The Role of the Electrochemical Hydrogen Separator and Compressor (EHSC) in the Hydrogen Distribution and Transportation Infrastructure

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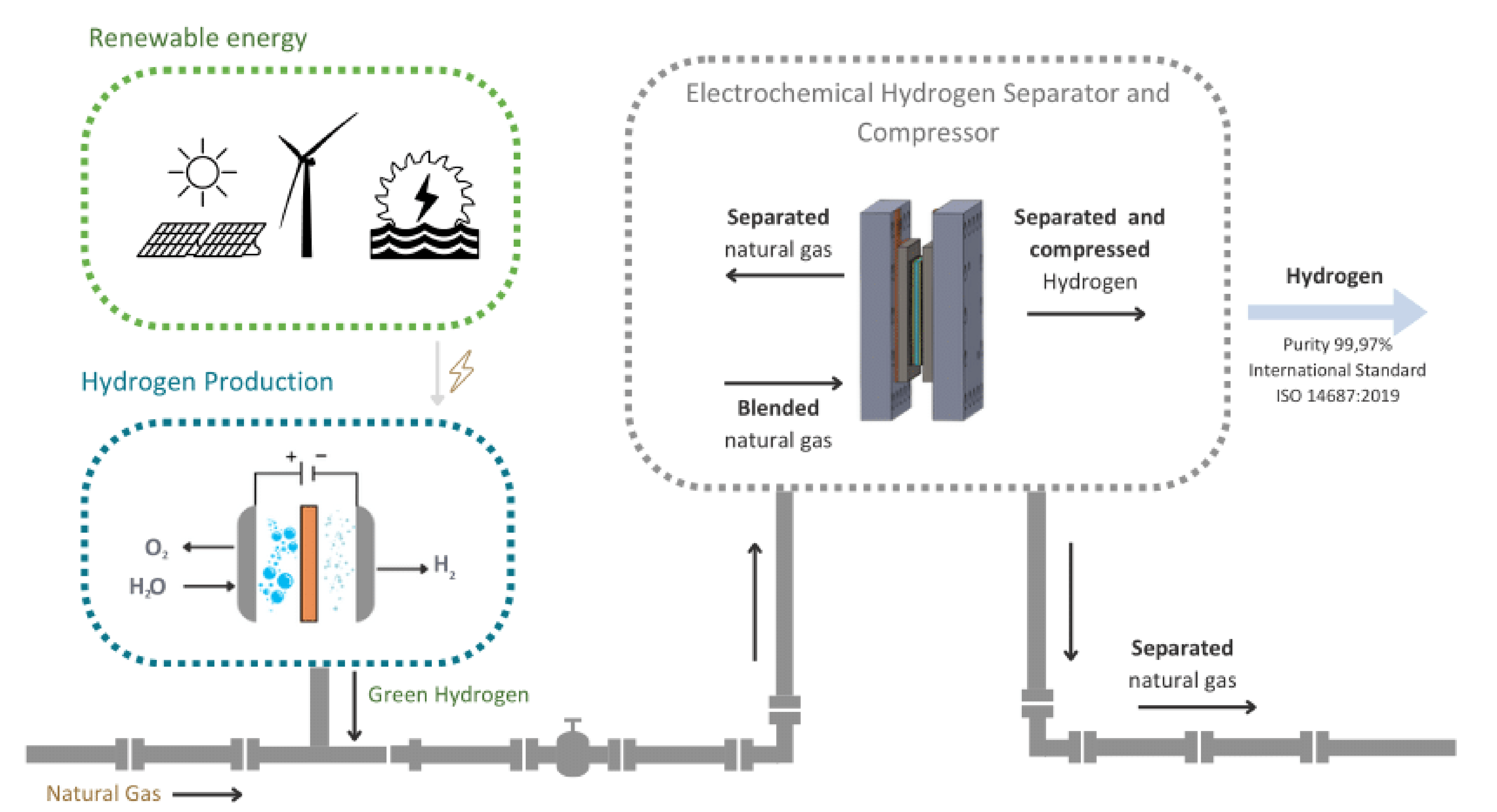
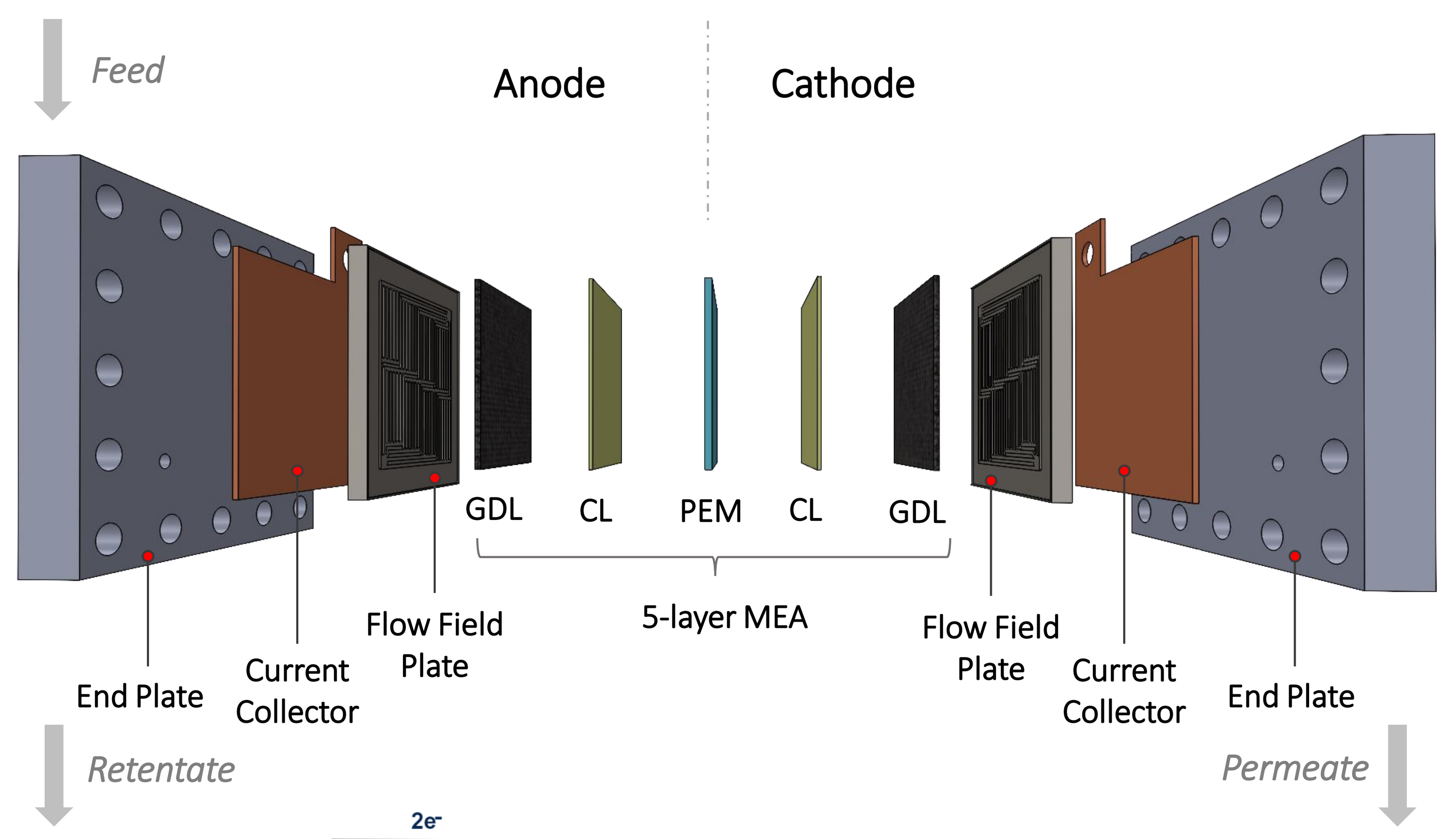
Introduction

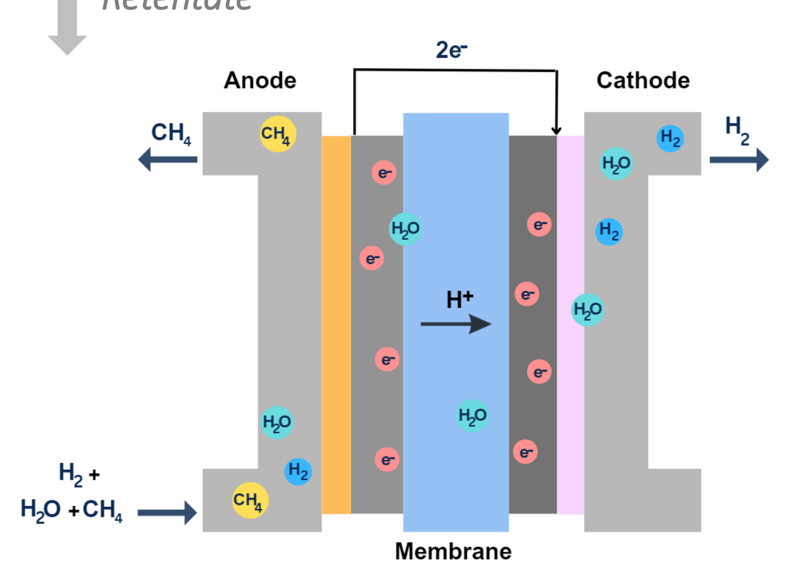
- Hydrogen storage and transportation currently involve energy-intensive and costly reprocessing methods.
- These methods require final reconversion of the chemical carrier for use in end-use applications, such as fuel cells.
- A potentially more sustainable and cost-effective solution is blending green hydrogen into existing natural gas pipelines without repurposing capability. [1]
- The novel electrochemical hydrogen separator and compressor (EHSC) serves as a downstream deblending technology.



Working Principle

- Blended hydrogen is fed at low pressure to the anode.
- The hydrogen is transported through the flow field channels to the gas diffusion layer (GDL).
- The GDL enables the diffusion of hydrogen molecules to the catalyst layer (CL).
- In the CL, hydrogen splits into two atoms and oxidizes to protons (H+) and electrons (e-).
- The protons diffuse over the membrane (PEM) and are reduced on the cathode side at high pressure.[2][3]





Anode: $H_2(LP) \rightarrow 2H^+ + 2e^-$

Cathode: $2H^+ + 2e^- \rightarrow H_2(HP)$

Overall reaction: $H_2(LP) \rightarrow H_2(HP)$

The Role of the EHSC in the Hydrogen Infrastructure

Pipeline transmission is recognized as the most cost-effective solution for transporting large quantities of hydrogen over long distances [4]. In Europe, gas networks can admit hydrogen admixtures of 10vol% without requiring further modifications in the end-use infrastructure. However, certain industries are sensitive to the gas composition, requiring highly pure hydrogen concentrations [5].

98%	99,9%	99,97%	99,995%
ICE and residential	Industrial fuel (power generation)	Fuel Cells for vehicles	Aircraft and space vehicles

Information obtained from [12]

Deblending Requirements	Technology Compatibility Chart			
	EHSC	**PSA**	**Cryogenic Separation**	**Membrane Separation**
High hydrogen purity	**99,97% [5] (ISO 14687:2019-D) – 99,999% [6]**	Up to 99,999% [7]	90% [7]- 99,8% [8]	Up to 99,995% [7]
High hydrogen recovery	Up to 95 mol% [7]	80-90% [7]	80-90% [7]	70% [7]-99% [7]
Flexible feed hydrogen concentrations	**4% [2] to 80% [5]**	**40% [8] -90% [7]**	**15 - 80 vol% [8]**	**>25% [8]**
Low energy consumption	**3,5 – 12,5 kWh/ kgH_2 [5]**	Coupled with mechanical compression 8 – 29 kWh/kgH_2 [5]	2,01 kWh/kgH_2 [9]	Dependant on membrane material
Compatible with impurities (e.g., CO, CO_2, CH_4, and H_2O)	Further research on catalyst inhibition by CO_2 [10]	Impurities are efficiently adsorbed [8]	CO_2 and water provoke solidification and equipment damage [9]	Mature technology on CO_2, CH_4, N_2 and light hydrocarbons separation [9]
Single-step operation	Purifies and compresses hydrogen up to 875 bar [11]	Requires an additional compressor for the separated natural gas	Feed gas requires pretreatment to reduce water content and CO_2 concentration[9]	Requires an additional compressor for the purified hydrogen

Conclusions and outlook

- The EHSC offers high-purity, pressurized hydrogen with significantly lower energy consumption than the PSA technology.
- Hydrogen purities of up to 99,97% (ISO 14687:2019 – Fuel Cell quality) after H2/NG separation can be achieved.
- An optimized low-temperature EHSC stack is currently under development at TU Wien for the separation of H_2/NG mixtures.
- The PEM-based electrochemical system will operate at 80°C and pressure differences of up to 10 bar.
- The effect of the operational parameters (relative humidity, temperature, and gas pressure), components material, and stack design will be evaluated.

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