current state-of-the-art ZBO system:

- technologically very complex;
- economically not cost competitive

Goal: This research is centered on developing an ambitious, highly efficient Zero Boil-Off (ZBO) system that both minimizes the hydrogen boil-off rate and is economically competitive.

This research only addresses a tiny wheel in our energy infrastructure that needs to be transformed for the benefit of a sustainable future.

We therefore NEED you!

References

[1] Alekseev, A. et al. "Hydrogen liquefaction, storage, transport and application of liquid hydrogen", Flagship Project TransHYDE
[2] Ghorbani, Bahram, et al. "Strategies to improve the performance of hydrogen storage systems by liquefaction methods: a comprehensive review." ACS omega 8.21 (2023): 18358-18399.
[3] Klell, Manfred. "Storage of hydrogen in the pure form." Handbook of hydrogen storage (2010): 1-37.
[4] Verfondern, Karl. "Hydrogen fundamentals." Hydrogen safety for energy applications. Butterworth-Heinemann, 2022. 1-23.

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