NL green H_2 potential

- Large offshore potential
- Strong knowledge basis from being a gas hub
- Access to salt caverns for large-scale storage
- Ports for import terminals

- Export to Ruhrgebiet
- Export to Antwerp
- High-tech suppliers
- Strong industry clusters
- Existing gas infrastructure can be re-used

1. **Fight climate change**
   achieve net-zero in 2050 by reducing greenhouse emissions in non-electrifiable applications using green H_2
2. **Boost earnings power**
   become a significant international player in the green H_2 & chemistry economy, unlocking potential of NL high-tech sector
3. **Retain key industries**
   within the Netherlands by facilitating their transition to net-zero in a sustainable way using green H_2 & chemistry
4. **Improve business climate and energy security**
   by creating national green H_2 production capacity in parallel with import infrastructure

Groenvermogen - Groenvermogen (groenvermogennl.org)

GroenvermogenNL instruments

Human capital

50 M€

- National human capital agenda

- Regional learning communities
- Digital platform
- National coordination

R&D

1. Making carbon neutral H_2
2. Transport & storage of H_2
3. Direct use of H_2
4. Green H_2 & e^- for C-based chemistry
5. Green H_2 & e^- for N-based chemistry
6. Green H_2 & e^- for specialties
7. Socio-economic aspects & H_2 implementation

177 M€

Pilot support & demonstration

Projects throughout the value chains of production, transport, storage and industrial use of green hydrogen (carriers).

- 3-5 projects in H_2 value chain
- Small scale demonstration
- Regional testing facilities

100 M€

Upscaling

Support for the manufacturing industry

Demonstrating value chain projects

Feed/feasibility studies

Potential endurance testing facility

500 M€

Special projects: HyXchange (trading platform)
Measuring Hydrogen leakage

LH2 en mogelijkheden GVNL

groen vermogen nl | Accelerating and realising the green hydrogen and green chemistry economy

R&D:

- HyTROS 2e ronde – publicatie Q4 2025

DEI regeling:

- Pilots en demo's voor groene waterstof door de hele keten Demonstratie Energie- en Klimaatinnovatie (DEI+) | RVO.nl

FEED/Feasibility studies:

- subsidie voor investeringen in pilots, demo 's, productie, import, conversie, transport TSE Industrie studies: Waterstof en groene chemie (GroenvermogenNL) | RVO.nl

VEKI:

- subsidie voor infrastructuur- en conversieprojecten + aanpassingen installaties die groene waterstof gaan gebruiken Versnelde klimaatinvesteringen in de industrie

HCA:

- deelnemen aan één van de regionale Learning Communities

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WP2 HyTROS
Hydrogen Transport, Offshore and Storage

Research and Development

Rene Peters – program coordinator
David Smeulders – technical manager

HyTROS consortium

The HyTROS consortium is a well balanced public private collaboration including

1. 11 Universities
2. 2 Research organizations (TNO, Deltares)
3. 2 Universities of applied sciences (Hanze, HAN)
4. 17 Industrial partners, of which 2 are co-applicant and 15 are co-funders
5. Coordinated by TNO and TUE
6. Budget 18 Meuro
7. Start 1 March 2024

- Industry

- Research organizations

HyTROS R&D program

Main objectives:

- ❖ Enable a safe and reliable H2 infrastructure
- ❖ Assess the potential for reuse of offshore pipelines
- ❖ Derisk large scale H2 storage options

Structure of the proposal:

- Technical tasks:
  - ❖ Infrastructure development
  - ❖ Offshore pipelines
  - ❖ Large scale H2 storage
- Enabling tasks:
  - ❖ Safety, standardisation and regulation
  - ❖ Upscaling and system integration

Scope of research of task 5 Large Scale H2 Storage in HyTROS

Task leaders: Remco Groenenberg (TNO) and Chris Slootweg (UvA)

Subsurface

1. Quantifying risks and impacts of hydrogen-induced **bio-geochemical processes** on storage integrity and performance.
2. Quantifying impact of cyclic pressure changes and hydrogen exposure on **wellbore and caprock integrity.**
3. Developing a framework for assessment of **re-use potential of wells** for hydrogen storage.
4. Field-scale characterization and **performance modelling** of hydrogen storage reservoirs for efficient operation

Surface

5. Evaluating the technology readiness of suitable **hydrogen carriers**
6. Assessing the technology readiness of **LH2 Import Terminals**, and developing an economic boil off gas recondenser for large LH2 maritime tankers and storage tanks

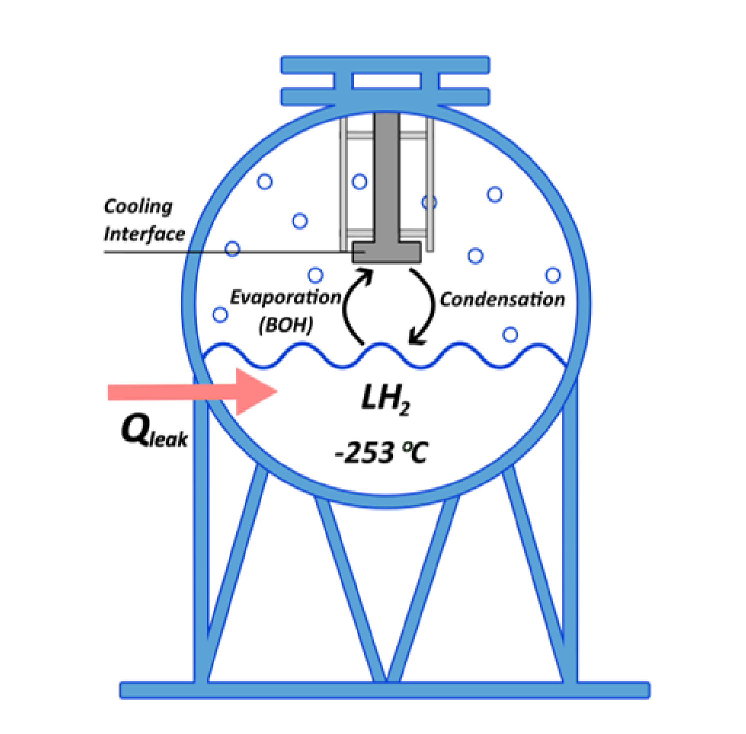

PhD Research: Developing a Zero Boil-Off System for LH_2 Storage

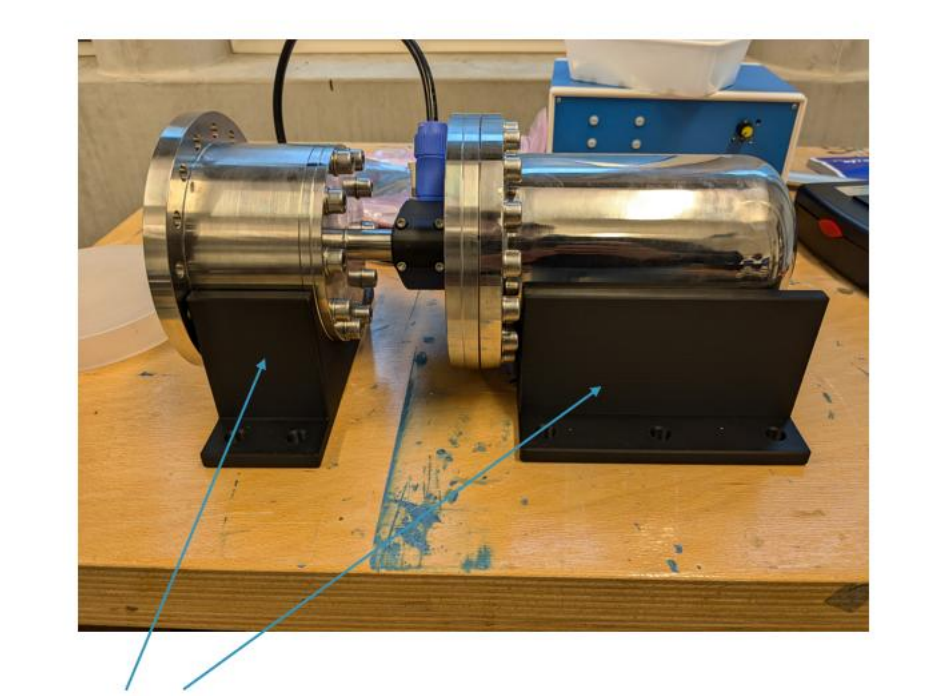
Harro Beens

UNIVERSITY OF TWENTE.

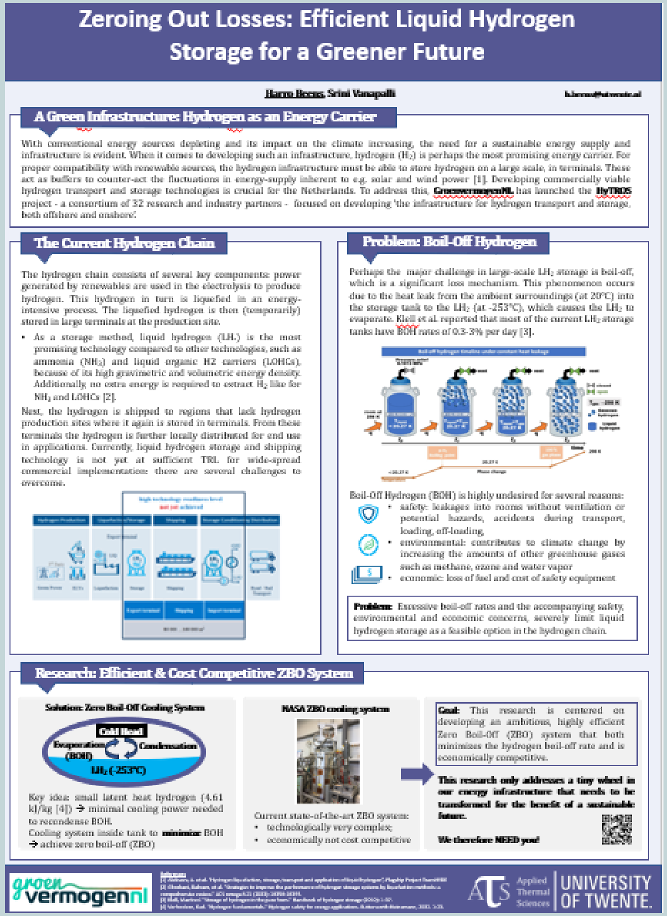
Develop zero boil-off storage system with active cooling (recondensor)

PhD student: Harro Beens
Supervision: Prof. Srini Vanapalli





3D-printed supports



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

Harro Beens, Srini Vanapalli

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

Cold Head — Evaporation (BOH) — Condensation — LH_2 (-253°C)

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 minimises 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!

groenvermogenNL | ATS Applied Thermal Sciences | UNIVERSITY OF TWENTE.

Phase 2 of HyTROS

- Budget GVNL: 13 Meuro, industry support required
- Expected start 2026, 6 years of execution
- Workshops to structure program HyTROS-2 planned in Q4 2025
- New partners invited to participate the workshop and join the consortium
- New Topic: Import of hydrogen
    - Ammonia import, storage and cracking
    - LOHC production (selection of carriers), regeneration, storage
    - LH2 transport, storage, conversion, transport for direct use (mobility)
    - Conversion of LNG import terminals
    - Reuse of tank storage facilities
    - Developing import chains in port regions

Interest to participate?

Contact us

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