# Accelerating Green Hydrogen Production with Advanced Membrane Design


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*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.

### Scalability

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

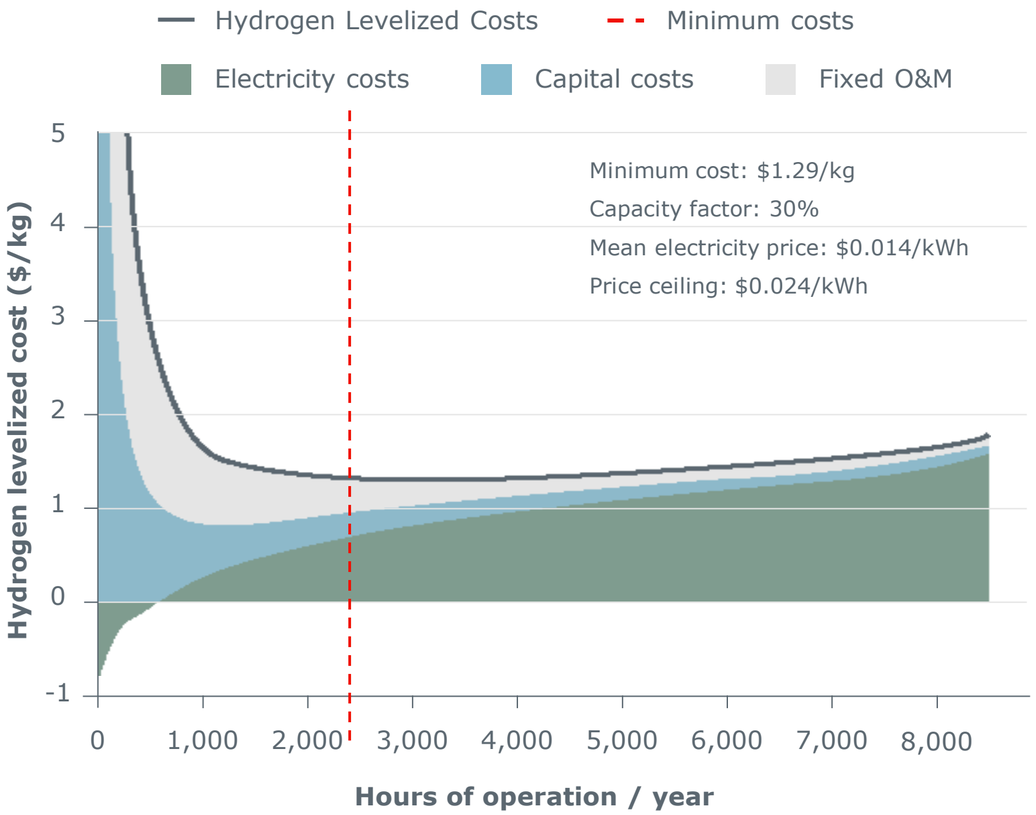
### System Integration

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

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:**

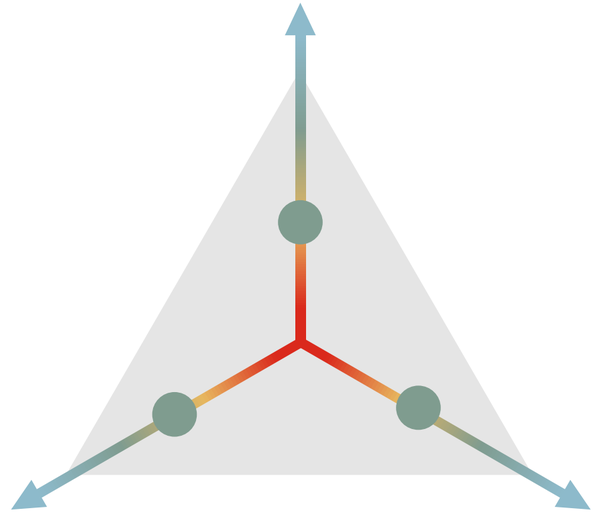
- Increased plant size & economies of scale.
- Optimized electrolyzer design & plant integration cost.

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

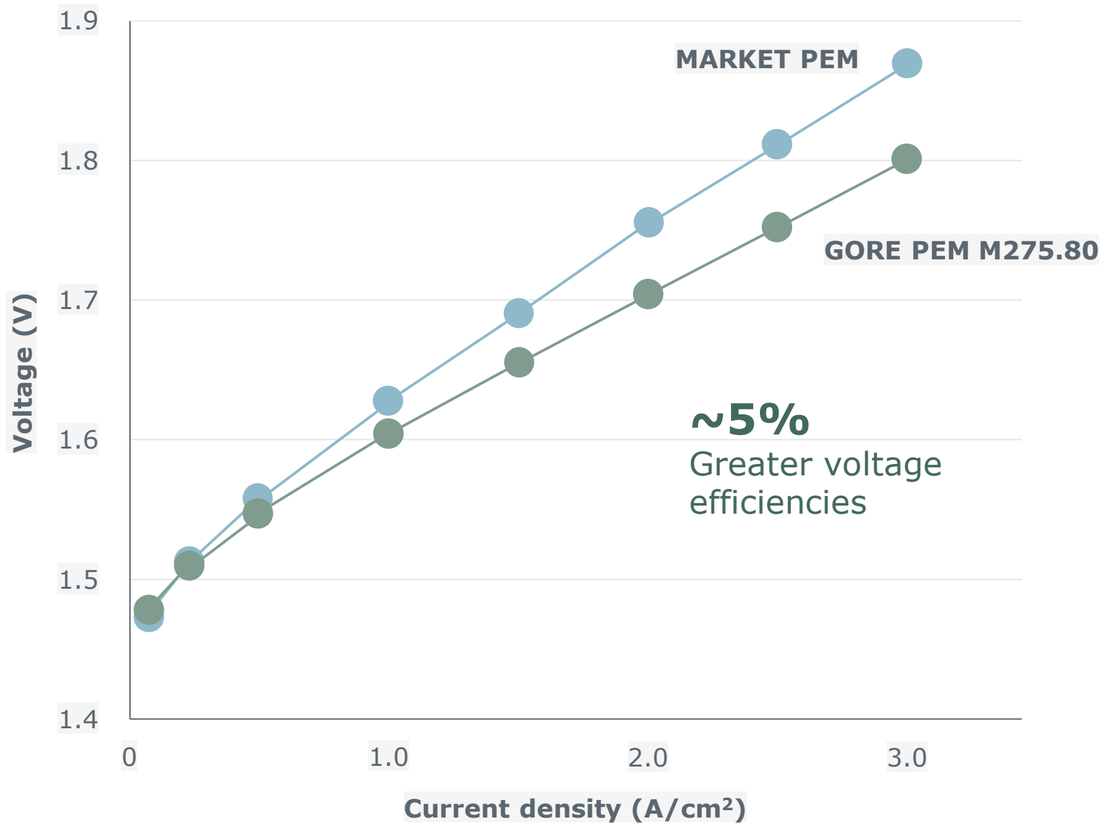
# Tackling technology trade-offs to reduce OPEX

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**.



# Increased performance with Gore‘s PEM




- 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.

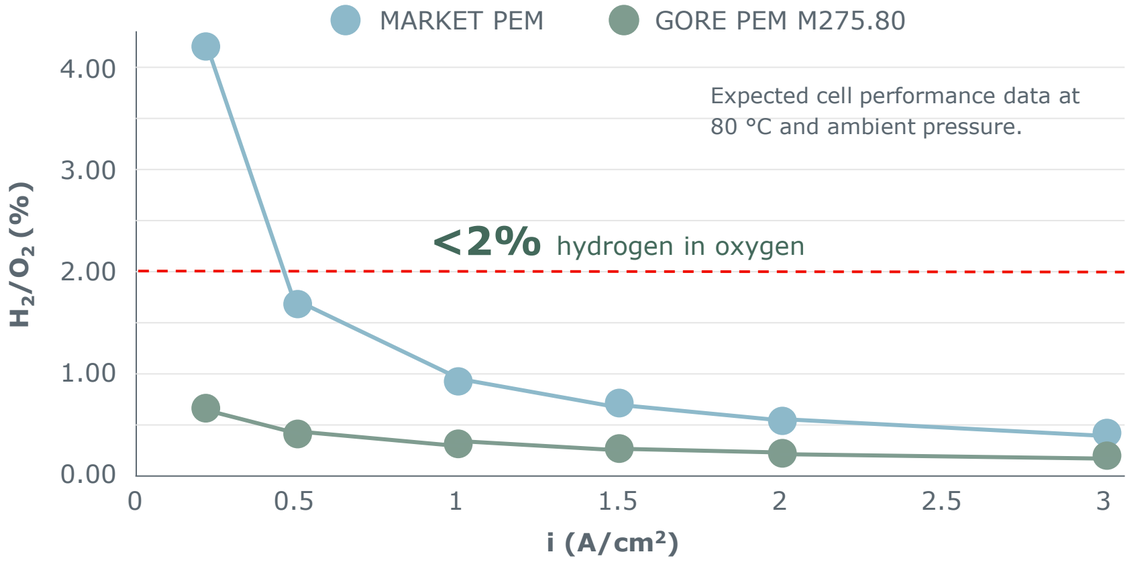
Increasing voltage efficiency enables **higher $H_2$ output for the same energy consumption** (or vice versa; less energy consumption for the same $H_2$ output)

# How does Gore’s PEM improve safety & durability?

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

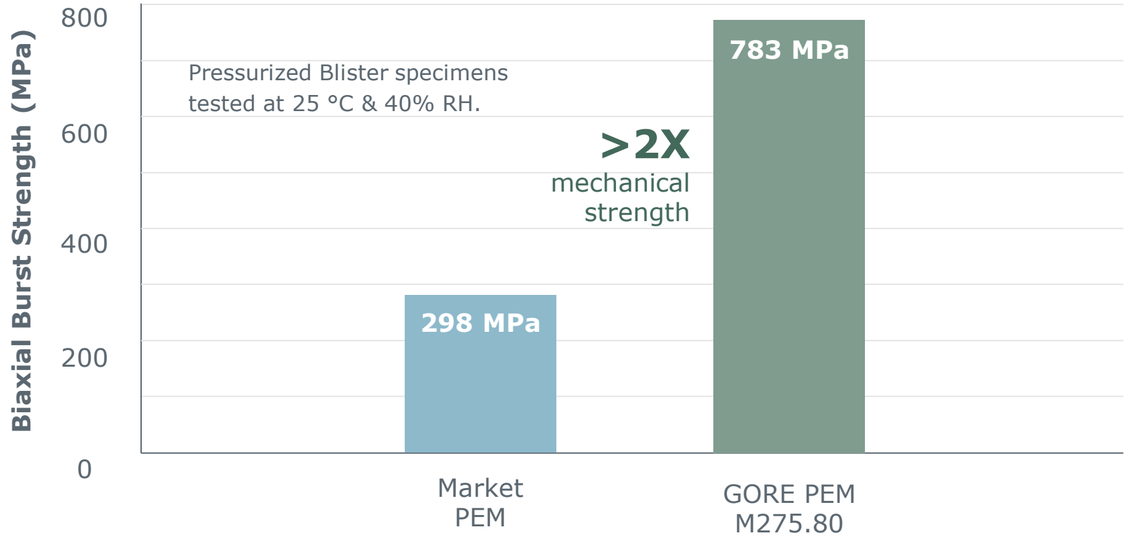
## SAFETY

(e.g. hydrogen gas crossover)




## DURABILITY

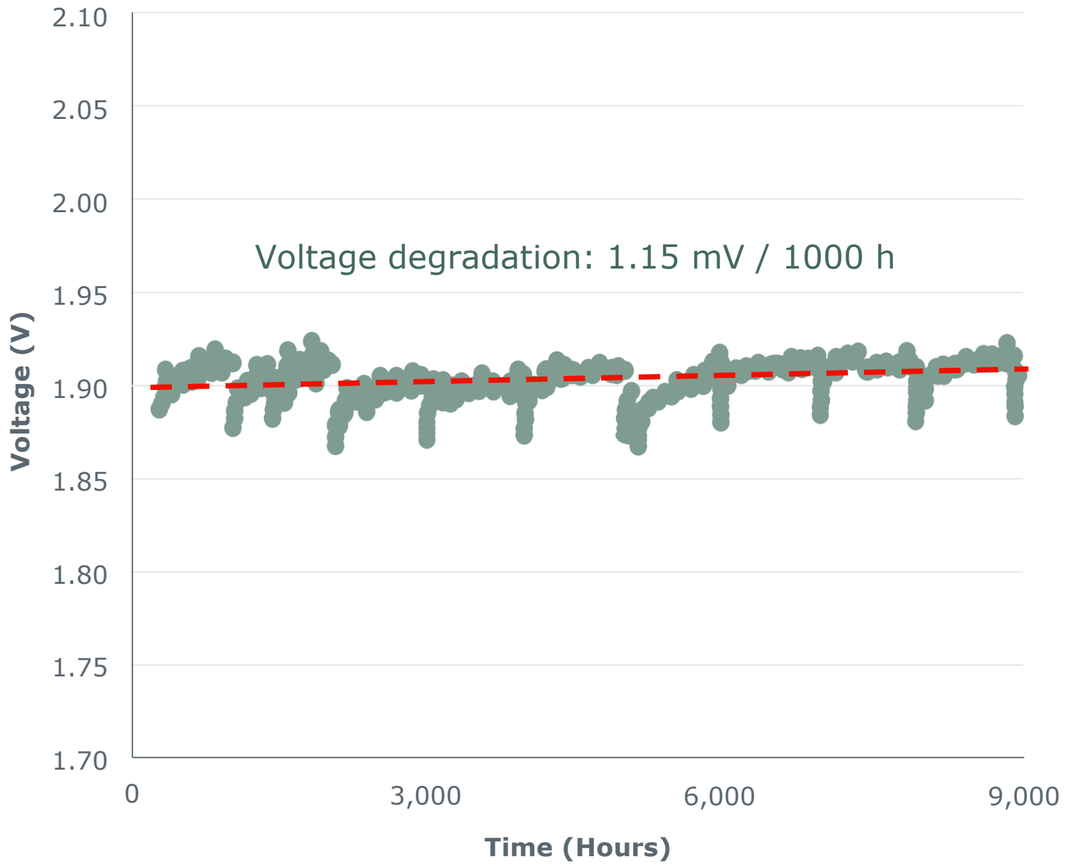
(e.g. chemical/mechanical stability)




- Gore’s additive technology enables <2% hydrogen in oxygen concentrations over a wide operating range - even at low 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

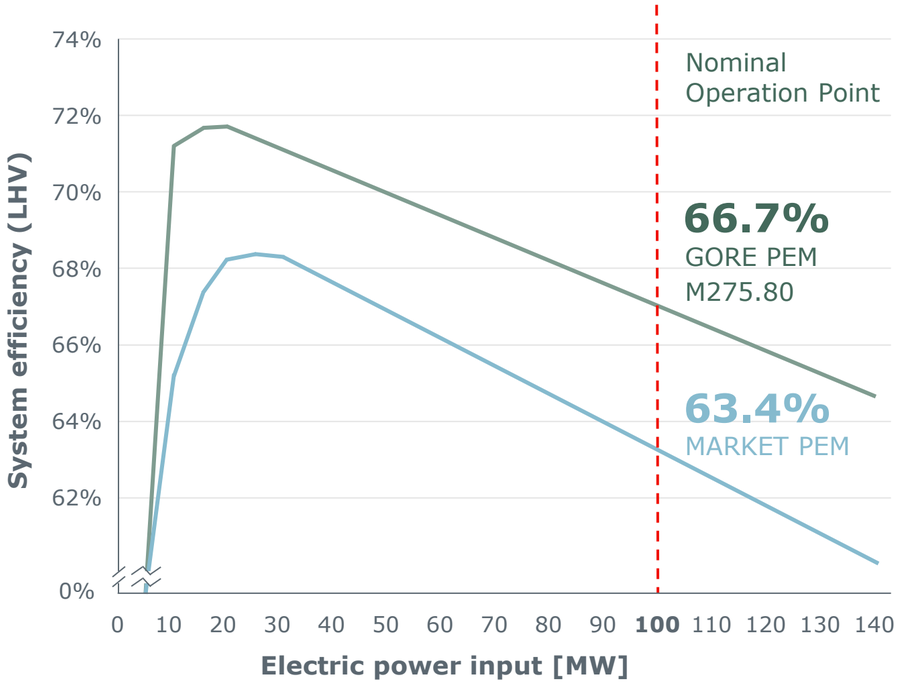
- Durability testing of Gore's PEM M275.80.
- Undertaken at ITM's state-of-the-art test facility.
- Test performed under high current conditions (3.3 A/cm²) to maximize hydrogen production.
- Cell operation **>9,000 hours (and ongoing)**.

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

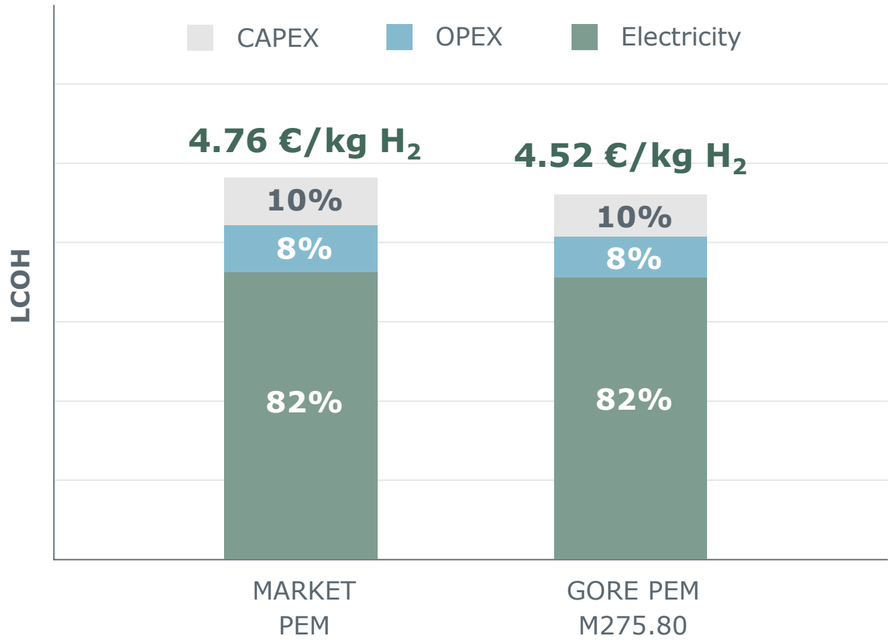
# Achieving better efficiency and LCOH with Gore's PEM

## Electrolyzer simulation for 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

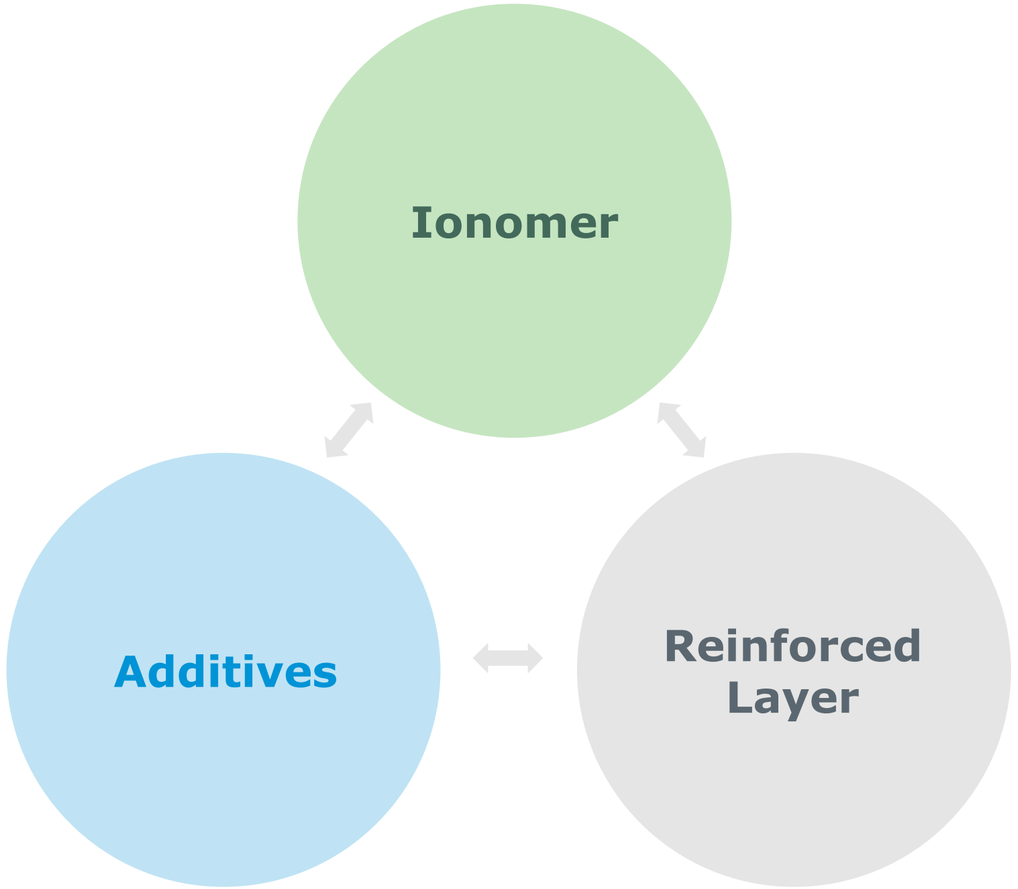
# Breaking performance barriers with Gore's high-performance PEM

Reducing system trade-offs with our advanced membrane technology.

**Ionomer**
- High proton conductivity + high voltage efficiency for **increased performance**

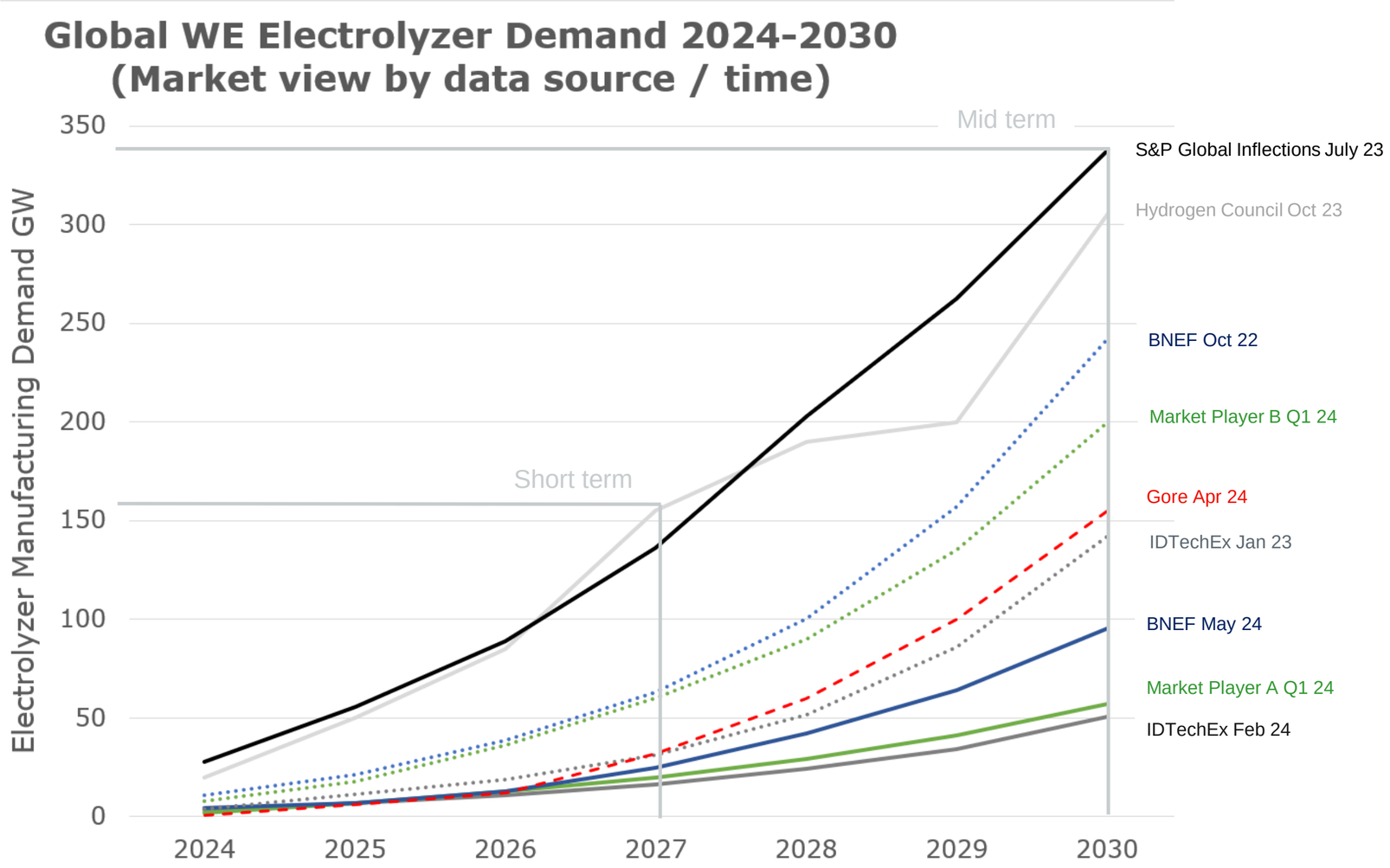
**Additives**
- Greater chemical durability + reduced $H_2$ crossover for **increased durability and safety**

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



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

# Next decade will see significant Green $H_2$ growth. Global water electrolyzer manufacturing has to scale to meet market demand




- Rate of market growth is uncertain
- As a critical component supplier Gore is uniquely positioned in the value chain
- Gore is investing to develop our own market perspective to ensure we are ready to meet future demand

# Applying our fuel cell expertise to water electrolysis

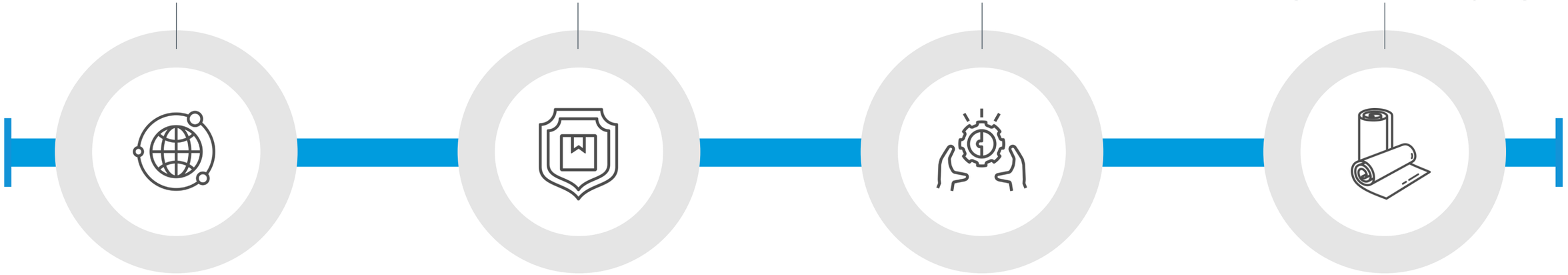
Overcoming challenges and reducing risks in an uncertain environment.

**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



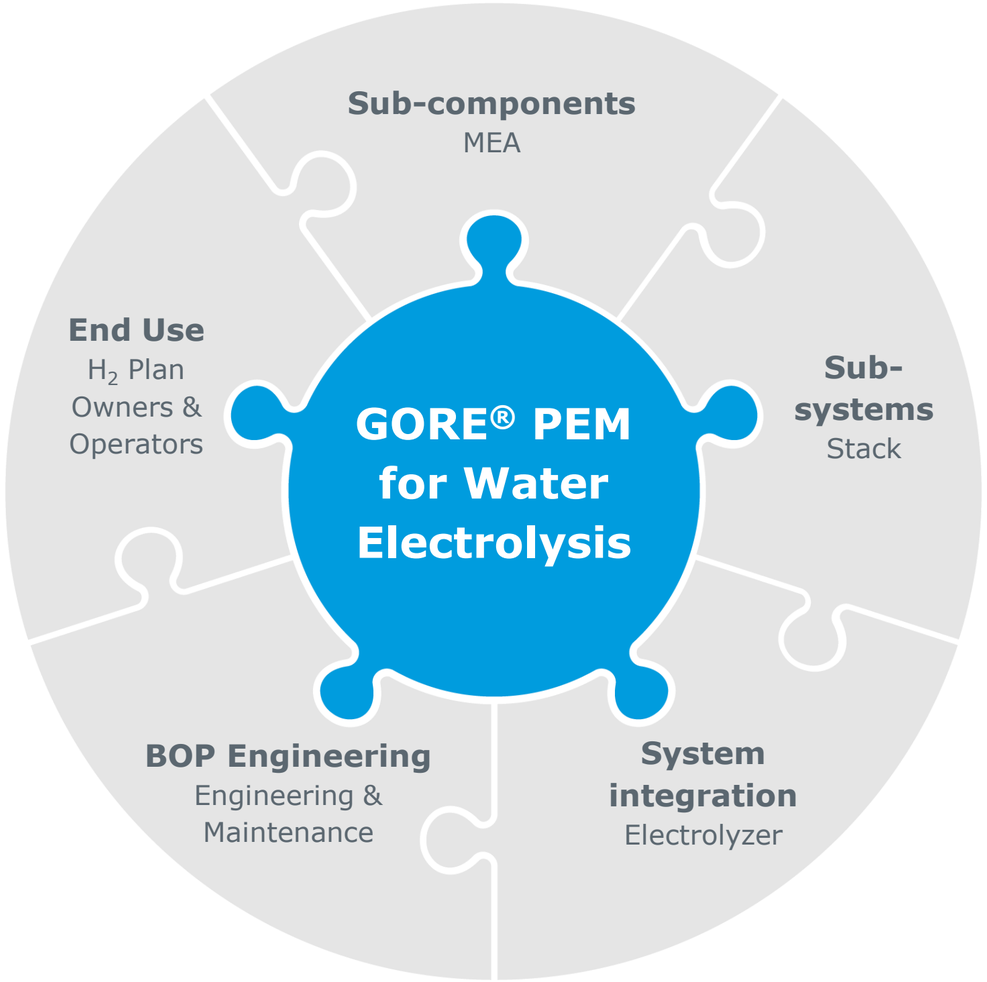
Gore’s established enterprise resources are set up to support **Multi-Gigawatt installations TODAY**.

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 may 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**

# In Summary - 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**.

# DOWNLOAD YOUR DIGITAL COPY.

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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*