ADVANCED MEMBRANE DESIGN & CRITICAL FACTORS IN SCALING PEM WATER ELECTROLYSIS SYSTEMS

Maximizing the potential
of membrane technology to
meet our net-zero targets.

Amr Kobaisy
New Product Development Manager
W. L. Gore & Associates GmbH

Together, improving life

Agenda: Three Pathways to Progress

Identifying — and overcoming — the challenges for green hydrogen production.

PEM Electrolysis is a viable production pathway to achieving decarbonization targets.

Efficiency

PEM systems must become more efficient to make hydrogen more affordable.

System Integration

For individual components to work in complex systems, we need collective experience, expertise – and collaboration.

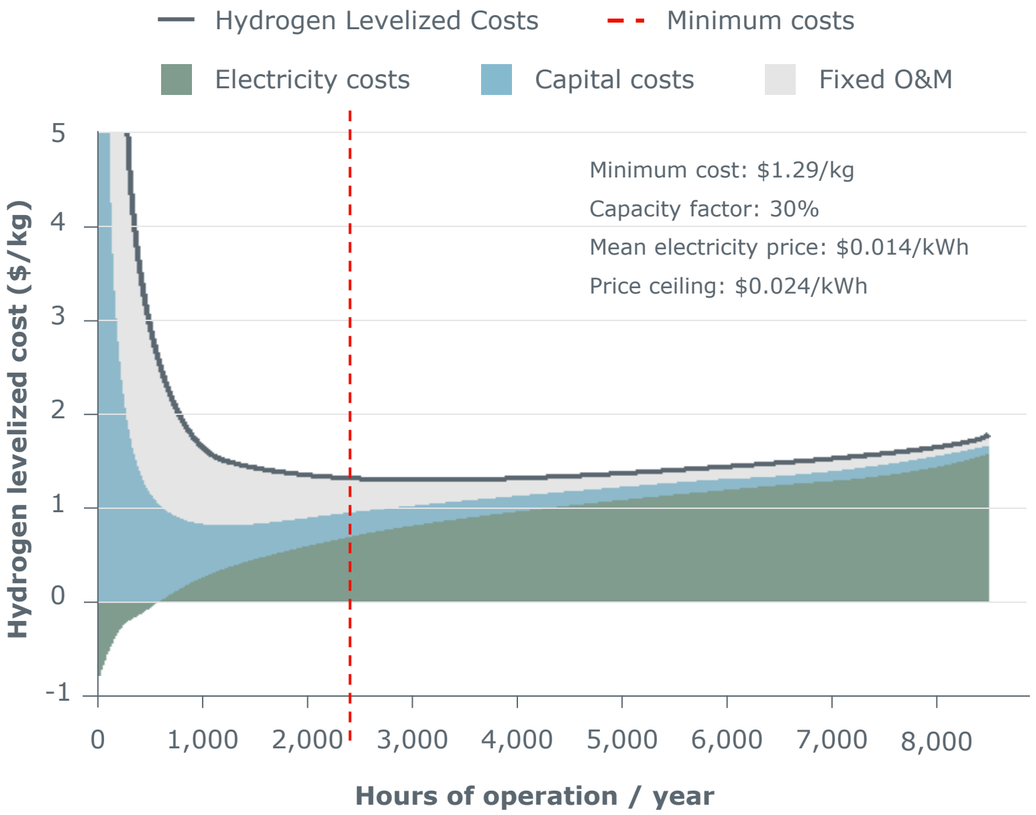
Scalability

PEM systems need to scale up quickly to meet growing demand (requiring a reliable, sophisticated supply chain)

PEM SYSTEMS MUST BECOME MORE **EFFICIENT** TO MAKE HYDROGEN MORE AFFORDABLE.

Reducing OPEX is key to delivering results

CAPEX is important. OPEX is **critical**.



NREL (2022), Operating strategies for dispatchable PEM electrolyzers that enable low-cost hydrogen production, Alex Badgett, Bryan Pivovar, Mark Ruth at the International Conference on Electrolysis 2021, Golden, Colorado, US

Massive industry scale-up will enable lower CAPEX via:

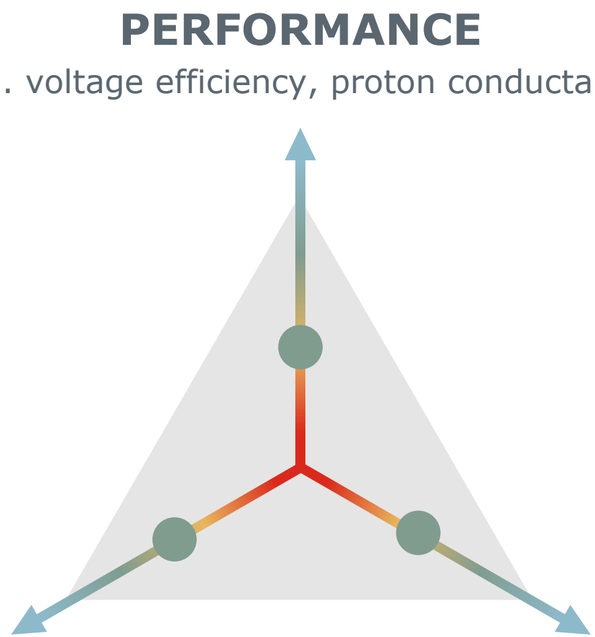
- Increased plant size & economies of scale.
- Optimized electrolyzer design & plant integration cost.

To scale up to meet net-zero demands, OPEX is the deciding factor in delivering a lower levelized cost of hydrogen.

Tackling technology trade-offs to reduce OPEX

Why compromise – when you can optimize?

- Engineers typically face the ‘system dilemma’ of **optimizing performance**, **safety** and **durability**.
- Optimizing for 1 criteria has meant compromising on the others... until now.
- Gore has developed **an advanced PEM that can optimize them all – at the same time**.



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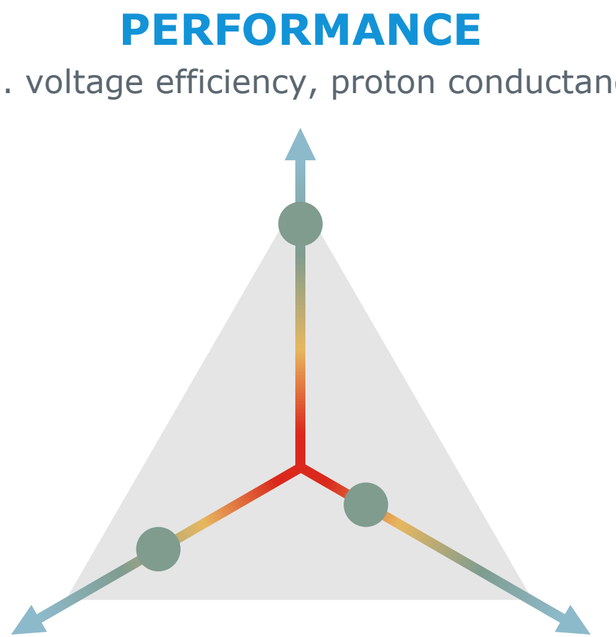

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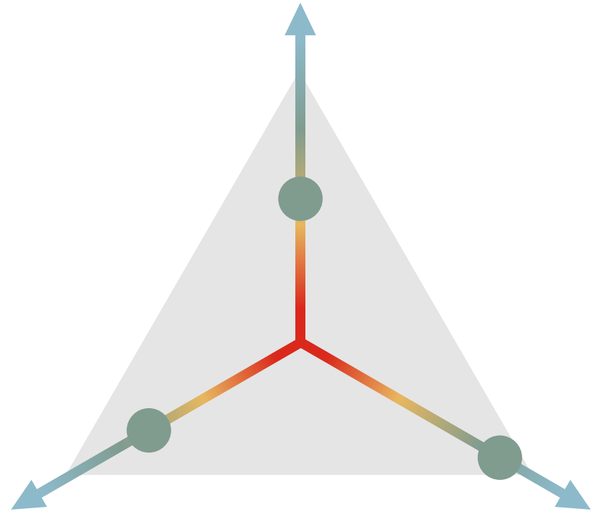

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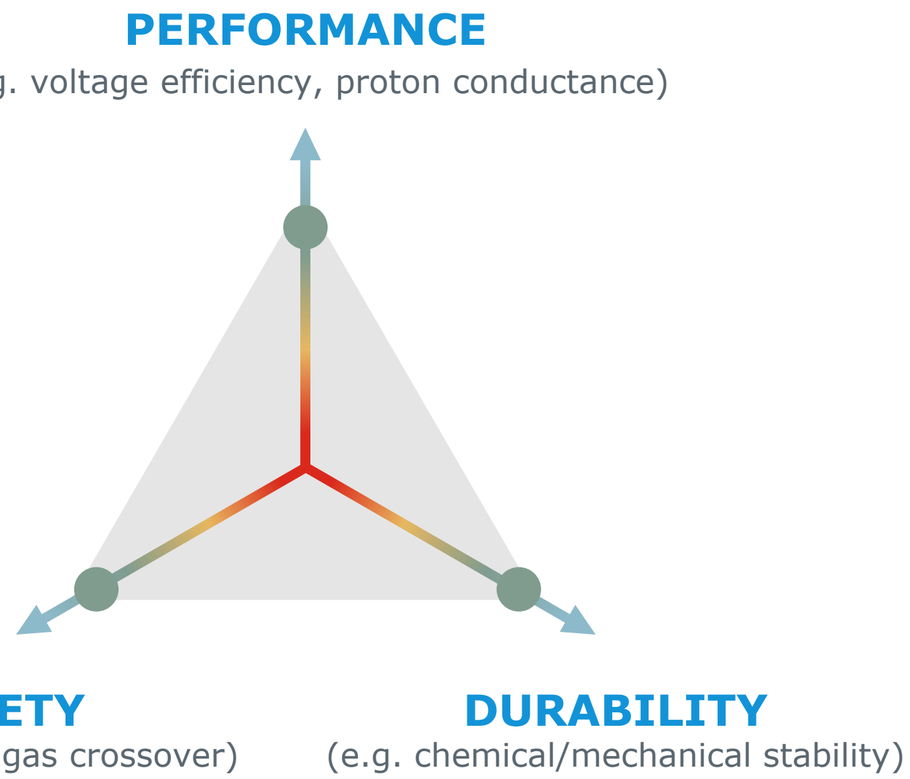
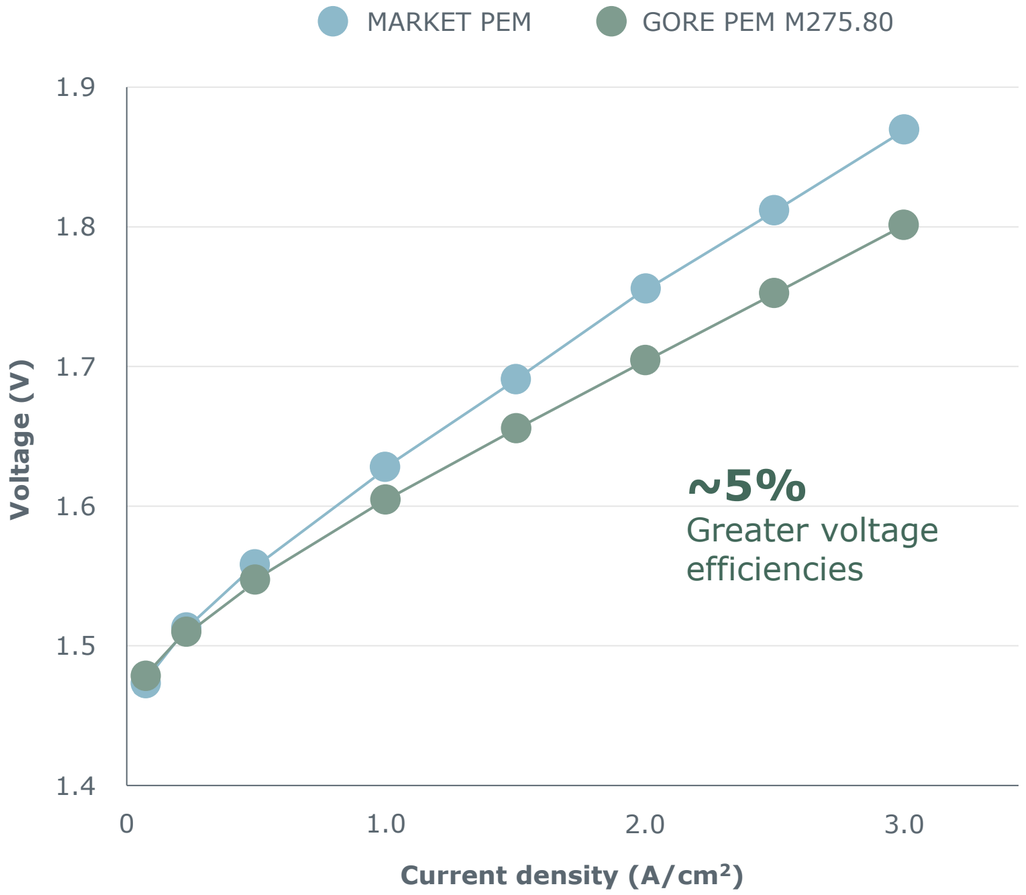


How does better performance benefit your **output**?



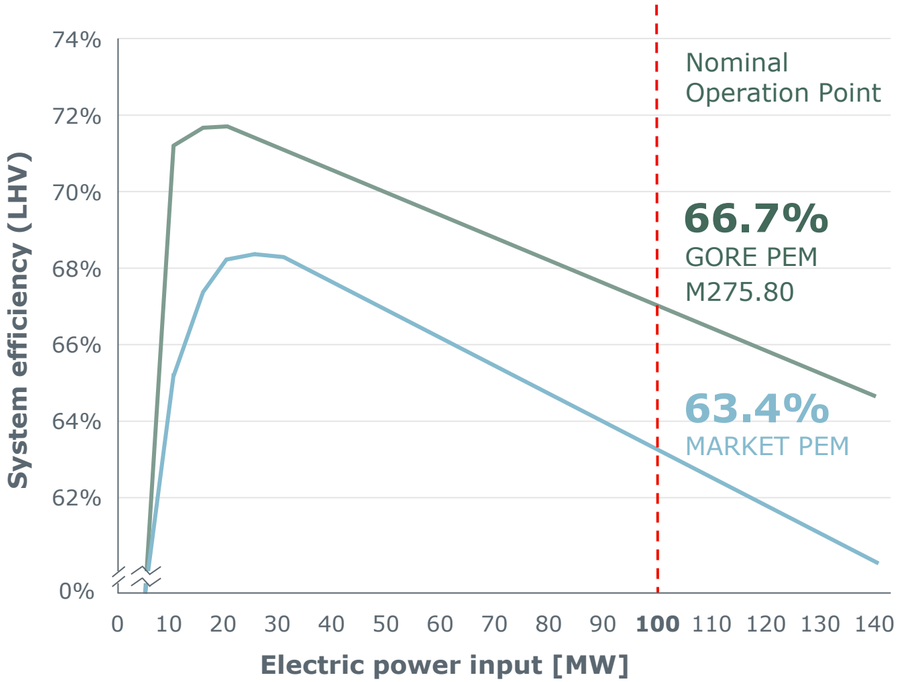
- Gore's PEM M275.80 offers **~5% greater cell voltage efficiencies over other PEM** while meeting safety & durability requirements.
- This **reduces the amount of electricity required** to produce 1 kg of Hydrogen.
- A more efficient PEM enables a **smaller stack and a higher production of H_2**. Small stacks are important where space is premium/key.

Increasing voltage efficiency enables **higher H_2 output for the same energy consumption** (or vice versa; less energy consumption for the same H_2 output)

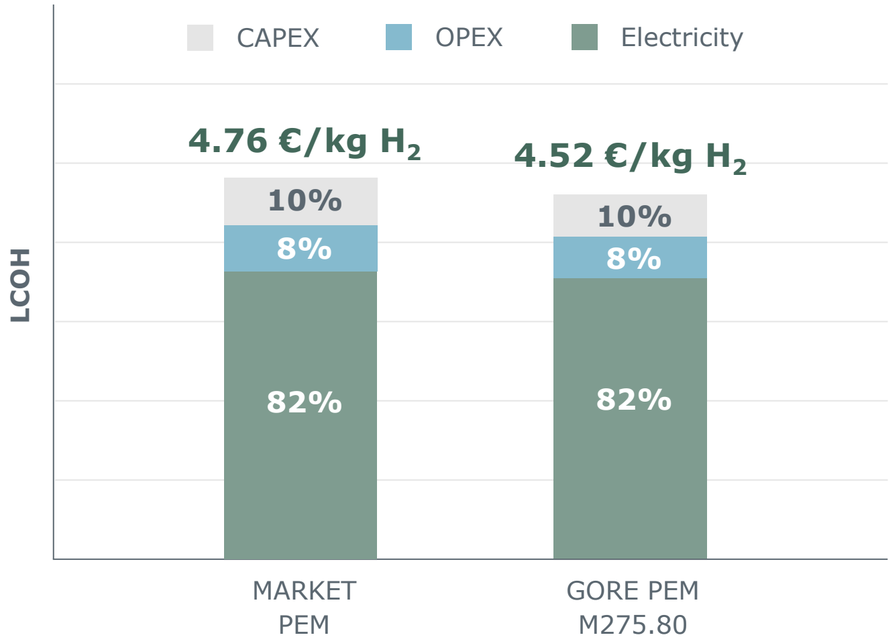
Achieving better efficiency and LCOH with Gore's PEM

Electrolyzer simulation for North Sea off-shore wind park

- Wind Park: 200 MW
- Electrolyser: 100 MW
- H_2 output @ 30 bar
- Off-shore typical load profile
- FLH: ~5,600 hrs.



- Highest system efficiency is enabled with Gore PEM M275.80 – not only at nominal power but also in part load.



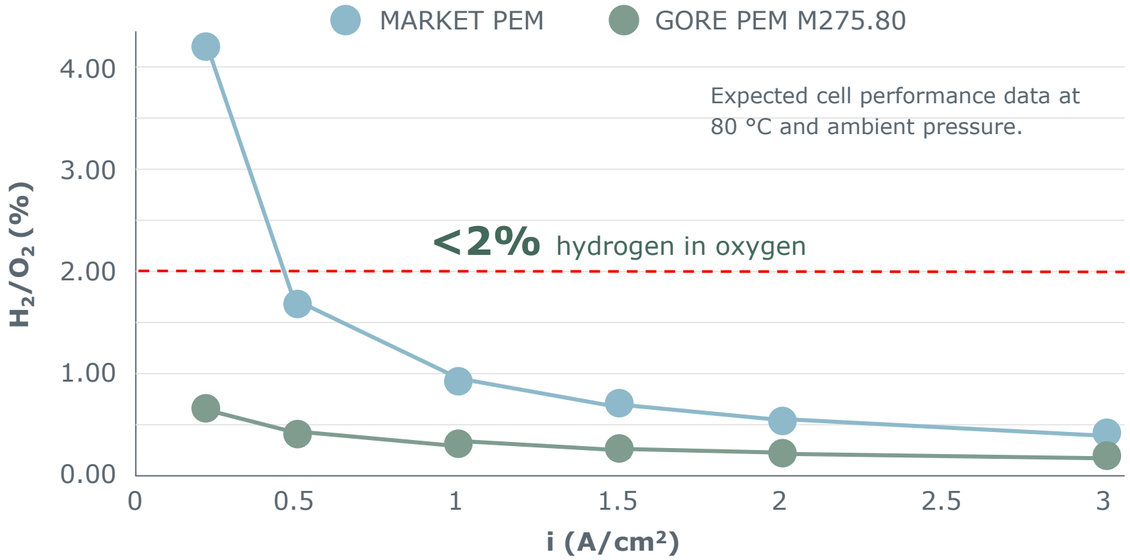
- System efficiency is crucial – electricity expenditures account for over 80% of the LCOH
- Gore membrane demonstrates **clear LCOH advantage** over Market PEM

How does Gore’s PEM improve safety & durability?

Applying our materials science expertise to enable reliable and long-lasting WE systems.

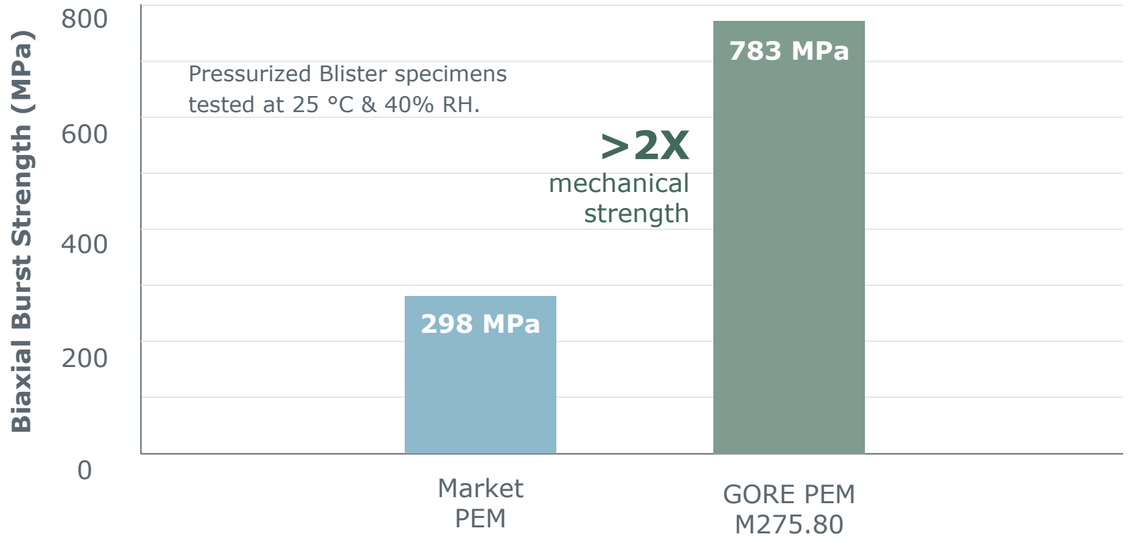
SAFETY

(e.g. hydrogen gas crossover)



DURABILITY

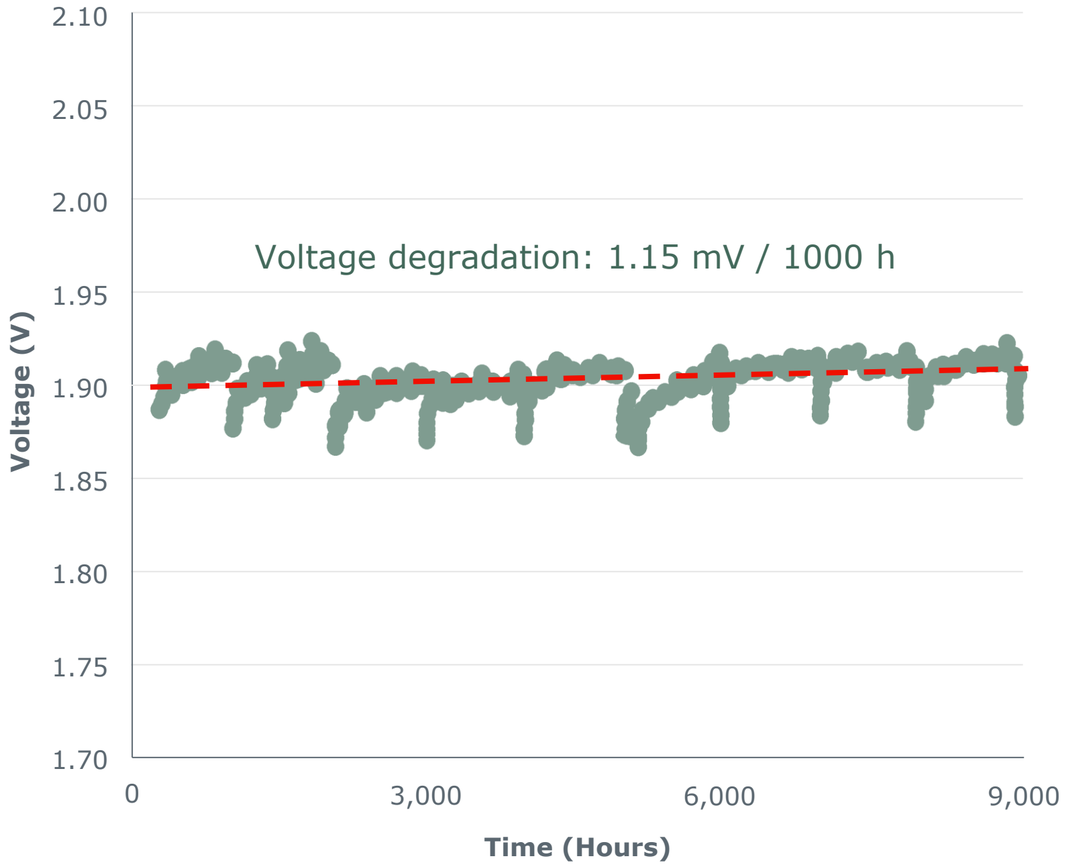
(e.g. chemical/mechanical stability)



- Gore’s additive technology enables <2% hydrogen in oxygen concentrations over a wide operating range - even at low ampere/current densities.
- Wider Operation Range following load cycles results in longer uptime while staying below safety limits.

- This extends WE system durability and reduces service intervals for continuous operation.
- Higher mechanical durability enables long-life WE systems and reduces maintenance for longer system uptimes.

Demonstrating our PEM durability with ITM POWER



Data acquired & shared by ITM Power

- Durability testing of Gore's PEM M275.80.
- Undertaken at ITM's state-of-the-art test facility.
- Test performed under high current conditions (3.3 A/cm²) to maximize hydrogen production.
- Cell operation **>9,000 hours (and ongoing)**.

Test demonstrates **excellent membrane durability and <1% voltage degradation** (over the 9,000 hours test duration)

Breaking performance barriers with Gore's high-performance PEM

Reducing system trade-offs with our advanced membrane technology.

Ionomer

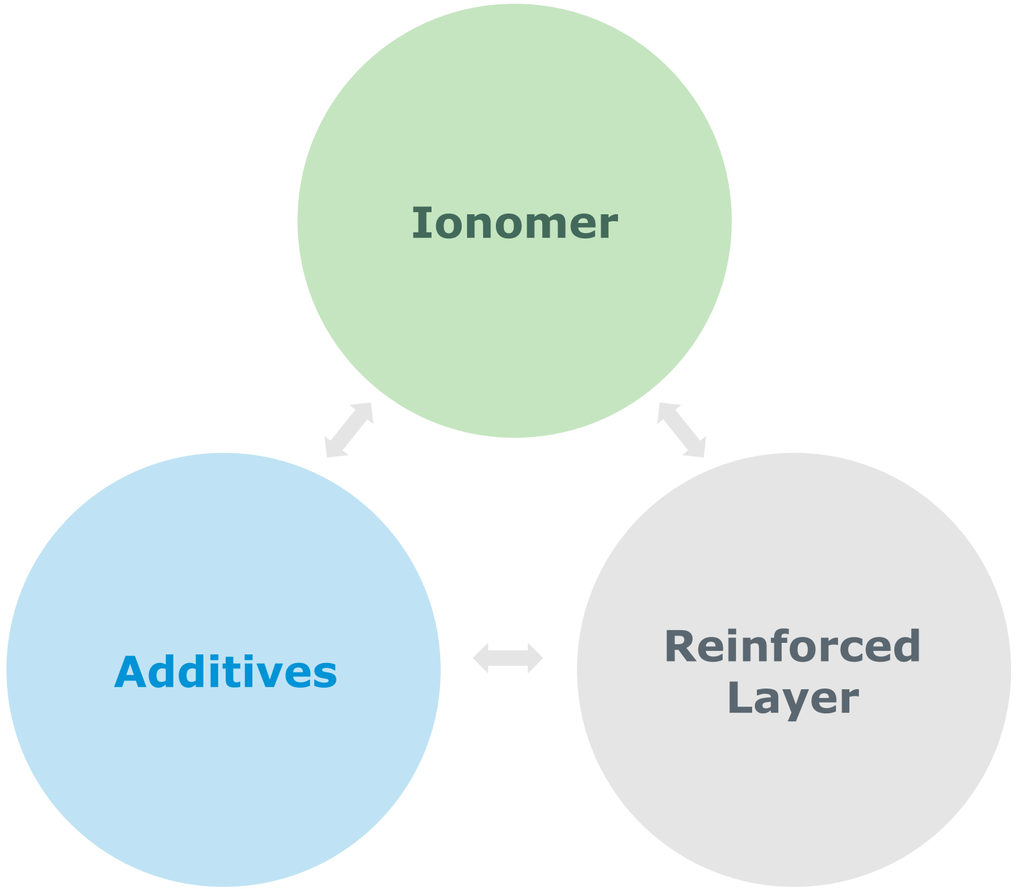
- High proton conductance + high voltage efficiency for **increased performance**

Additives

- Greater chemical durability + reduced H_2 crossover for **increased durability and safety**

Reinforced Layer

- Enabling thin, highly conductive, mechanically + chemically durable membranes for **increased durability and performance**

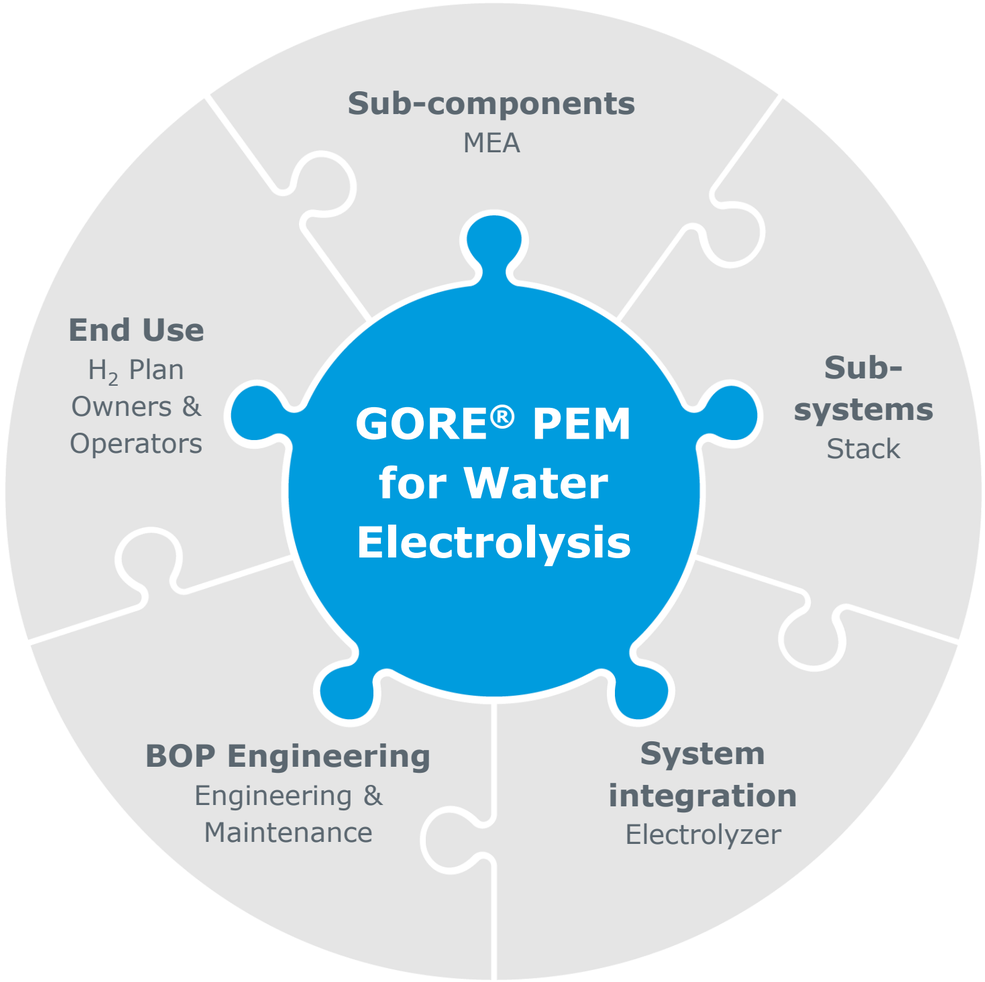


FOR INDIVIDUAL COMPONENTS TO WORK IN COMPLEX SYSTEMS, WE NEED COLLECTIVE EXPERIENCE, EXPERTISE – AND **COLLABORATION**.

Even an advanced membrane can't do it alone ...

- A new and complex technology presents new and complex challenges.
- Different stakeholders in the supply chain have competing requirements.
- The solution? **Collaboration**.

Interdependent components require orchestration. Our collective expertise and experience can solve component integration challenges!



Creating the clean energy future – together.

- We have developed a "multi-use" membrane for broad application in Water Electrolysis …
- … and with the right partners, we can develop tailored WE membranes for different systems + requirements.

WE OFFER

1. **25 years' membrane technology & electrochemical expertise**
2. **Global analytical capabilities and prototyping facilities**
3. **Proven, reliable and secure supply**

WE'RE LOOKING TO

1. **Expand our fundamental understanding on PEM fitness-for-use in Water Electrolysis systems**
2. **Increase our technical insights on system performance and component interactions**
3. **Align on future development vectors and product roadmaps**

PEM SYSTEMS NEED TO **SCALE UP** QUICKLY TO MEET GROWING DEMAND, REQUIRING A RELIABLE, SOPHISTICATED SUPPLY CHAIN.

Applying our fuel cell expertise to water electrolysis

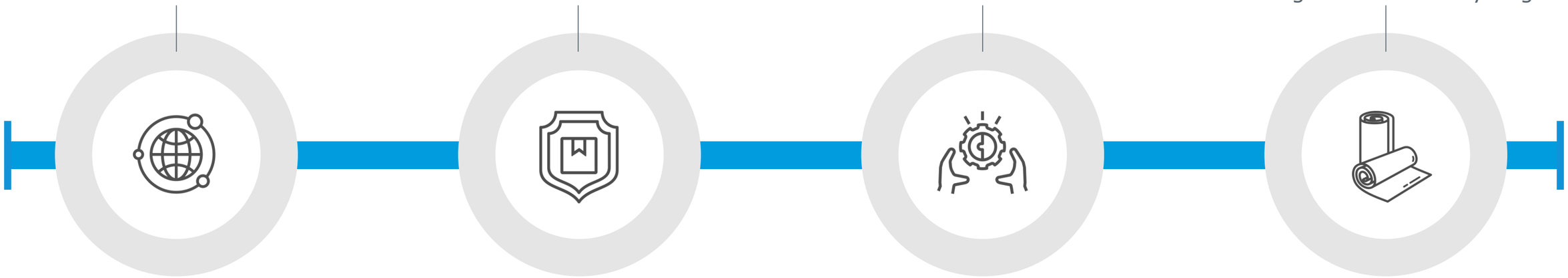
Overcoming challenges and reducing risks in an uncertain environment.

Global PEM capacity
with multiple state-of-the-art production lines

Proven supply security,
process stability + consistent quality

Strategic partnership
for critical raw materials with priority access

Market-leading PEM
that optimizes commercialization while enabling lower cost of hydrogen



Gore’s established enterprise resources are set up to support **Multi-Gigawatt installations TODAY**.

TO SUMMARIZE…

We can achieve our carbon targets – if we collaborate

EFFICIENCY. SCALABILITY. SYSTEM INTEGRATION.

- WE systems must become more **efficient** to make hydrogen more affordable – enabled through Gore‘s **highly conductive and durable PEM.**
- For individual components to work in complex systems, we need **collective experience and expertise** – enabled by **effective collaboration.**
- WE PEM systems need to **scale up quickly** to meet growing demand – enabled through Gore‘s already established **high volume capacity and proven supply security.**

LET'S NOT WAIT TO CREATE A CLEAN ENERGY FUTURE.
PEM TECHNOLOGY IS **AVAILABLE AT SCALE TODAY**.

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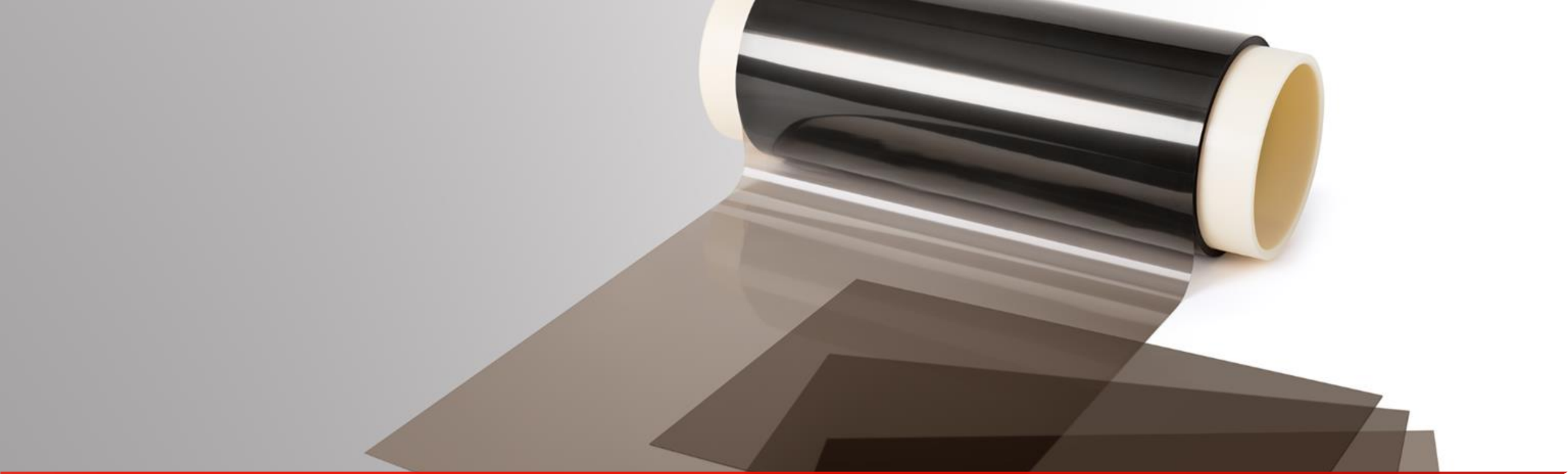

THANK YOU.

Contact our Clean Energy team to learn more about the new

GORE® PEM for Water Electrolysis.

gore.com/alt-energy

Together, improving life