

White Paper: HyGear's PEM Electrolyser Technology for Optimal Green Hydrogen Production

Introduction

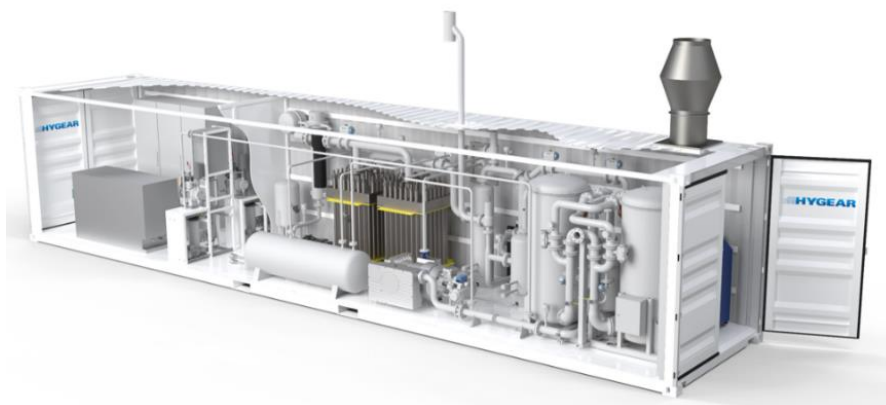
The global shift towards renewable energy sources is accelerating, with green hydrogen being recognized by Renewable Energy Directive (RED) III as a crucial component for decarbonizing sectors like industry and transport. Proton exchange membrane (PEM) electrolyzers are well suited to produce hydrogen from green (solar, wind, hydropower, etc.) energy because they can efficiently operate at variable power inputs, which is essential for effectively managing the intermittent nature of renewable energy sources. HyGear offers both alkaline and PEM electrolyzers to meet diverse market needs. However, since alkaline electrolyzers are less suited for producing green hydrogen due to their slower reaction times and narrower operating range, both of which struggle to accommodate the fluctuating loads of renewable energy sources, this white paper will specifically focus on PEM electrolyser technology: the Hy.GEN-E PEM.

As a hydrogen expert with more than 20 years of experience and over 100 systems installed worldwide, HyGear is well-positioned to deliver efficient and effective hydrogen solutions. HyGear is a unique company that has, aside from electrolysis, also SMR (Steam Methane Reforming) and electric reforming (both with carbon capture) as its own proprietary technology options for hydrogen production. HyGear is part of the HoSt Group, which has its own business units specialized in sustainable systems, manufacturing and electronics.

Meeting Market Demands for Green Hydrogen

The Hy.GEN-E PEM is strategically positioned in the market to address the increasing demand for green hydrogen sourced from renewable energy through the following key features:

- **Flexible Operation:** With its exceptional turndown capabilities, HyGear's PEM electrolyser can operate across a wide range of capacities: from 20% to 100% of its maximum load. The PEM electrolyser can also quickly ramp production up or down and easily switch on and off. These features are essential for effectively managing the fluctuations inherent in renewable energy sources.
- **Scalability:** Its modular design allows for easy scaling to accommodate varying production needs, making it suitable for both small-scale and large-scale applications (1.25 up to 20 MW).
- **Environmental Sustainability:** By producing green hydrogen, the electrolyser significantly reduces carbon emissions compared to conventional hydrogen production.



System Components of HyGear's Hy.GEN-E PEM

With over two decades of hydrogen experience, HyGear has developed a variety of hydrogen generation and purification technologies. HyGear's PEM electrolyser features several key components designed for optimal performance:

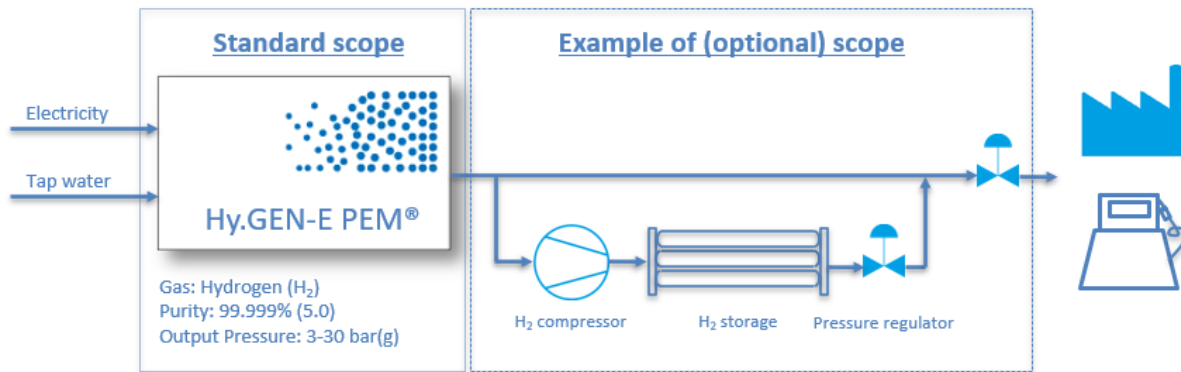
- **Water Treatment:** This system ensures that feed water is purified and conditioned, removing impurities that could impact the electrolyser's efficiency and longevity. The integrated water treatment system enables the use of tap water.
- **PEM Stack:** The stack manufactured by Bosch GmbH is an important part of the electrolyser. The proton exchange membrane stack facilitates the electrochemical reactions necessary for hydrogen production. HyGear has a long-standing partnership with Bosch, a leading supplier of PEM stacks. Stack production is different from designing customized systems and is about operational effectiveness. Bosch's commitment to operational excellence and large-scale manufacturing ensures that HyGear receives consistently high-quality components, enhancing overall system reliability.
- **Rectifier and Transformer:** These components convert the alternating current (AC) of the medium-voltage grid to the direct current (DC) required for electrolysis, providing stable power for efficient operation while connected to the grid.
- **Cleaning Module:** This section guarantees that the hydrogen meets purity standards by eliminating contaminants from the produced gas. It incorporates in-house developed deoxygenation (DeOxo) and Temperature-Swing Adsorption (TSA) technology, achieving the fuel cell grade purity (99.999%) required for most hydrogen applications.
- **Control and Monitoring System:** A smart control system controls the entire process, enabling real-time monitoring and automation of the electrolyser system.

What Sets HyGear's PEM Electrolyser Apart from the Competition

The Hy.GEN-E PEM distinguishes itself for several unique reasons that establish it as a leader in hydrogen production technology:

- **Proven Performance and References:** HyGear's technology is deployed in various applications worldwide, demonstrating reliable and efficient hydrogen production. As one of the few companies specialized in hydrogen for more than 20 years with over 100 systems installed globally with an uptime of >98%, its operational success underscores its credibility.
- **Proprietary Technology:** HyGear is an expert on various electrolyser types and develops and manufactures the full system in-house, thereby ensuring full control over the design and integration of their electrolyser systems.
- **Short Supply Chain:** HyGear maintains established relationships with European suppliers and manufacturing experts, this enables us to stay in control and ensures a streamlined and efficient supply chain that supports timely production and installation.
- **One-stop Shop:** HyGear stands out by offering a plant design and supply option that integrates hydrogen production, compression, and storage, streamlining the process for customers. Available upon request, this comprehensive approach simplifies logistics and

enhances efficiency, facilitating the adoption of hydrogen technology. Refer to the picture below for an example of such a plant.



The Business Case for On-Site Hydrogen Generation via PEM Electrolysis

HyGear's PEM electrolyser presents a strong business case for industries aiming to optimize hydrogen production and logistics:

- **Lower Levelized Cost of Hydrogen (LCOH):** On-site hydrogen production via electrolysis reduces LCOH by eliminating transportation and storage costs, achieving significant savings while utilizing renewable energy.
- **Operational Flexibility:** The Hy.GEN-E PEM can significantly reduce costs by producing hydrogen only during low electricity price periods, if desired, thereby optimizing operational efficiency. This strategy allows users to take advantage of fluctuating energy costs, maximizing savings while ensuring a reliable hydrogen supply.
- **Regulatory Compliance and Environmental Benefits:** On-site production with renewable electricity helps meet environmental regulations, enhances corporate sustainability, and appeals to eco-conscious consumers. Additionally, adopting the Hy.GEN-E PEM may unlock government incentives promoting green technologies.

In summary, on-site hydrogen generation through electrolysis offers significant cost savings and aligns with sustainability goals, making it an attractive solution for businesses in the evolving hydrogen economy.

For a detailed business case analysis, refer to Annex 1. This business case is for a glass factory in Germany and does not include possible green subsidies, reducing the Hy.GEN-E's hydrogen price even more.

Conclusion

HyGear's Hy.GEN-E PEM electrolyser stands at the forefront of hydrogen production technology, effectively addressing the rising demand for green hydrogen. With its flexible operation, scalability, and commitment to environmental sustainability, the Hy.GEN-E PEM not only offers significant cost savings but also aligns with corporate sustainability goals. As industries increasingly seek reliable and eco-friendly hydrogen solutions, HyGear's innovative approach and proven track record position it as a key player in the transition to a greener future.

HyGear can design and build optimal customized electrolyser systems realizing cost-effective, reliable and sustainable green hydrogen. In addition, HyGear has also developed and supplied stand-alone DeOxo and TSA systems (marketed as the DeOxo Hydrogen) which remove oxygen and water from hydrogen and realizes 5.0 purity (99.999%).

Annex 1 Business case example Hy.GEN-E PEM

To be filled!

Utilities price		
Natural Gas	0	€/ Nm3
Electricity	0,13	€/ kWe
Feed water	0,25	€/ L
Cooling water	0,15	€/ m3
Compressed air	0,05	€/ Nm3

Operations		
Inlet natural gas pressure	n.a.	bar(g)

Plant operations		
Hours of operation	8760	hours/y

Hydrogen		
Current hydrogen price	1,03	€/ Nm3

Financing rate	6,0%
Finance type	Jaren

Select HyGear product!

Drop down selection	Hydrogen Capacity
Hy.GEN-E 250 PEM	240 Nm3/h

Unit(s) required	1
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Results		
HyGear's Levelized Cost of Hydroger	0,880	€/ Nm3
	9,768	€/ Kg
Annual savings	311.204	€/ year
15-year investment savings	4.668.060	€/ 15 year

