Boil-off recovery of LH2 infrastructure using metal hydrides

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Motivation

Background:

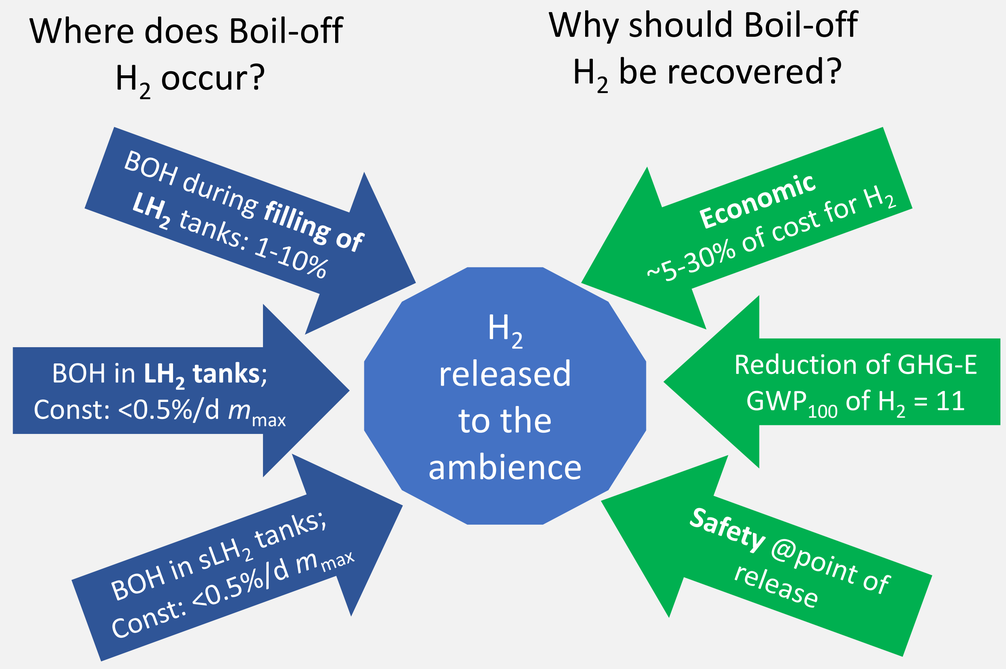
- H_2 Infrastructure is increasing (e.g., “Hydrogen Backbone”)
- For high density storage, liquid H_2 (LH2) is an option

Challenge:

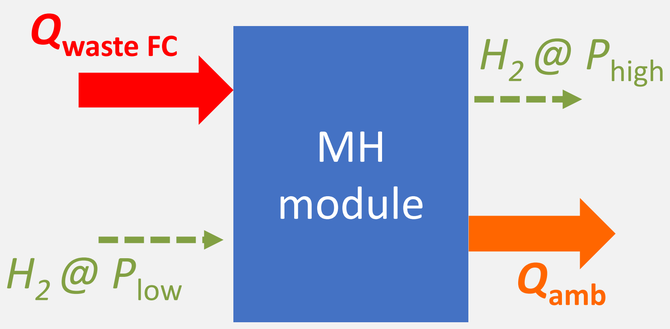
- As H_2 production is energy intensive, this energy carrier is very valuable and should be used as efficiently as possible
- However, filling, transport and storage of LH2 are related to heat input and thus to the occurrence of Boil-off H_2 (BOH)

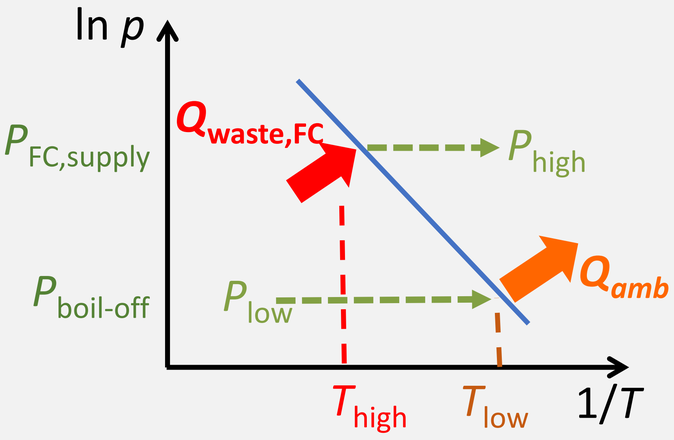
Idea:

- Using a metal hydride to capture Boil-off H_2 at the point of release and compress it to a useful pressure level by thermal compression [1].



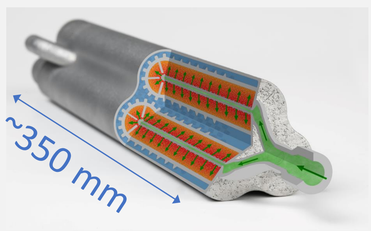
Concept: Thermal compression of Boil-off H_2 (BOH) using metal hydrides (MH)





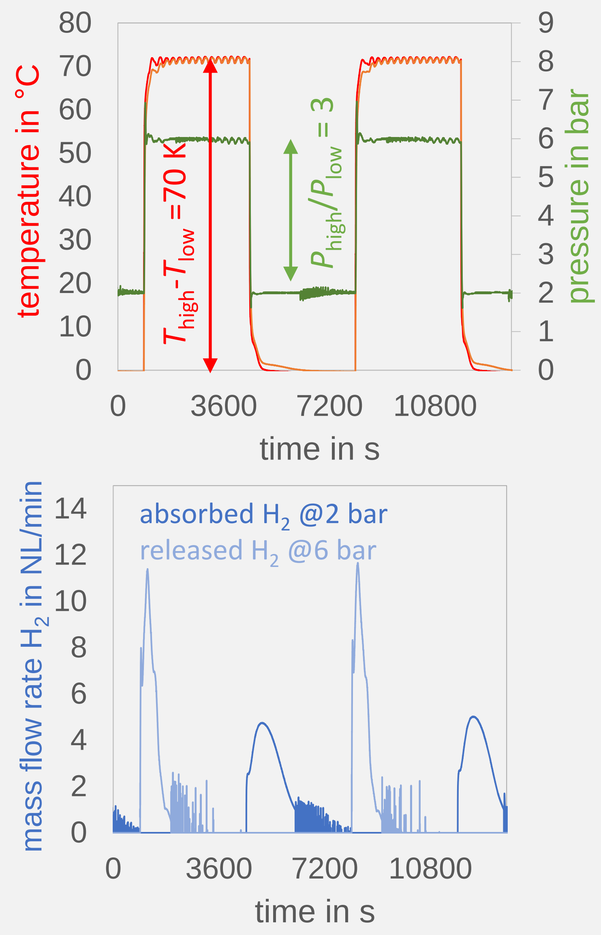
Generic process:

- H_2 gas is provided at low pressure level
- Using heat at elevated T (e.g. FC), thermal energy is provided to the system
- H_2 is released at increased pressure level



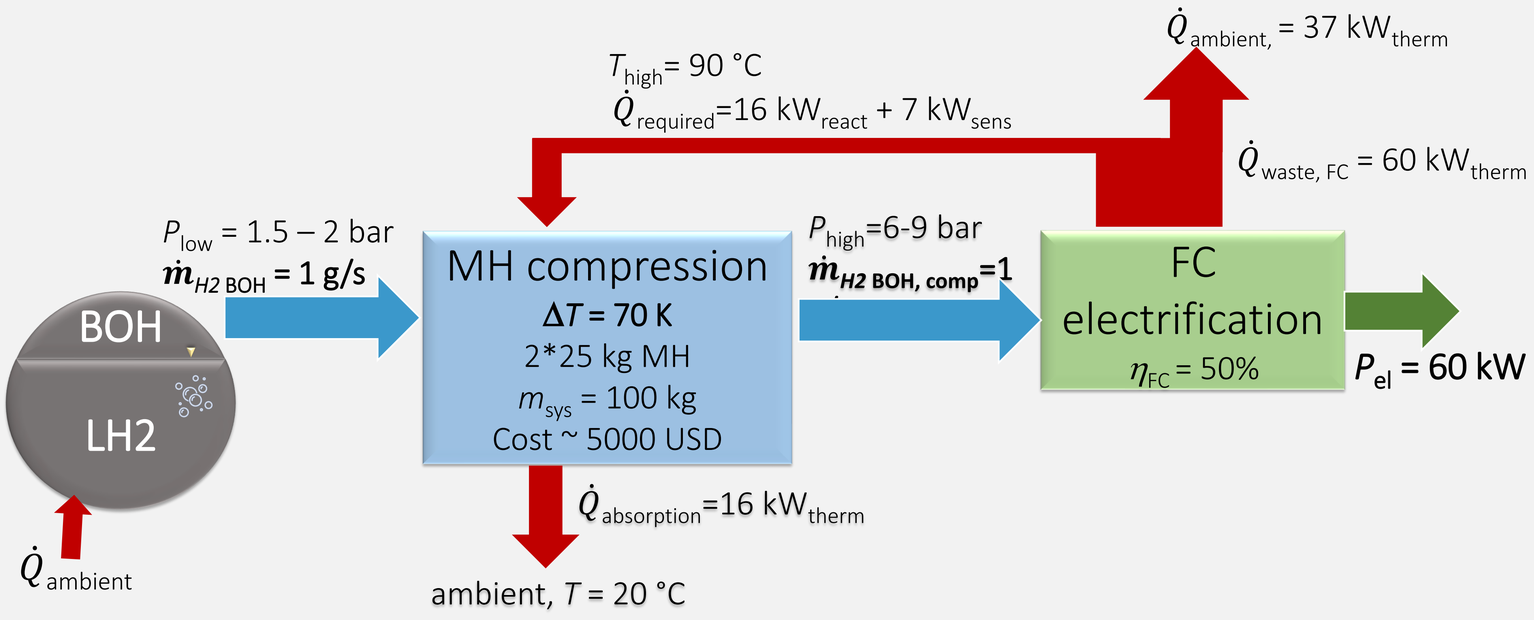
Lab-scale testing setup:

- 345 g of $LaNi_5$
- Boundary conditions with two pressure levels: P_{high} / P_{low} = 3
- Temperature swing btw: T_{high} - T_{low} = 70
- →cycling abs/des induced
- →absorption of H_2 below 1 bar proven (not shown here)



[2]

Feasibility and evaluation of system with re-electrification of Boil-off H_2 using a fuel cell



Results for this use-case:

- For 1 g/s BOH, 60 kW_{el} can be produced in a FC
- ΔT = 70 K btw. T_{low} and T_{high} required
- Thermal energy for compression:
  - ΔH of MH material: 12.5 MJ/kg_{H2} → 10% of LHV_{H2}
  - $\dot{Q}_{sens}$ for switching MH and reactor mass between T_{amb} and T_{high} →5-10 % of LHV_{H2}

Conclusion & Outlook

- Metal hydride based compression can enable re-electrification of BOH using a fuel cell
- Waste heat with ΔT=70 K to ambient required
- 10-20% of LHV of H_2 required for compression

Future work:

- Integration in different applications possible, P_{high}/P_{low} ~ 5
  - E.g. Tank (LH2) to H_2-Pipeline
- Transfer of technology to extraction of H_2 from gas mixtures
  - E.g., exhaust gas of fuel cells or gas turbines

[1] M. J. Rosso and P. M. Golben. Capture of liquid hydrogen boil-off with metal hydride absorbers. *Journal of the Less Common Metals*, 131(1-2):283–292, 1987. ISSN 00225088. doi: 10.1016/0022-5088(87)90527-3
[2] „Metal hydrides for Hydrogen Boil-off Recovery“, Bachelorthesis, Annika Eskens, Universität Stuttgart 2024

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