Scaling High-Pressure Electrolysis: Advancing Green Hydrogen for Industrial Decarbonization

Paola Granados Mendoza[a], Hans Veenkamp[a], Hans Wiggenhauser[b], Dirk Ullmer[b], Fatemeh Razmjooei[b]
a) HyCC, The Netherlands, b) DLR, Germany

Scaling up innovative high pressure electrolysis

„Pressurized Efficient Alkaline Electrolyser“ (PEACE) is a research and innovation project funded under the EU Horizon Europe programme by the Clean Hydrogen Partnership.

76th ISE Annual Meeting, Mainz 2025

Peace Project

PEACE

The PEACE project develops a technology that utilizes a pressure vessel stack concept capable of reaching more than 50 bar in a dual-stage pressurization approach.

Goal: develop a technology of high-pressure alkaline electrolysis (AEL) to substantially reduce hydrogen production costs, enhancing the competitiveness of the hydrogen economy.

- Major PEACE KPI's
  - Pressure: >50 bar
  - Performance under pressurization: < 1.8 V at 1 A/cm²
  - Voltage efficiency (LHV): 70%
  - Degradation rate: <0.11%/kh
  - Minimal load: 14% of nominal load

Clean Hydrogen Partnership

The project is supported by the Clean Hydrogen Partnership and its members.

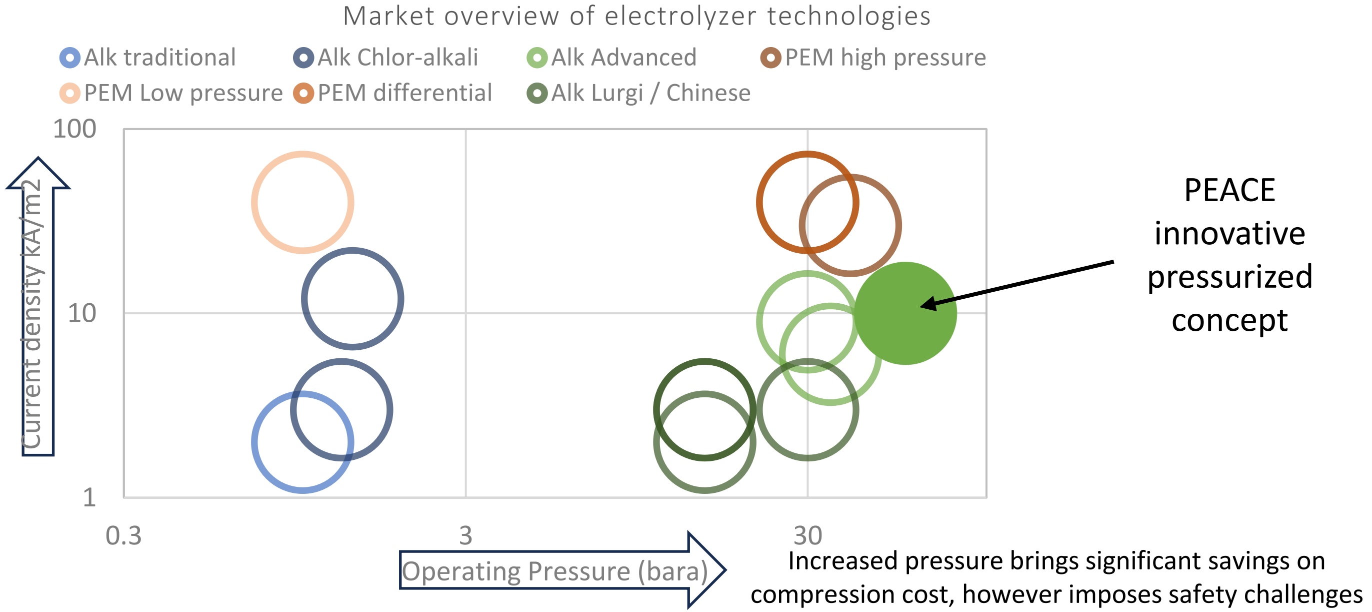
Co-funded by the European Union

Business case focus

With this innovative dual-stage pressurized stack concept the levelized cost of hydrogen (LCOH) can be reduced by:

- Operating **efficiently at higher current densities without noble metals**
- Operating **safely at higher pressures**, enabling better integration with downstream processes

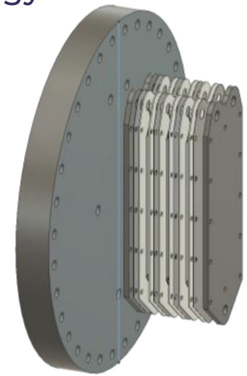
Increased current density means decreased footprint, but often requires rare metals



Increased pressure brings significant savings on compression cost, however imposes safety challenges

From lab to demo to industrial applications

- Lab tests identified components that meet performance targets under pressurized operation.
  - Main challenge: **gas crossover at high pressure**, especially in flexible operation.
- **Stack design:** optimized for a pressure vessel with materials chosen for strength, performance, and stray current control.
- **Proof of Concept:** demo unit will test degradation, min load, ramp speed, efficiency, and gas purity.
- **Integration modeling with methanol, ammonia, and fueling stations** to assess scalability.
- **Life Cycle Assessment (LCA):** quantifying the environmental impacts of this groundbreaking technology.

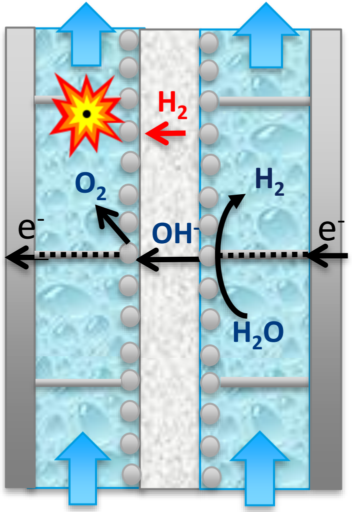


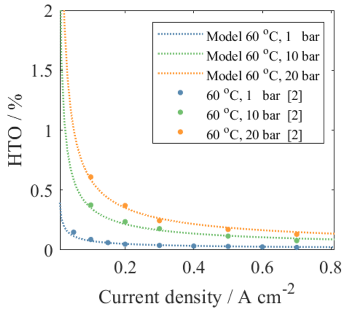
Safety in design

- Mixing of H_2/O_2 inside equipment and after loss of containment inside a building are among the top hazards that may result in fires and explosions, leading to injuries and fatalities.
- Pressure has influence on the explosion and fire parameters of Hydrogen and Oxygen mixtures. The explosion pressures increases (orders of magnitude) when increasing the initial pressure.
- Gas crossover (i.e. H2 "leaks" through the membrane and mixes with O_2) increase with pressure, particularly at lower loads due to flexible operation.
- Due to higher gas cross-over in the stack the likelihood of an explosive mixture might increase.
- The hazardous consequences of gas cross-over express themselves at the gas/liquid separator of the balance-of-stack, which also operates at high pressure. Here the gas holdup is higher and therefore the severity of consequences are also larger.
- There is an increased solubility of H_2 and O_2 in the electrolyte, giving increased contribution of gas cross-over through the electrolyte circuit.

- PEACE safety approach:
  - Selection of the safe operating range (minimum load) along with the right membrane selection to minimize gas cross-over.
  - Follow industry practices for safety assessments such as performing HAZOP studies to identify safety risks and implement learnings in the design.
  - Assess the hazards of the innovative aspects for both the stack and the balance-of-stack.

Gas crossover





M.T. de Groot et al. Int. J. Hydrogen Energy, 2022, 34773