
HyET Hydrogen
Efficient purification & compression

# KAUST Hydrogen Seminar
# Hydrogen Storage Technologies

## Cost-effective equipment for the **compression, storage and distribution** of H2

September 7th 2022

HyET High Yield Energy Technologies

# HyET Hydrogen is part of the HyET group of companies

# HyET Group of companies

## Critical components for the renewable, distributed energy supply chain providing fossil fuel parity

### HyET Solar
Flexible lightweight solar modules


Efficient & low cost PV compensating for conversion & storage costs

### HyET E-Trol
Low-cost electrolysis for hydrogen production

Low cost electrolysis at improved energy efficiency and reduced CAPEX

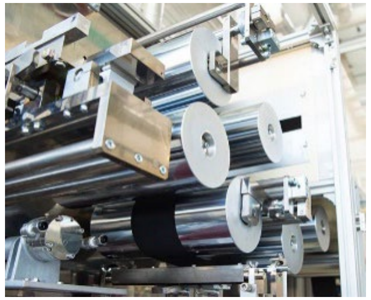
### HyET Hydrogen
Efficient purification & compression

Reliable & low cost storage and transportation of energy

### HyET NoCarbon
Decarbonizing the energy supply chain

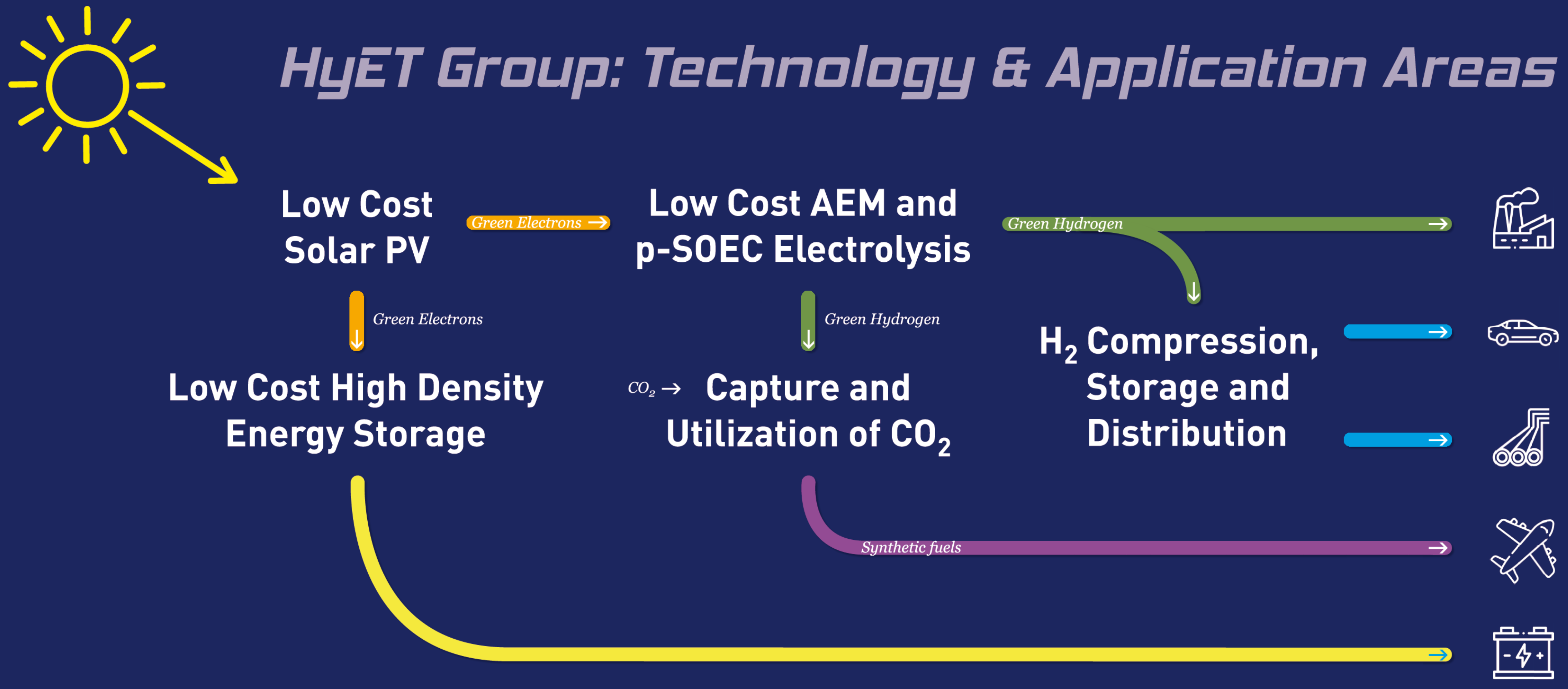
Modular membrane reactors to enable faster transition – SMR, $NH_3$ processes, $CO_2$ capture & Synthetic Fuels

### HyET Lithium
High energy density solid state batteries



Roll-to-Roll production of high density solid-state Lithium ion batteries

# HyET Group: Technology & Application Areas




HyET Solar — Flexible lightweight solar modules

HyET Lithium — High energy density solid-state batteries

HyET E-Trol — Low-cost electrolysis for hydrogen production

HyET NoCarbon — Decarbonizing the energy supply chain

HyET Hydrogen — Efficient purification & compression

HyET Hydrogen
Efficient purification & compression

# KAUST Hydrogen Seminar - Hydrogen Storage Technologies

Cost-effective equipment for the **compression, storage and distribution** of H2

Electrochemical Compression of Hydrogen


Electrochemical Separation of Hydrogen from Natural Gas

Innovative Hydrogen Refuelling concepts

# Electrochemical processing of Hydrogen

## Current challenge

**How can we get Hydrogen to end users for an affordable price?**

Compression and Purification represent a large part of the costs in the hydrogen supply chain.

High failure rate of compressors and complexity of purification systems prompt for a novel, reliable, alternative technologies.

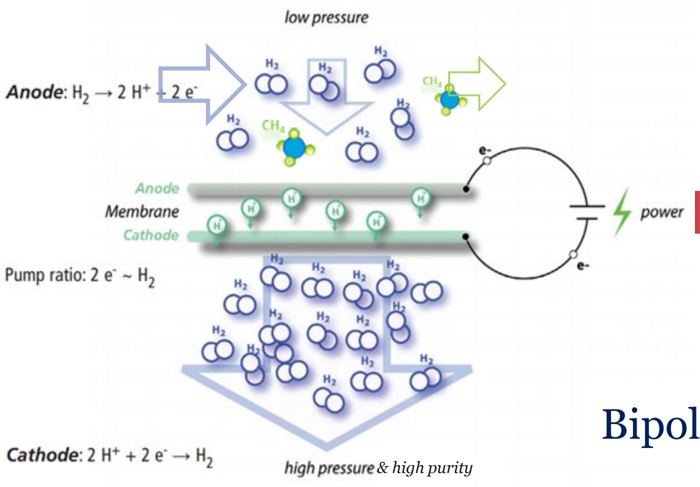
HyET Hydrogen has developed proprietary technology for compression, purification and extraction of H2.

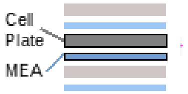
Electrochemical Processing offers:

- **Cost effective compression & stotrage of H2**
  - High uptime
  - Flexible, 10% to 100%
  - Inlet 100 mbar – outlet 900 bar (1 step)
  - No moving parts
  - Silent
  - Lowest total cost of ownership
- The possibility **to purify H2** waste streams to accelerate adoptions for Hydrogen as a fuel, and
- To **use existing infrastructure** (gas grid) for distribution of Hydrogen, selectively purify and extract the Hydrogen at the location where you need it the most

# Electrochemical H2 processing

## H2 compression + purification (EHC/P)



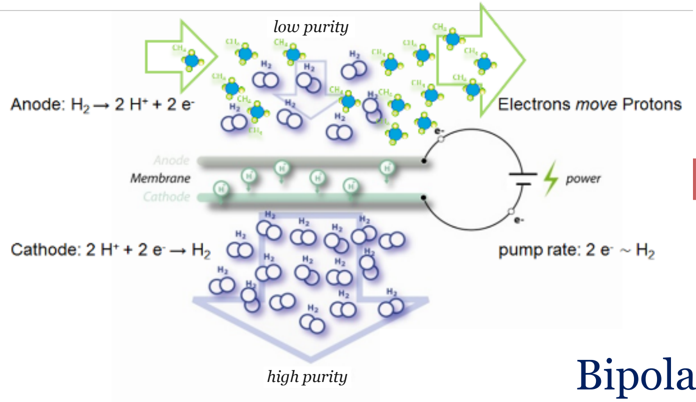



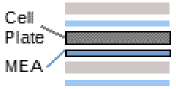

Bipolar plates/MEA

Compression/Purification Stack

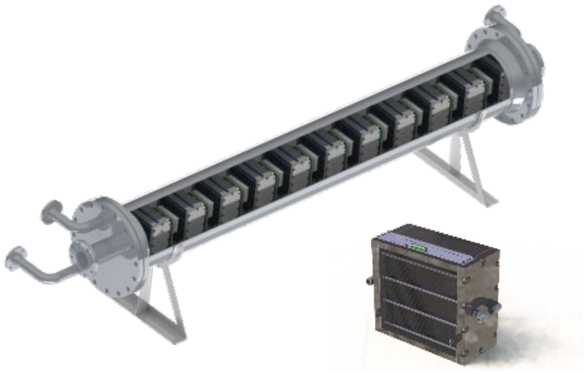
**EHC/P module**

## H2 extraction + purification (EHE/P)




Bipolar plates/MEA

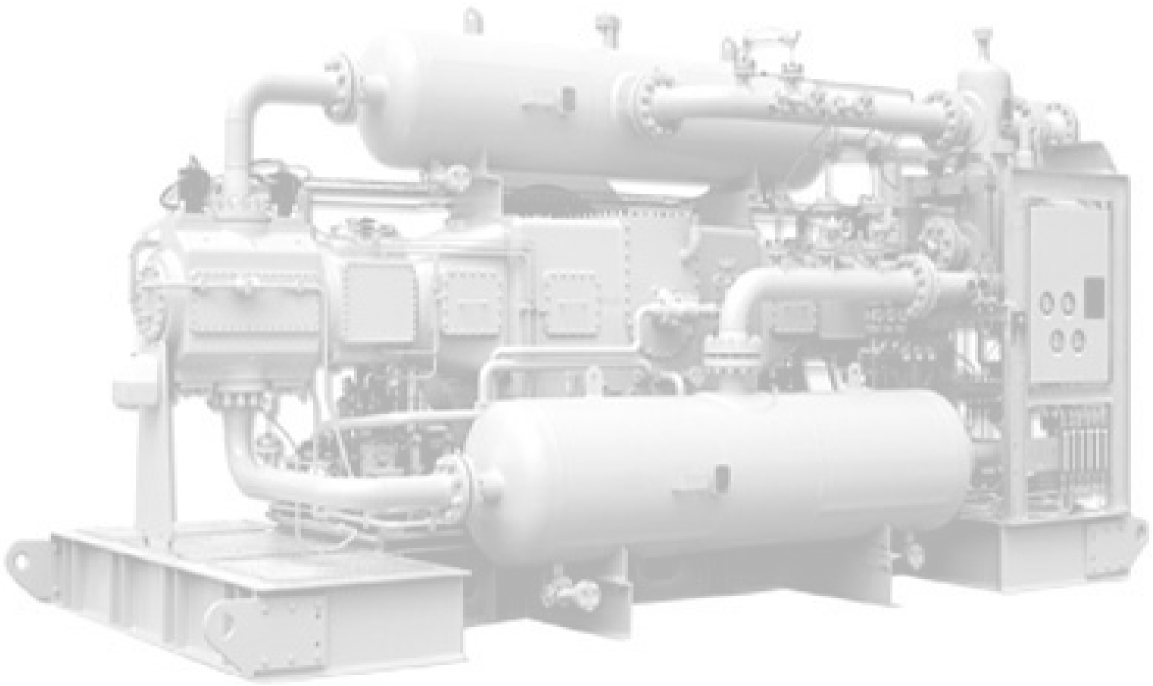


Extraction/Purification Stack

**EHE/P module**

# EHC systems are compact & modular

Measures: 2.8 m (L) x 2.1 m (W) x 2.3 m (H)

***HCS-500 compressor assembly***

*(example: 1500 kgpd – 875 bar H2 – 3.5 kWh/kg)*

# Example application of EHC: fast refueling of mining trucks

**Background**

Current high pressure hydrogen refueling systems are mainly designed and optimized for light and medium-duty vehicles. Medium and heavy duty FCEV refueling systems require improvement in order to reduce refueling times.

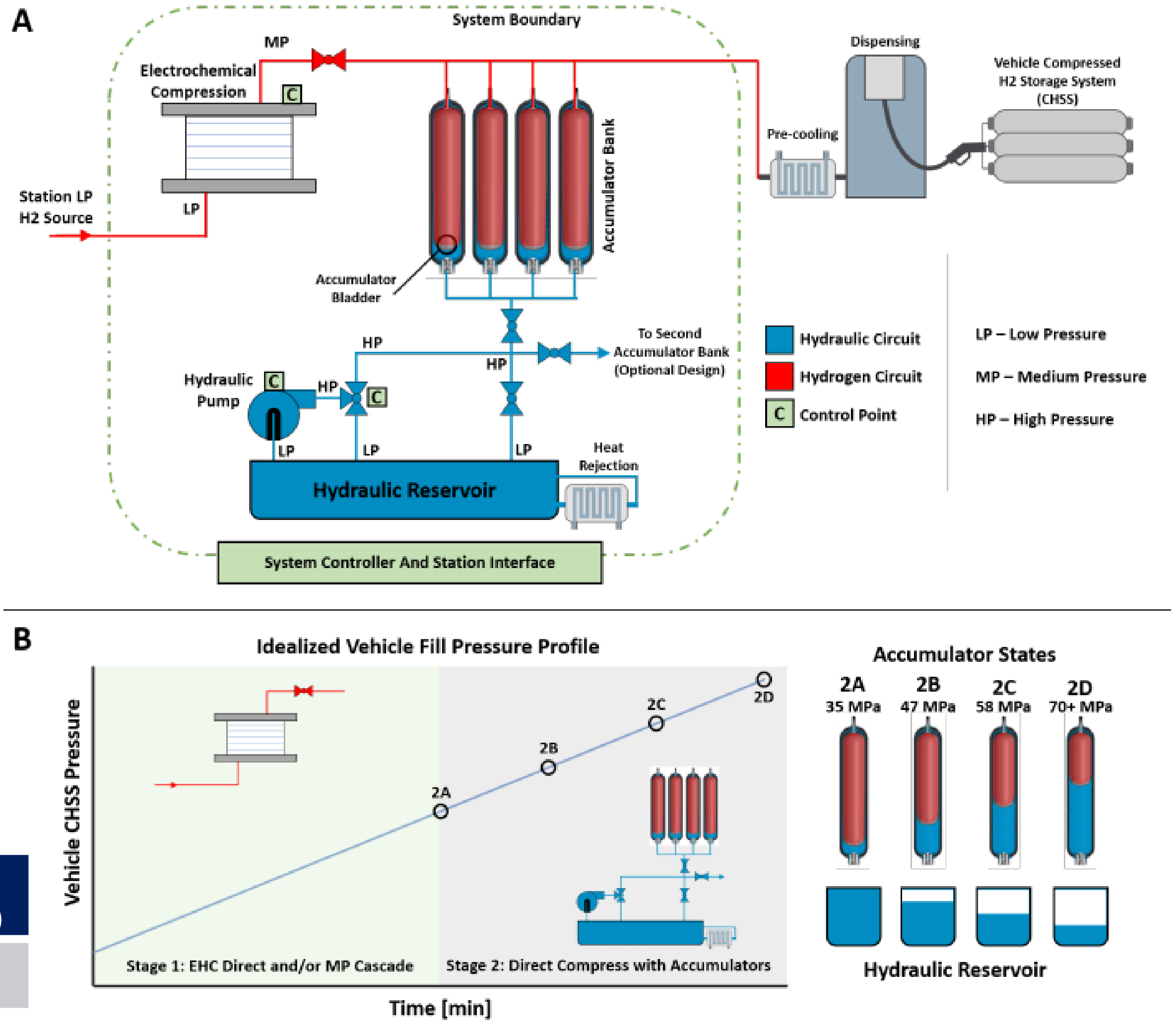

# Example application of EHC: fast refueling of mining trucks

The compression is performed in two stages:

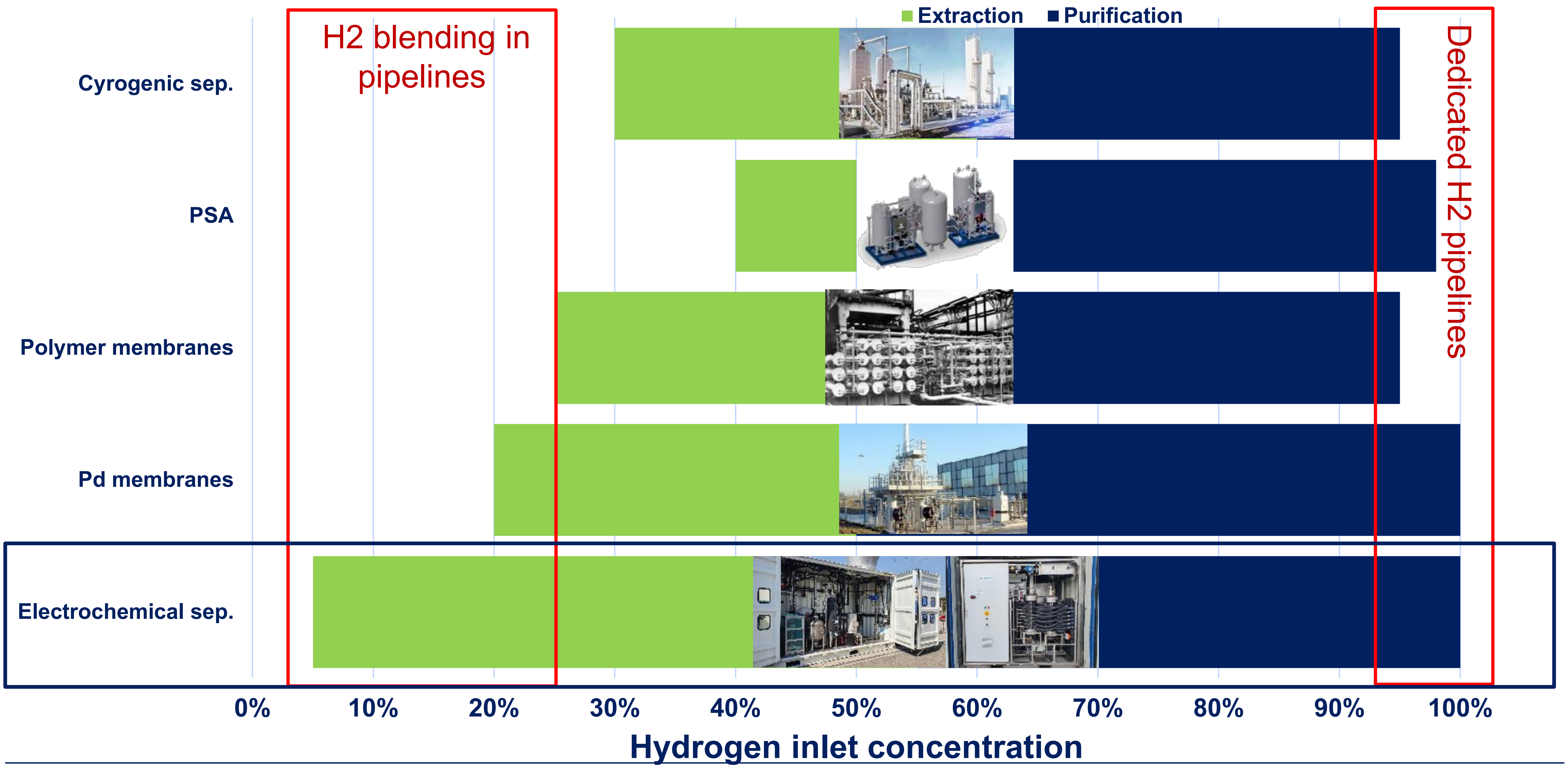
1. Low pressure → 350 bar(g) (inlet pressure dependent on the source of hydrogen)
2. 350 bar(g) → 500 / 700 bar(g) (outlet pressure dependent on vehicle type

- HyET's EHC is used to reliably perform the first compression step up to 350 bar(g)
- The mid-pressure hydrogen is stored in accumulator banks, from which it can be directly compressed with a low compression ratio to the desired tank pressure

| Availability (%) | Inlet prs (barg) | Outlet prs (barg) | Flow (kg/d) | TCO (€/kg/d) | Price (€/kg/d) |
|---|---|---|---|---|---|
| 99 | 1 | 875 | 1,000 | 0.5 – 0.6 | 380 |



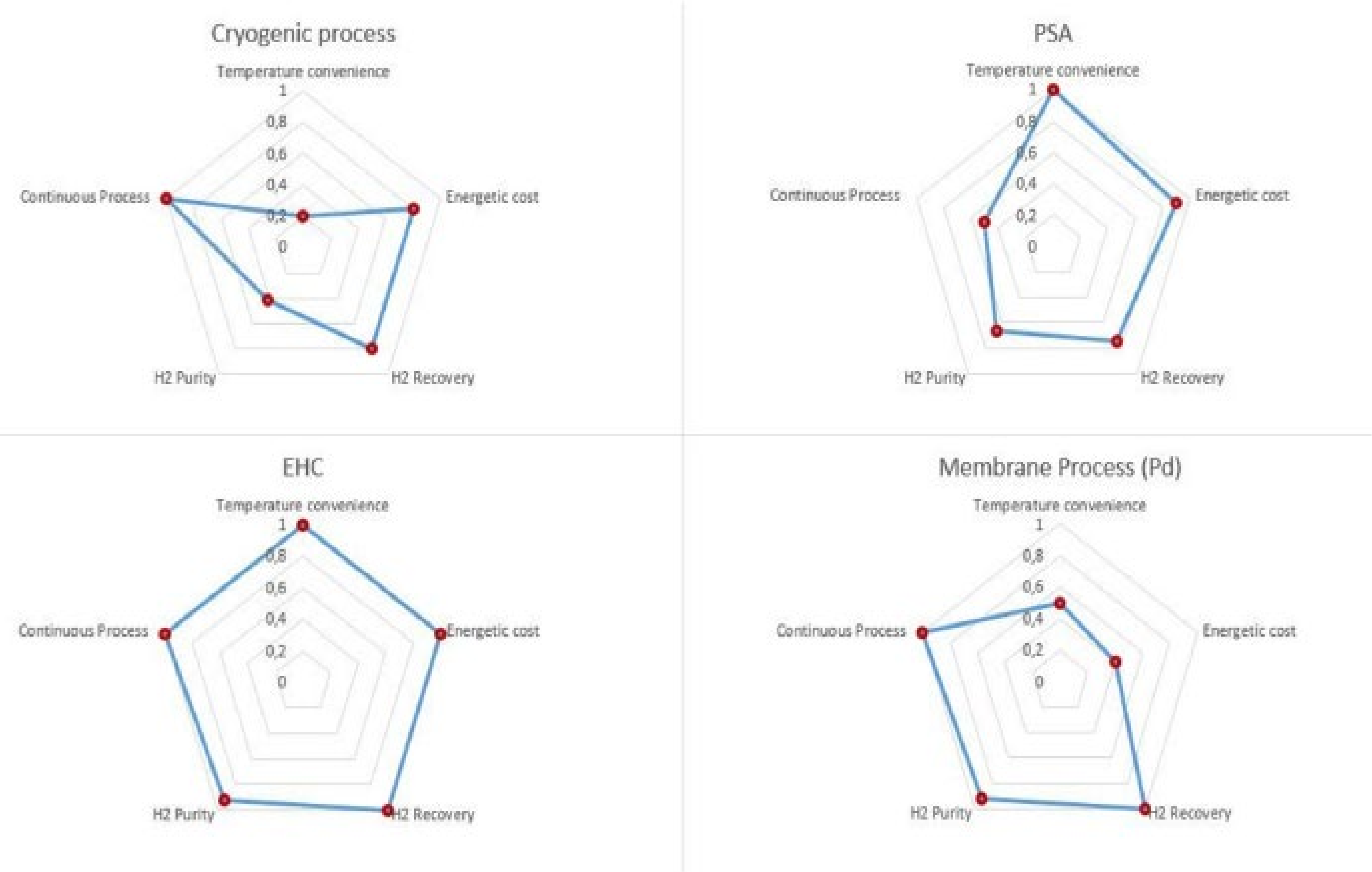
# Available H2 separation technologies



# H2 separation technology performance

Previous research work into the performance of H2 separation methods based on 5 KPIs. The main conclusions from this research are:

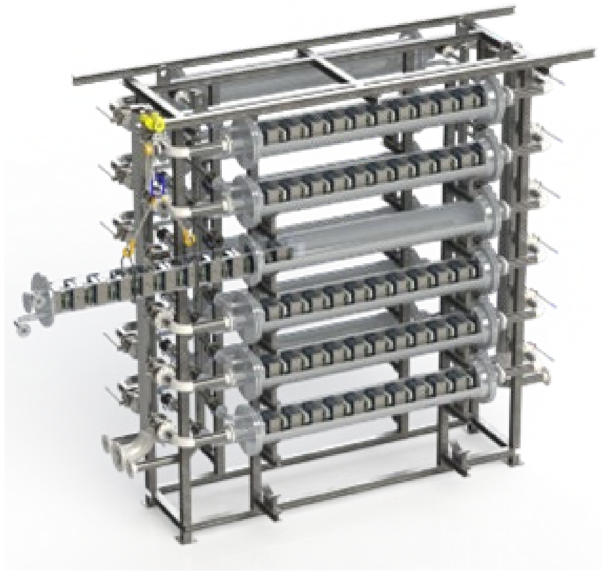
- **Electrochemical separation** systems appears to be the **best option** to simplify the purification / compression steps of hydrogen.
- Electrochemical separation processes combine **low energy cost**, **high H2 recovery and purity**, **little maintenance, low cost and low temperature** of operation, which neither the pressure swing adsorption, the cryogenic nor the membrane processes can do.
- Electrochemical processes can do both the **purification and compression in a single system**.
- Electrochemical processing systems are **compact and easily adaptable**, which allows use on new applications.

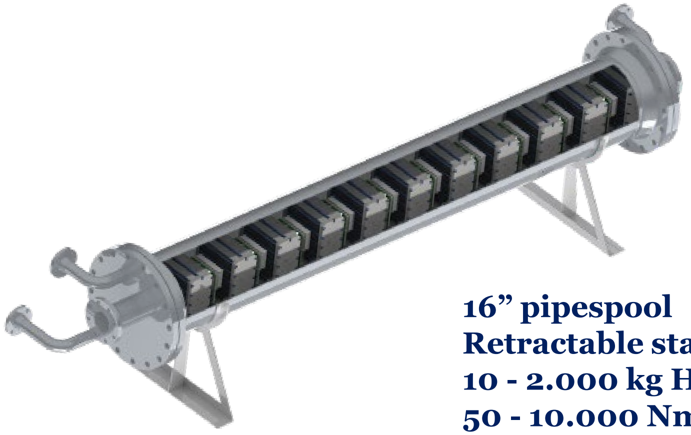



*Rhandi M. Trégaro M, et al in "Electrochemical hydrogen compression and purification versus competing technologies: Part I. Pros and cons"* https://doi.org/10.1016/S1872-2067(19)63404-2; *University of Grenoble; July 5th ,2020*

# Benefits of EHS/P systems

1. **Cost competitive:**
   CAPEX <1,800 EUR /kg $H_2$ /d for large scale systems, due to simple pipespool-internal design.
2. **High efficiencies:**
   <4 kWh/kg $H_2$; >90% $H_2$ recovery
   Proprietary MEA design provides high proton conductivity.
3. **Low OPEX:**
   <0.7 EUR/kg $H_2$ by virtual maintenance free systems design; low energy cost (no T / P swing)
4. **Flexible operation:**
   0 → 100% of design flow in seconds.
   Fast ramp-up & turndown
5. **Separation & compression in 1 system**
   Serves various market requirements





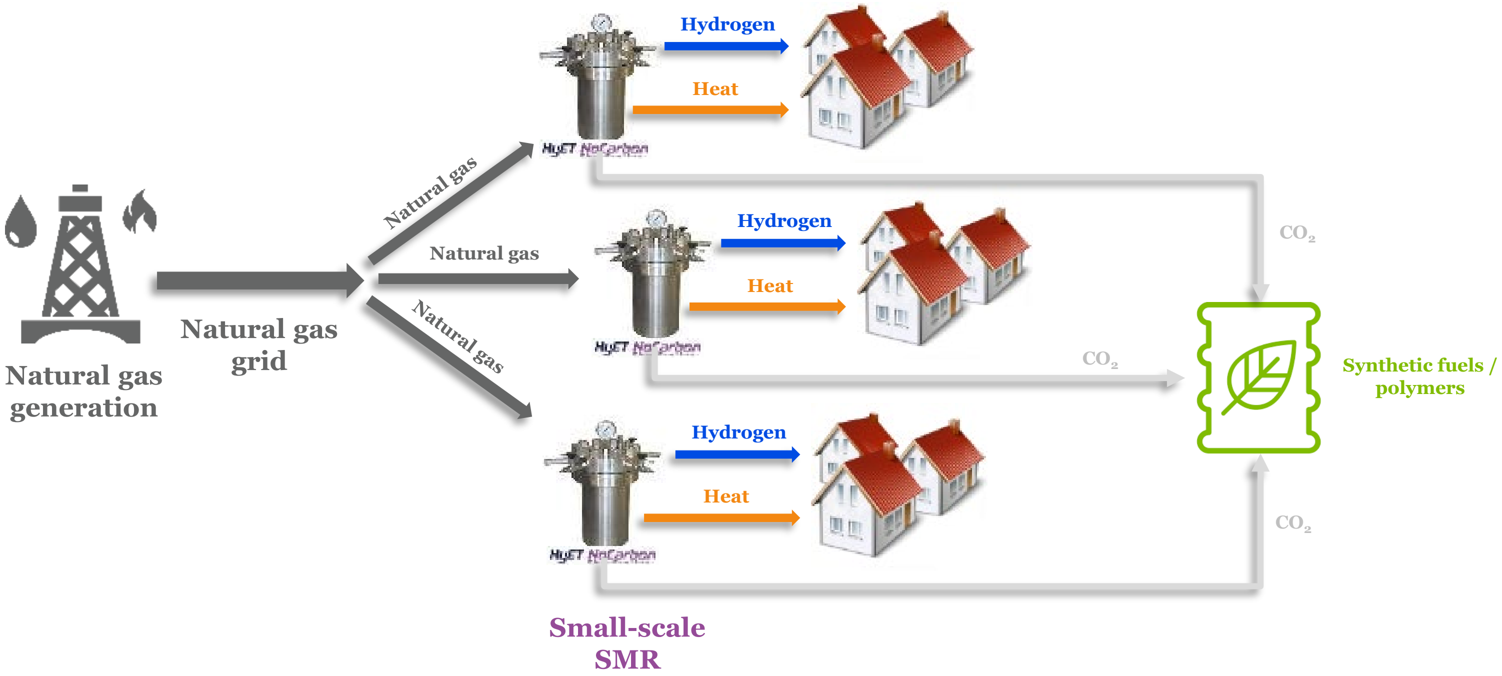
**16" pipespool**
**Retractable stack internals**
**10 - 2.000 kg $H_2$ /day**
**50 - 10.000 Nm³/h**
**2 - 300 bar Operating Pressure**

# Case study: Modular membrane reactors accelerate the energy transition

## Example: Gradual transition to pure H2 in gas grid

### **Phase 1 – Transition:** Small-scale blue hydrogen generation from SMR

- Small-scale **SMR equipment** at small industries / households to convert **natural gas into $H_2$ and $CO_2$**
- **Process heat** is used to partly fulfill heating requirements of the households
- **$H_2$** is used for personal FCEVs and local electricity provision
- **Pure $CO_2$** is captured and converted into synthetic fuel/polymers or used differently (e.g. centrally collected to be sold to green houses)

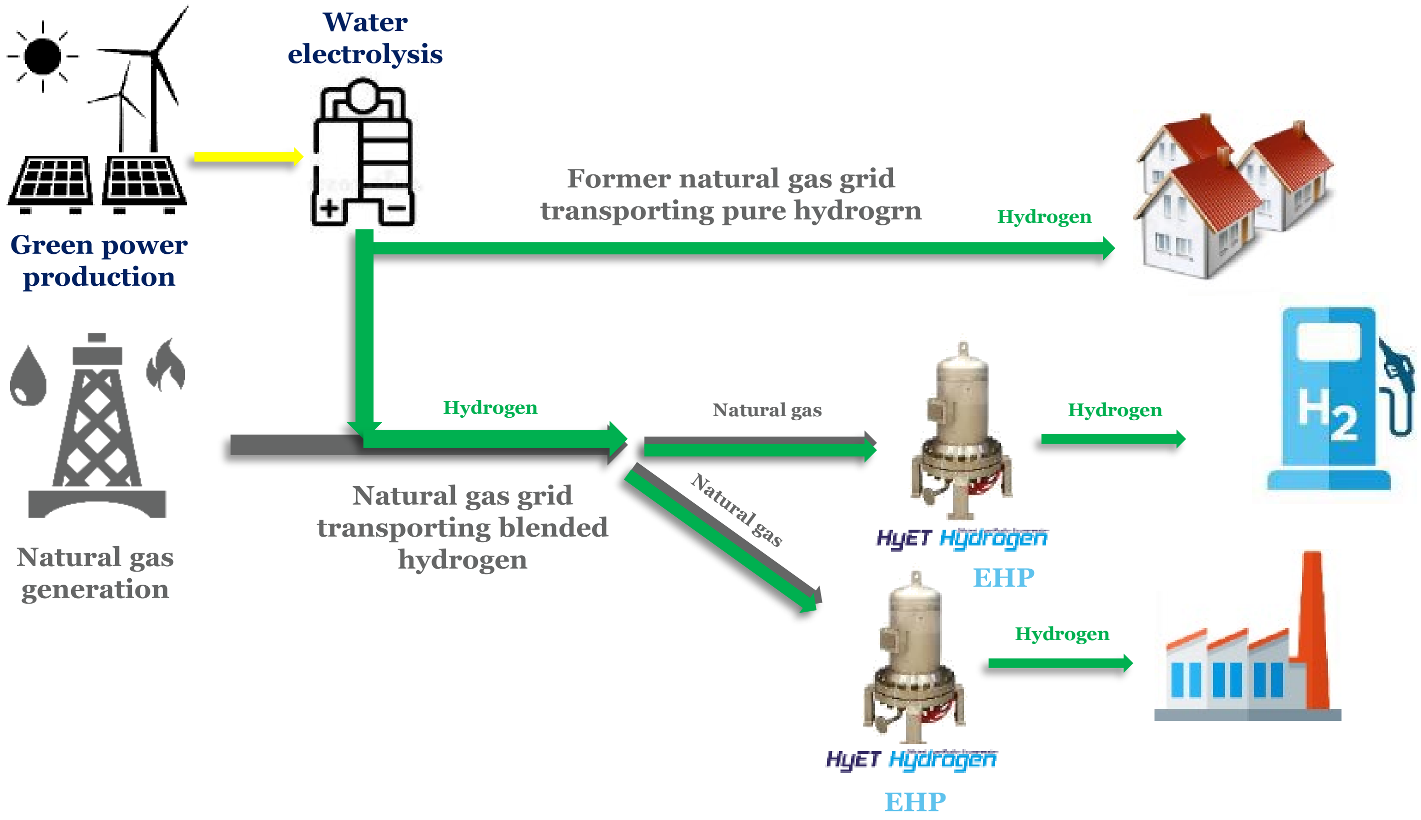


# Case study: Modular membrane reactors accelerate the energy transition

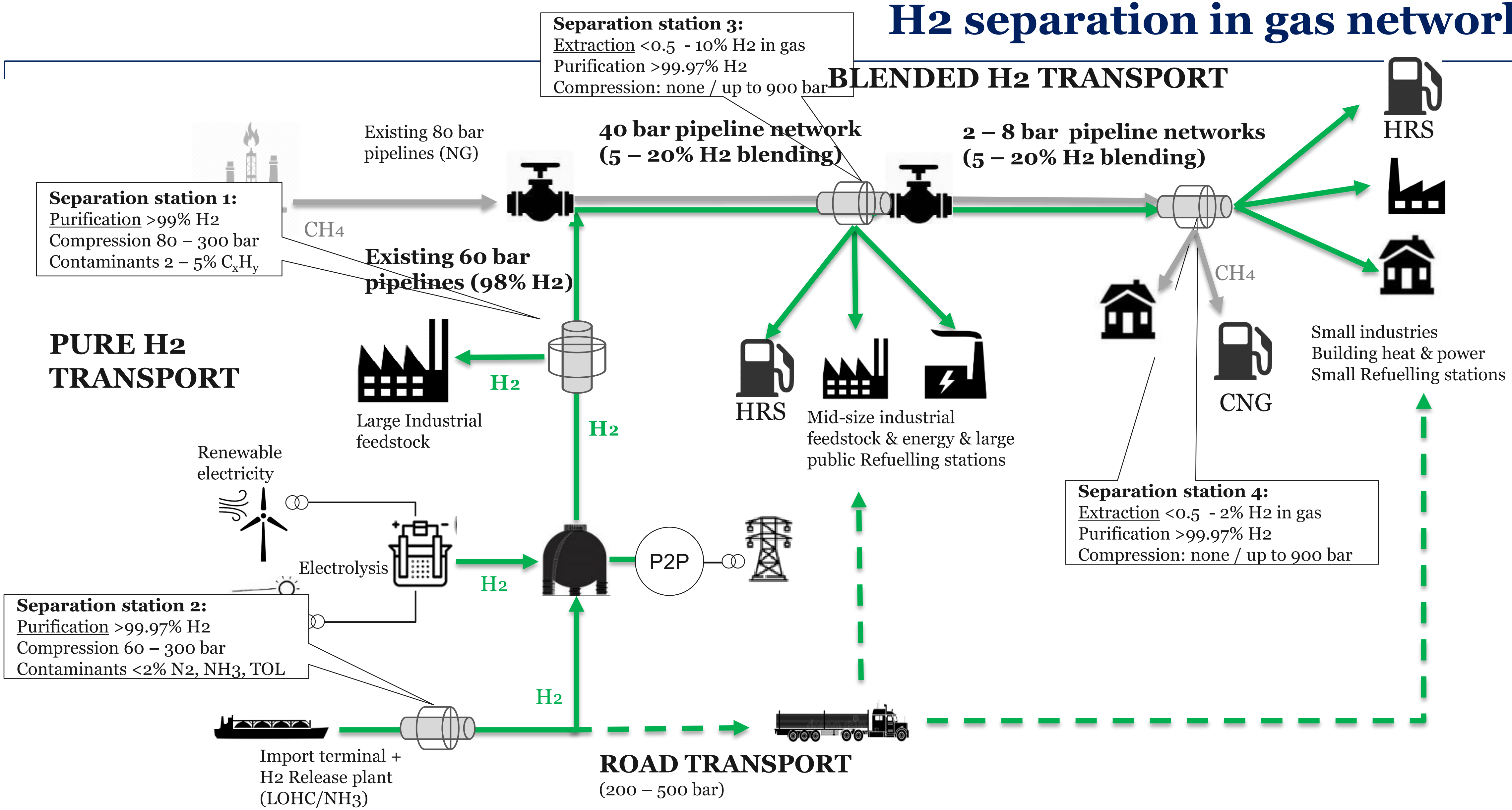
## Example: Gradual transition to pure H2 in gas grid

**Phase 2 – Post-transition:** Large-scale green hydrogen generation from renewable sources

- **Green Hydrogen** is generated on large scale, fulfilling the increased H2 demand.
- Sufficient scale of use of H2 exists in parts of the gas grid to convert these to transport **pure H2**.
- The remainder of the gas grid is used to transport **blended H2,** to gradually increase further scale of use, and convert larger parts of the gas grids to **pure H2**.
- **HyET's EHP (Electrochemical H2 Processing)** equipment can be used to extract the H2 from the natural gas.



# H2 separation in gas networks



# *HyET Hydrogen*

## *Thank you !*

*HyET Hydrogen B.V.*
*sales@hyethydrogen.com*
*+31 26 3623 944*

HyET Hydrogen
Efficient purification & compression