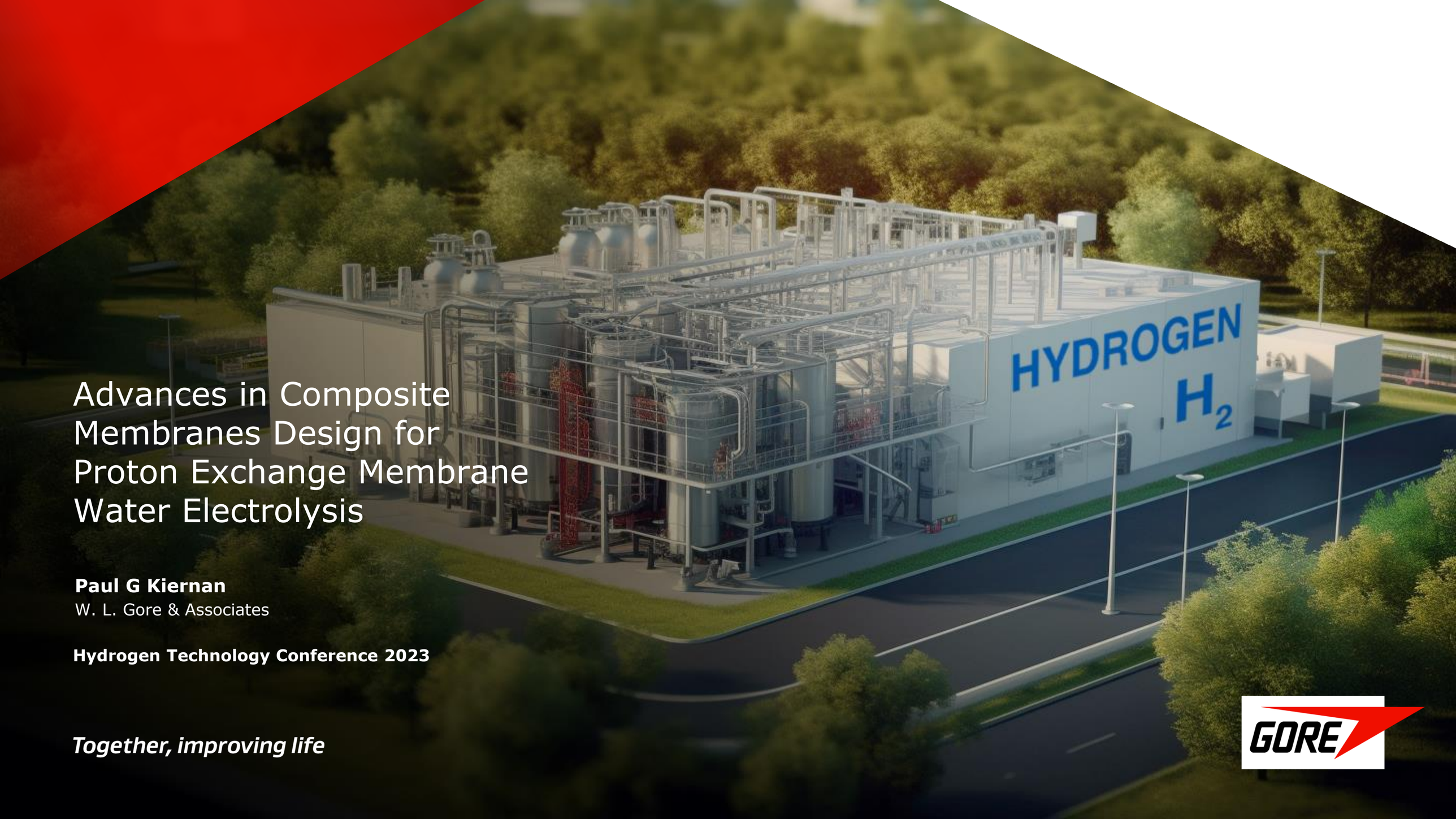


Advances in Composite Membranes Design for Proton Exchange Membrane Water Electrolysis

Paul G Kiernan
W. L. Gore & Associates

Hydrogen Technology Conference 2023

Together, improving life

Agenda

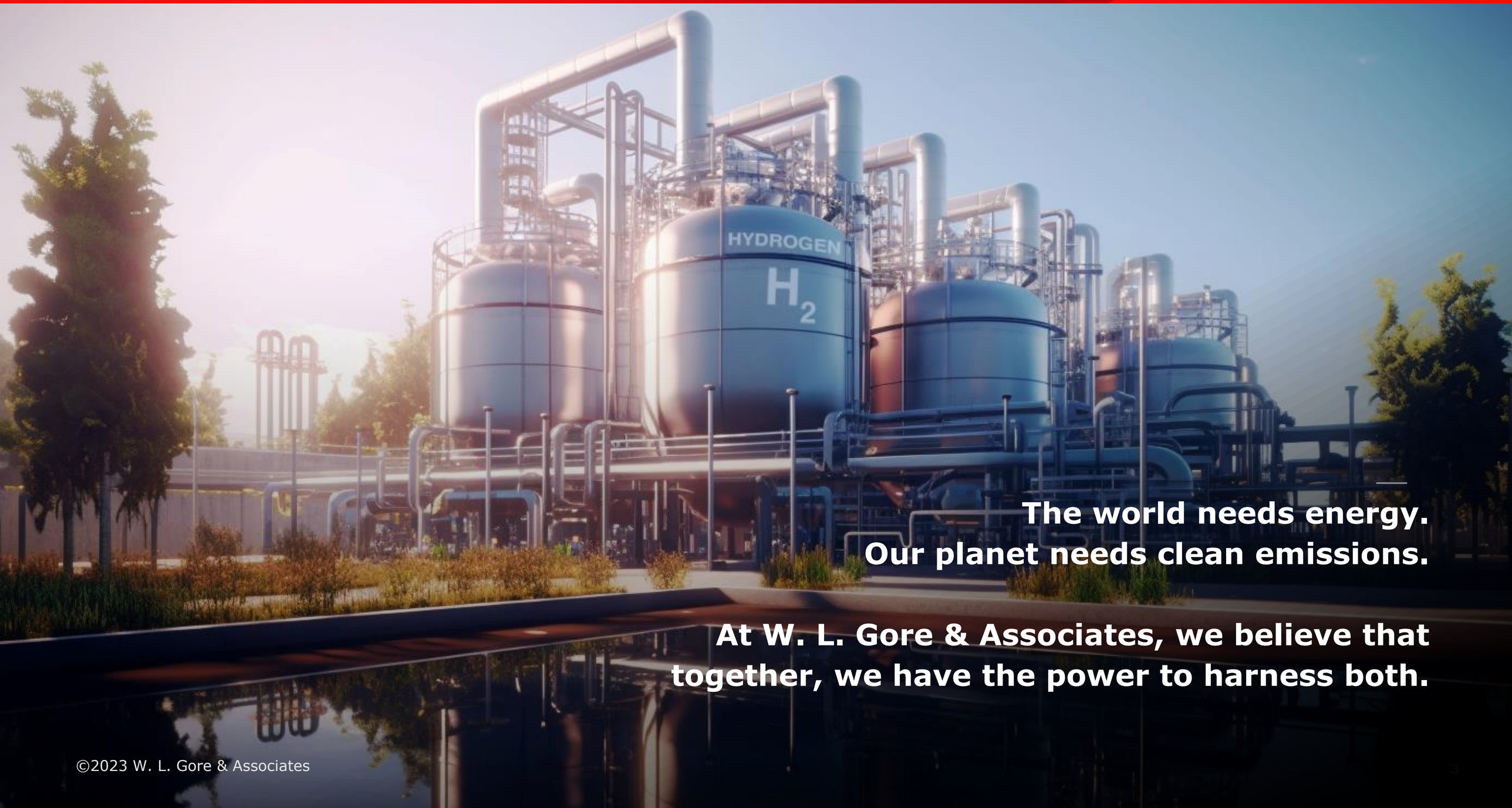
1.0
Introduction of W. L. Gore & Associates

2.0
Clean energy ecosystem & challenges

3.0

Technology development for water electrolysis application

- Trade-offs incorporating thin membranes
- Technology for breaking through the trade-off relationship



The world needs energy.
Our planet needs clean emissions.

At W. L. Gore & Associates, we believe that together, we have the power to harness both.

Gore: A global materials science company

Our advanced materials capabilities allow our customers to push boundaries — with confidence.

Our knowledge of diverse materials, including polymers, and our engineering capabilities, enable a wide range of remarkable products.

Polymer properties

PHYSICAL
Mechanical energy absorption / Expandability / High electrical resistance / Low coefficient of friction / Low fatigue / Dimensionally stable

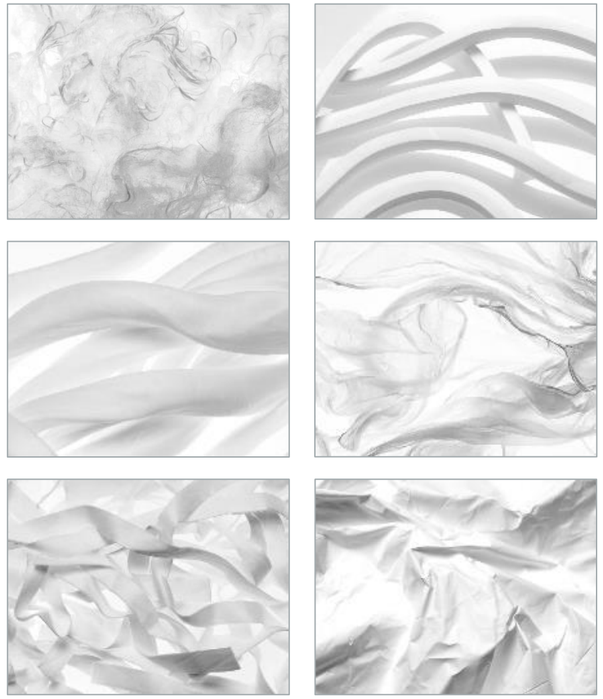
CHEMICAL
Chemical Inertness / Hydrophobicity / Oleophobicity / Low chemical absorption / Low flammability

ELECTROMAGNETIC
Broad thermal range / Low dielectric constant / Low fluorescence / Low light absorption / UV resistance

BIOLOGICAL
Biocompatibility

+

Forms



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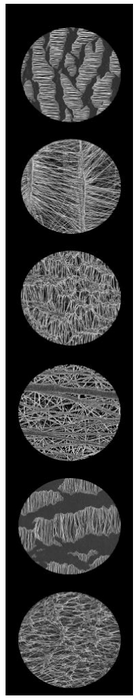
Capabilities



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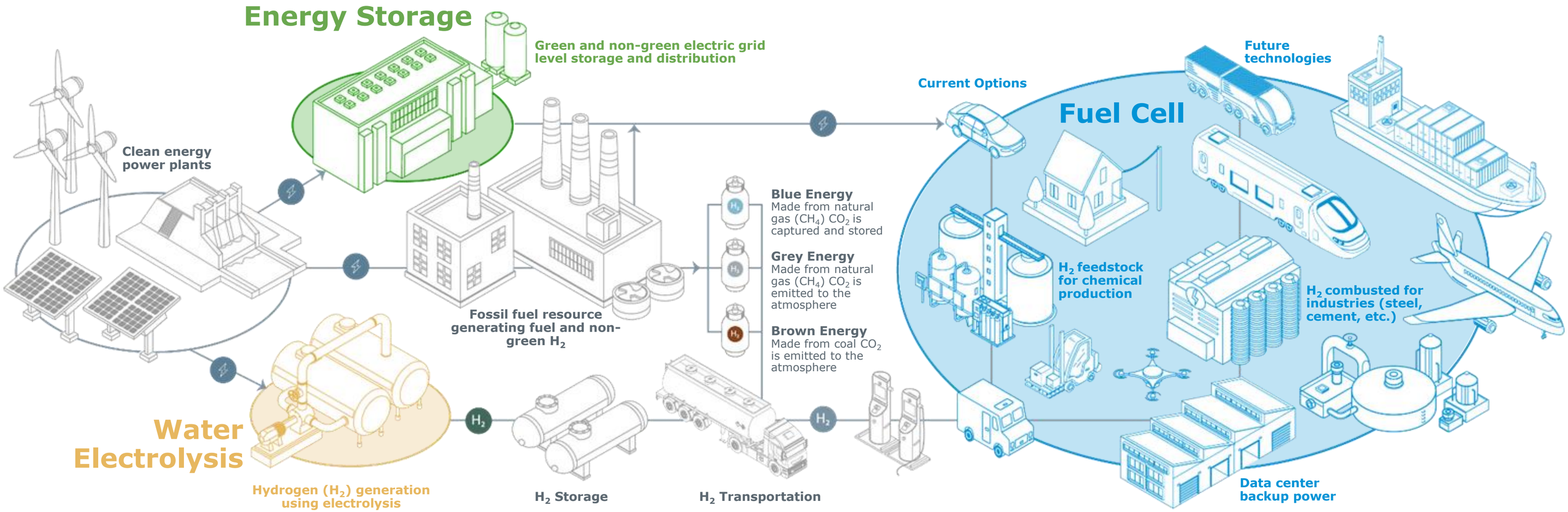
Products

Clean energy ecosystem for Gore



Levelized cost of hydrogen production - Electrolyzer system

System Cost

Simpler system, less components, cheaper manufacturing

Operation / Maintenance

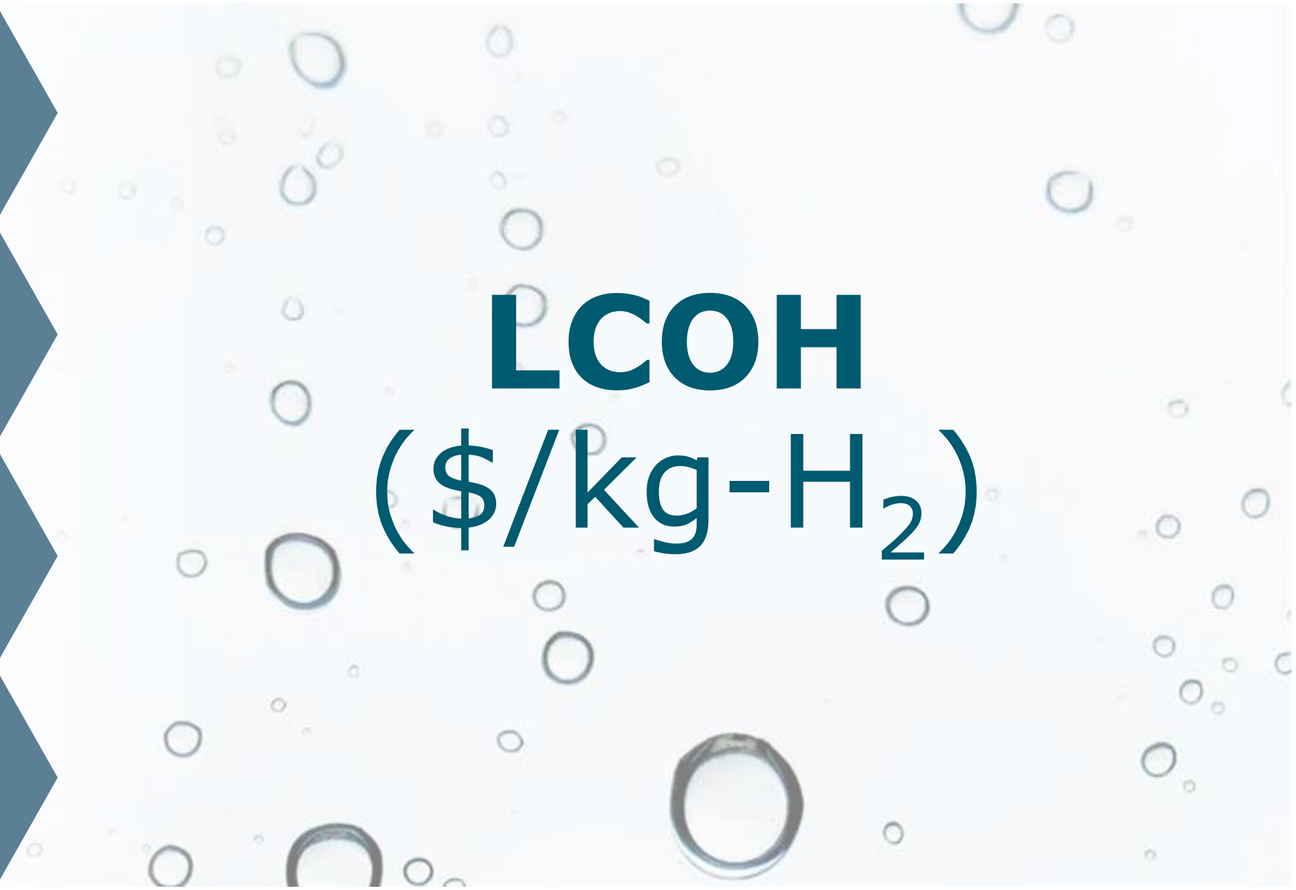
Reliable, relaxed inputs, longevity

Electricity

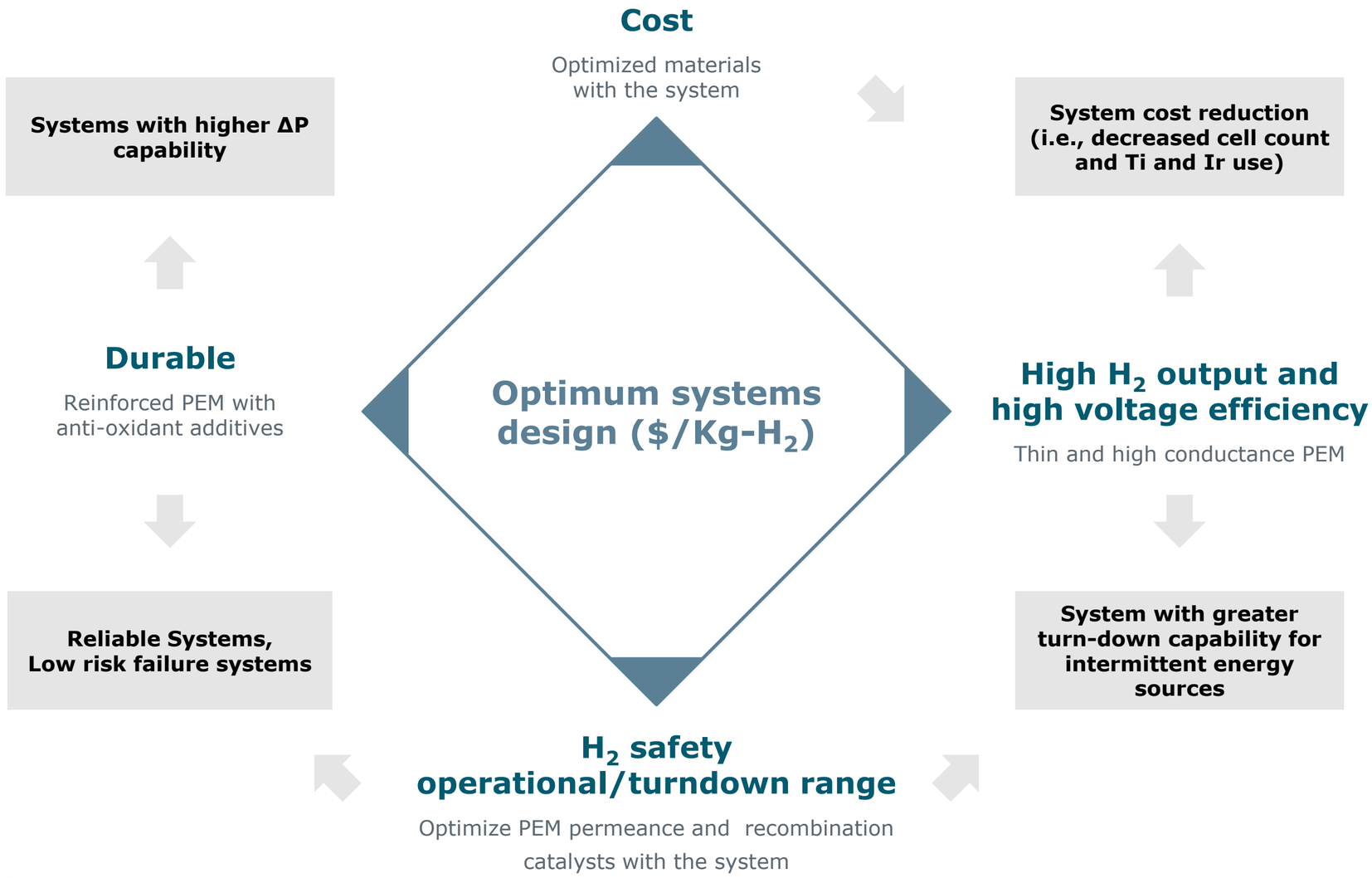
High H_2 output per electricity, less parasitic loss, high utilization, turndown ratio

Other considerations

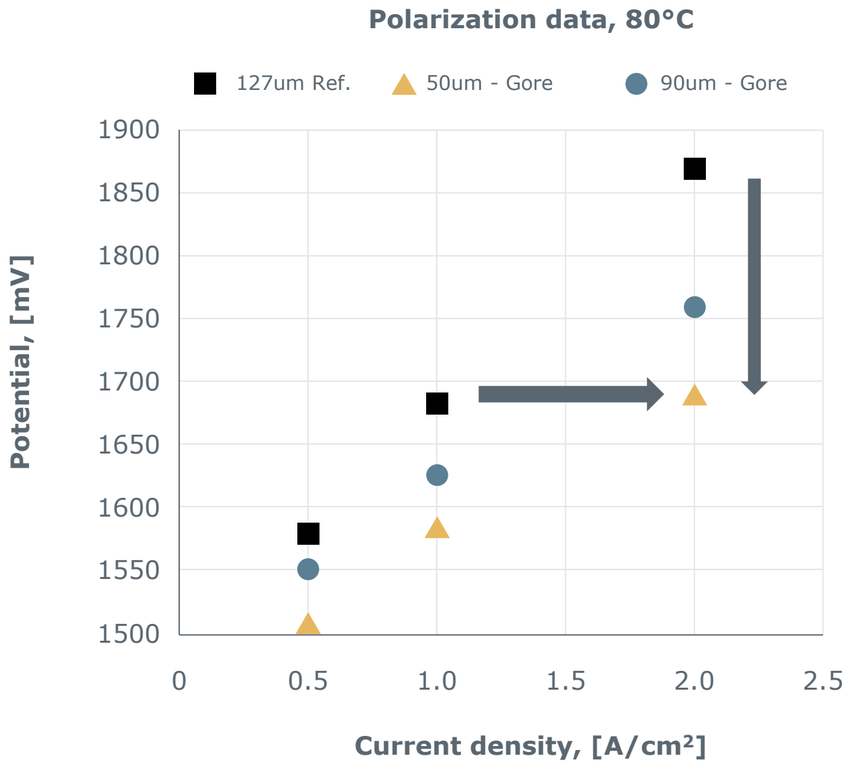
Grid fees, construction costs, land use and etc.



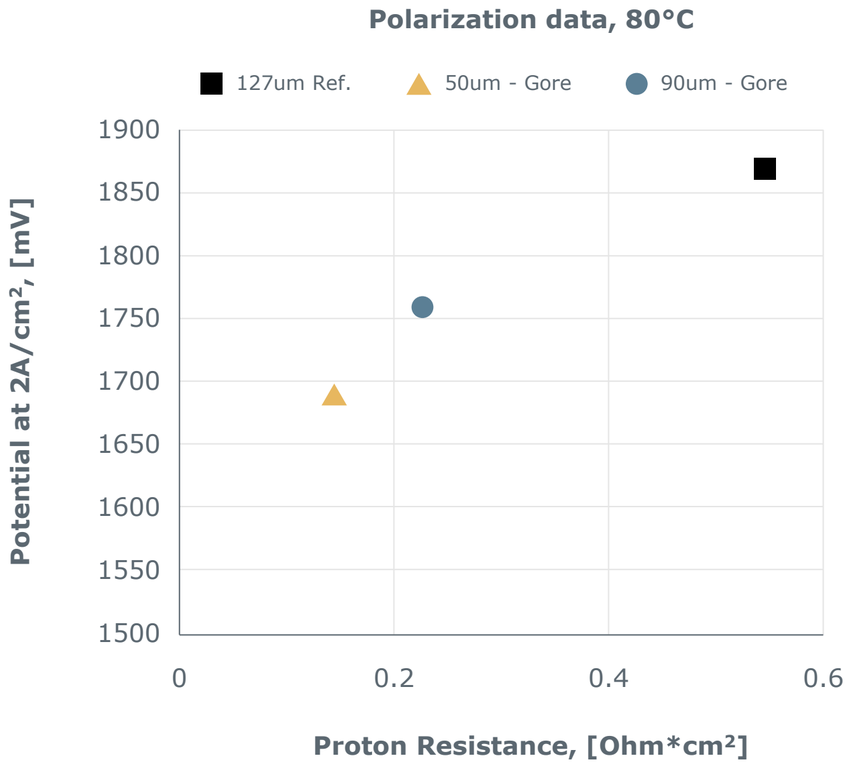
How can we manage trade-offs to optimize system design?



Advantage of thin membrane for high power output



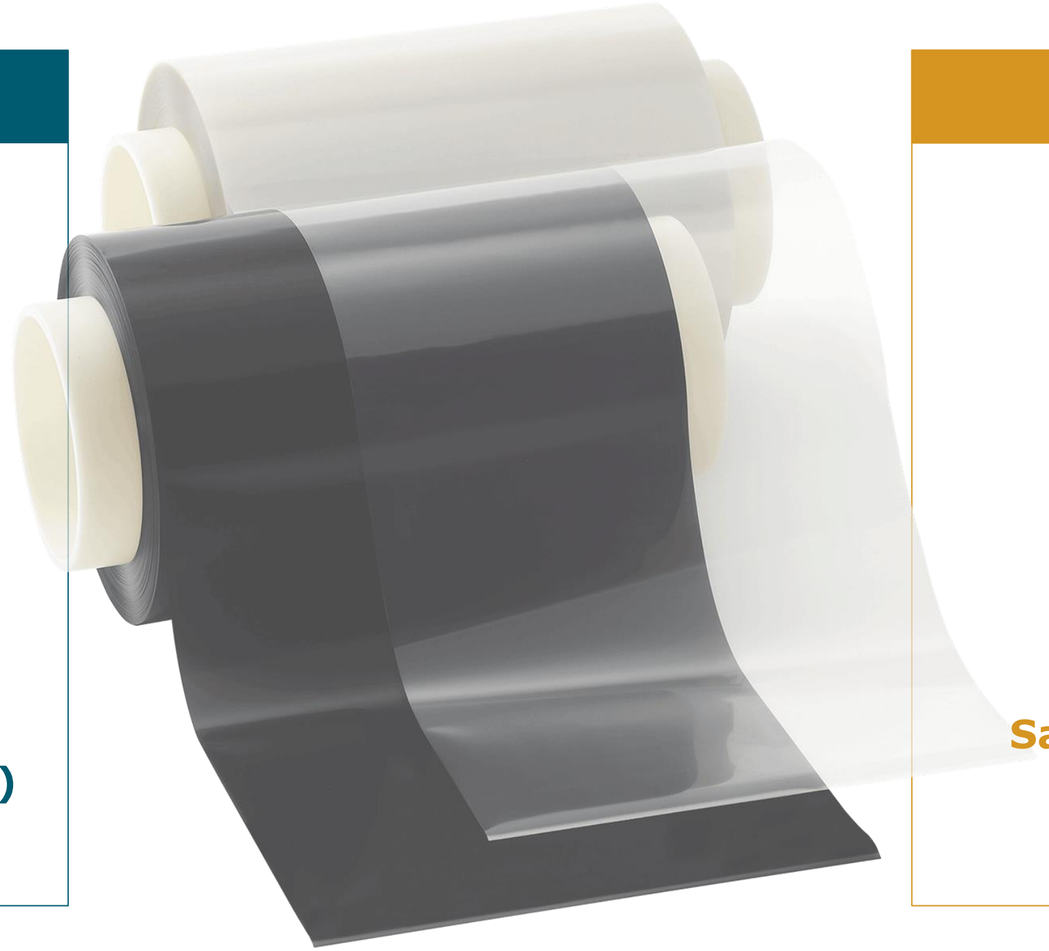
CAPEX $↓ from increased H_2 output
OPEX $↓ from increased voltage efficiency



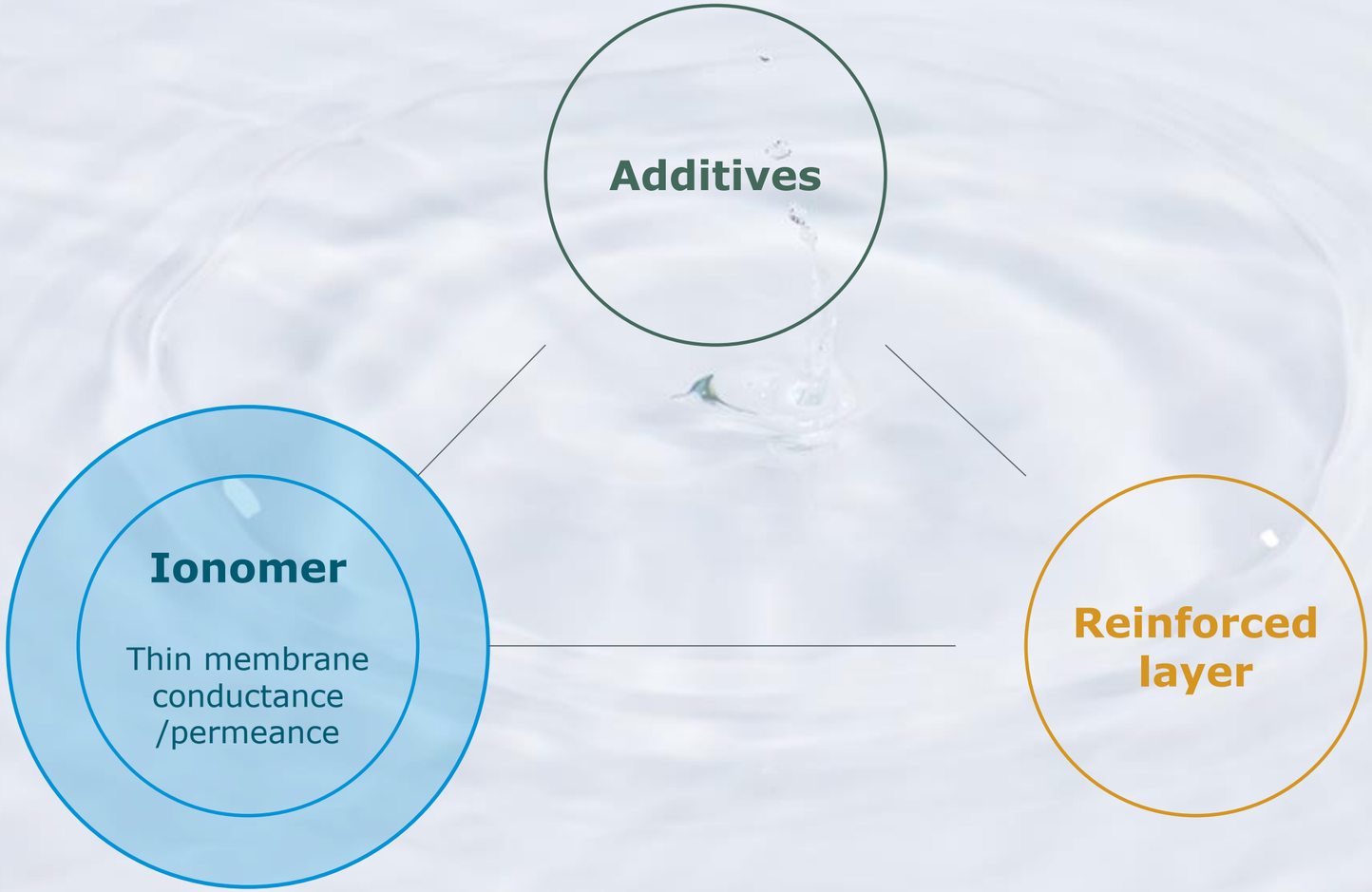
No surprise – membrane resistance is a large controlling factor

Trade-off between thin membrane and properties

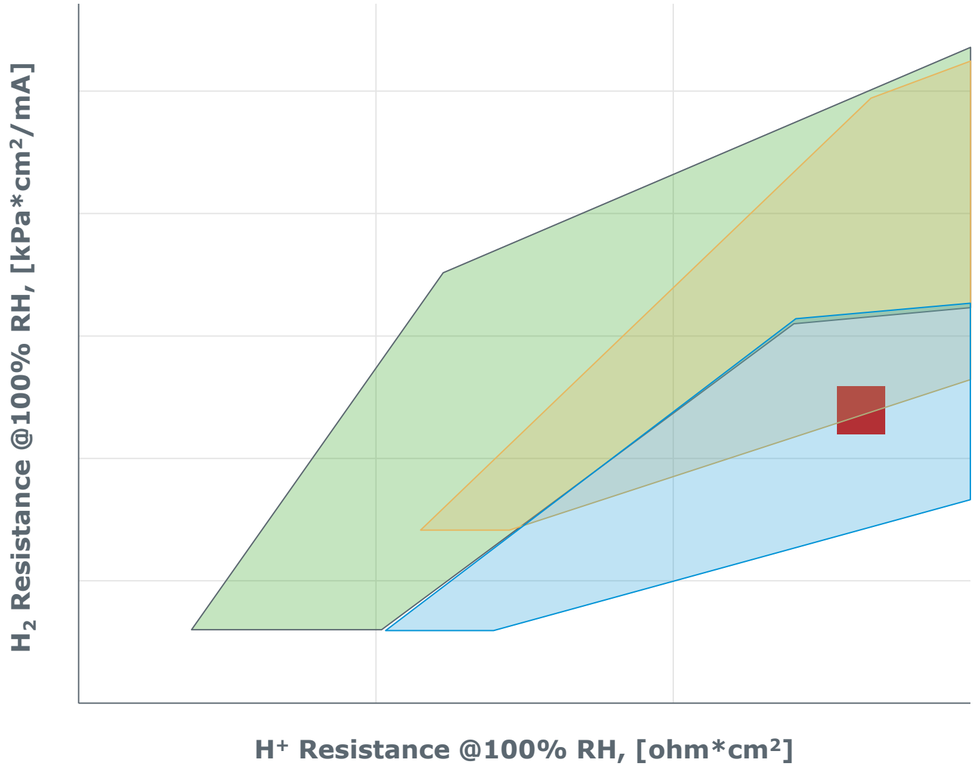
Advantages	Challenges
High Voltage Efficiency	H_2 Efficiency
High H_2 Output	Durability
Reduction of Balance of Plant (BOP)	Safety / Operation range



Technology for breaking through the trade-off



Gore proton exchange membrane (PEM) performance space



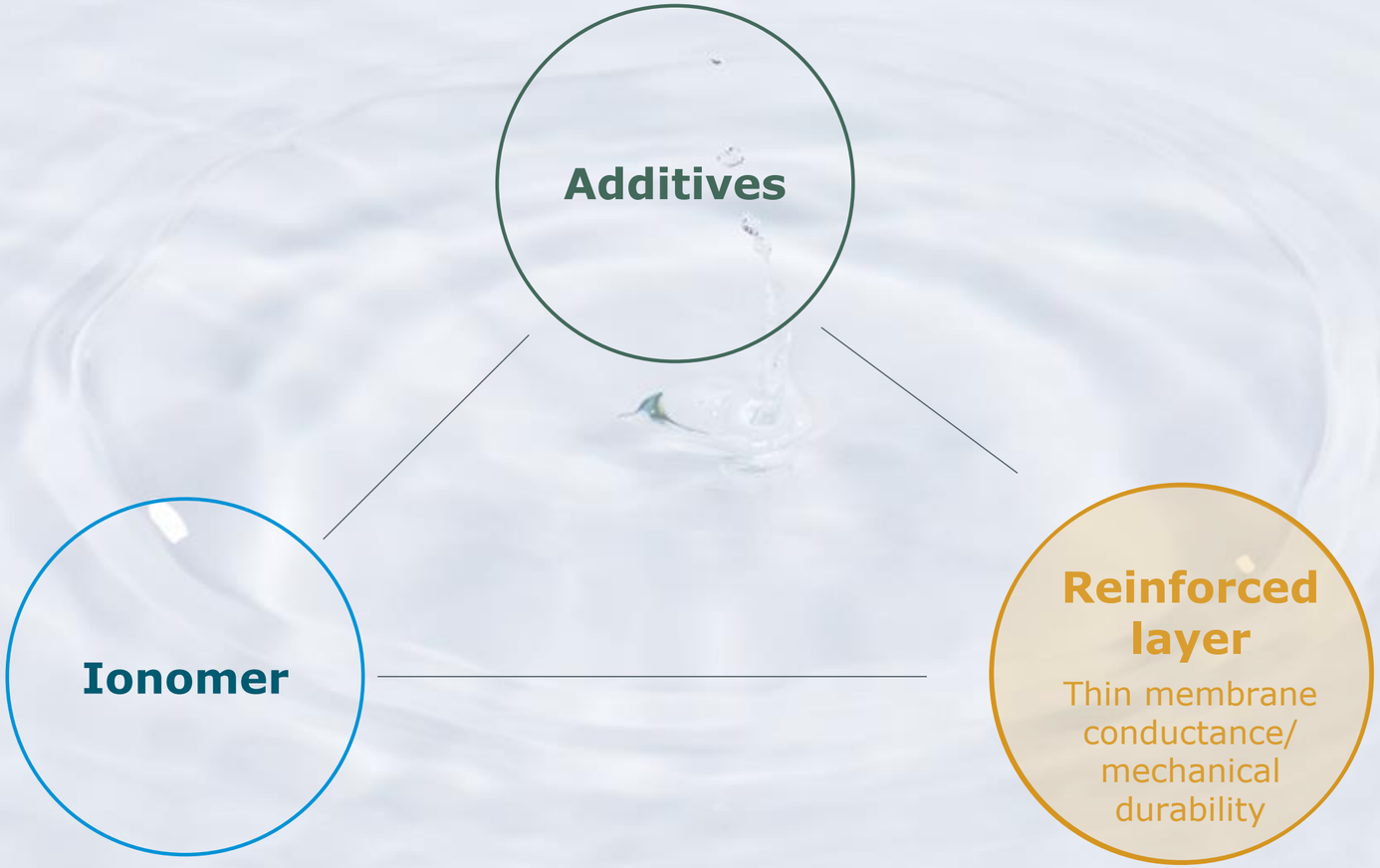
**Shaded space estimated by modeling*

Design target considerations:

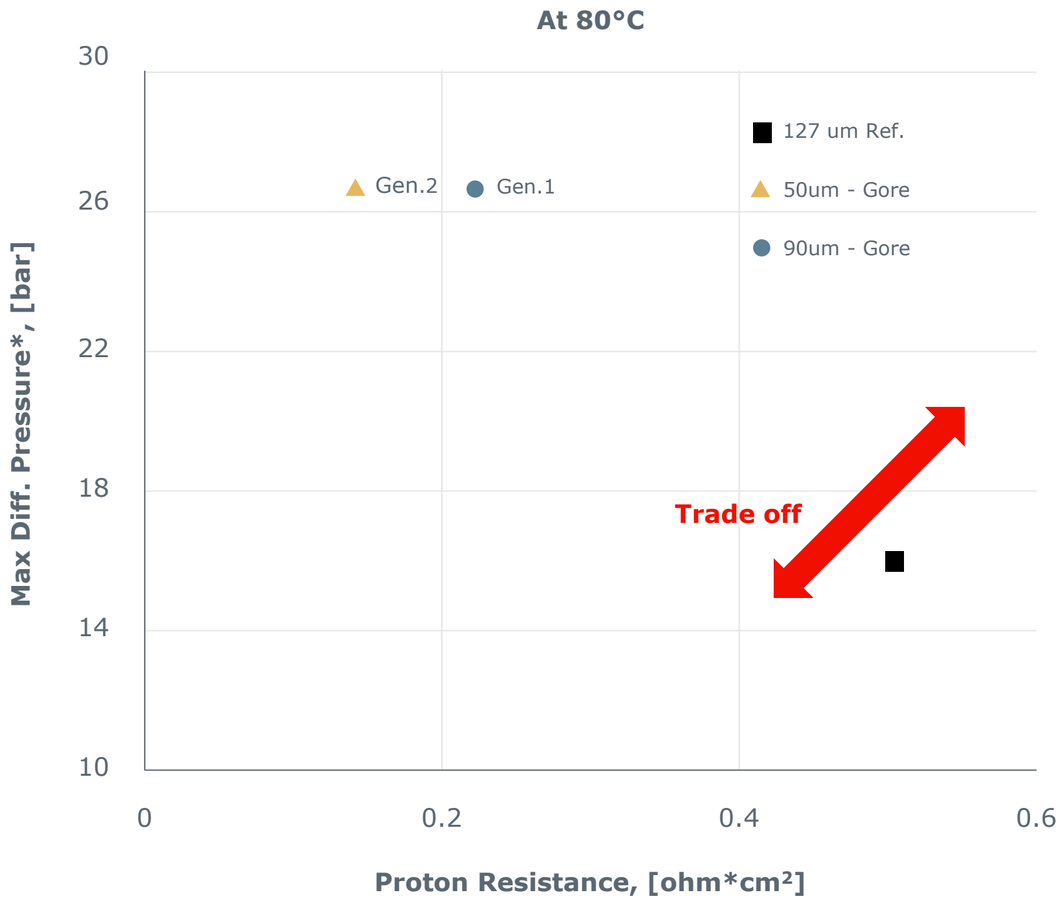
- H^+ conductance → stack power / efficiency
- H_2 crossover → current efficiency
- Durability requirements
- Contamination
- Mechanical / chemical stressors
- CCM / MEA process requirements

Gore can reduce membrane resistance while maintaining same hydrogen crossover

Technology for breaking through the trade-off



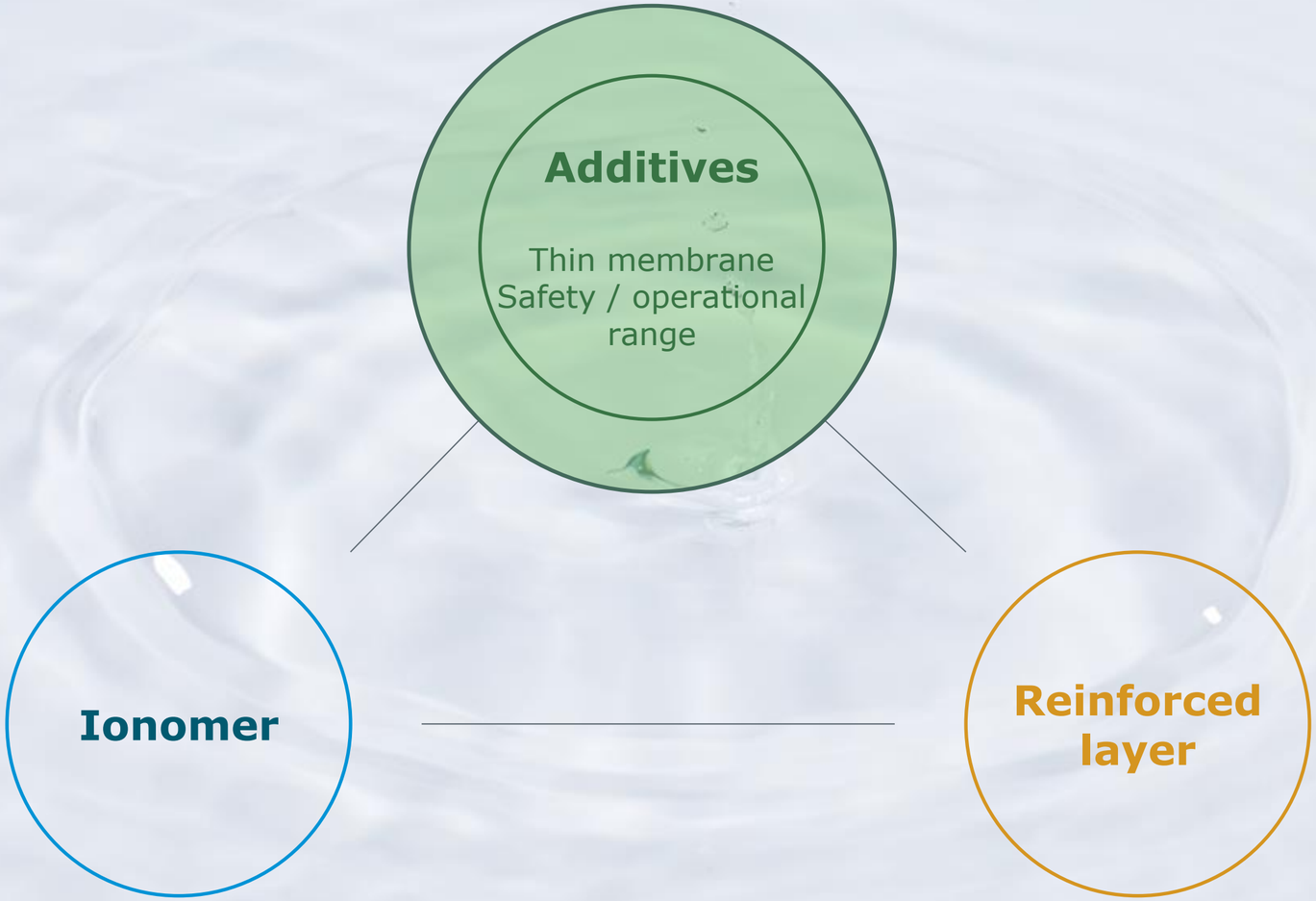
Development of reinforced layer



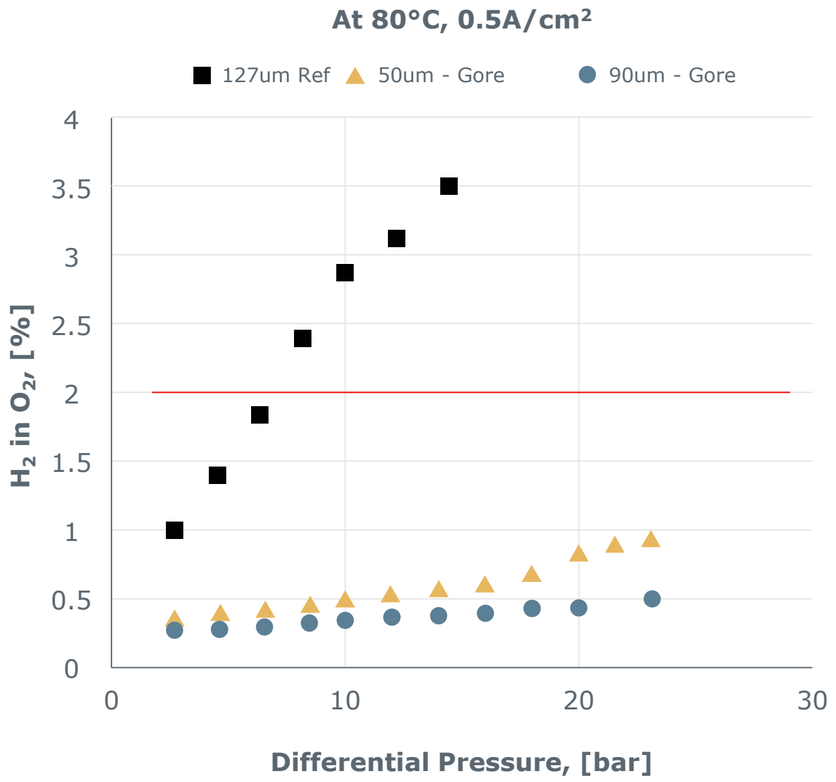
Improved trade-off between performance and mechanical durability by construction and reinforced layer

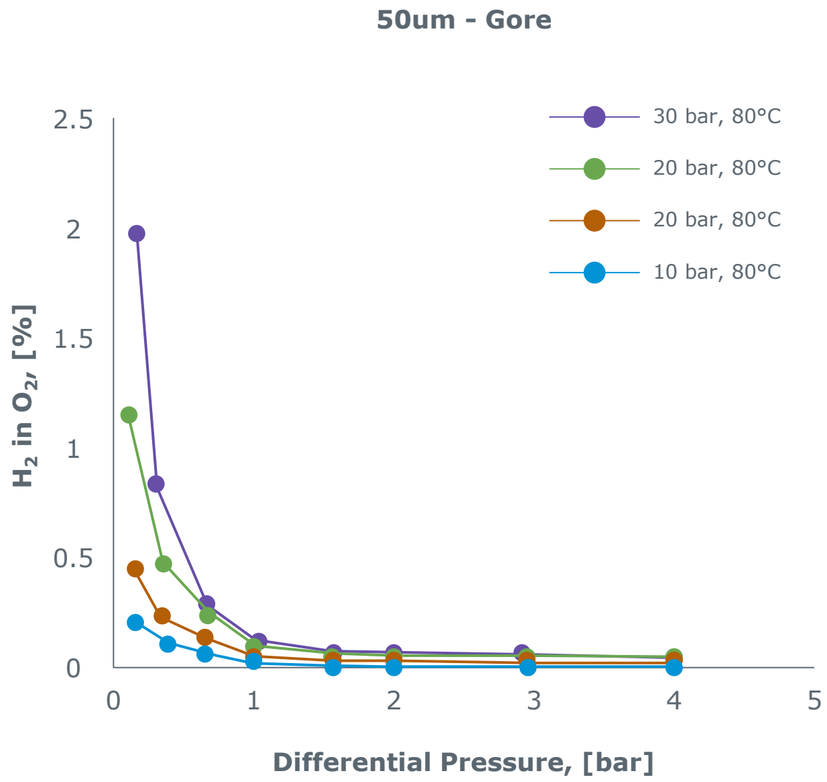
***Cell design dependent**

Technology for breaking through the trade-off



Recombination catalyst (RC) for wider operational range

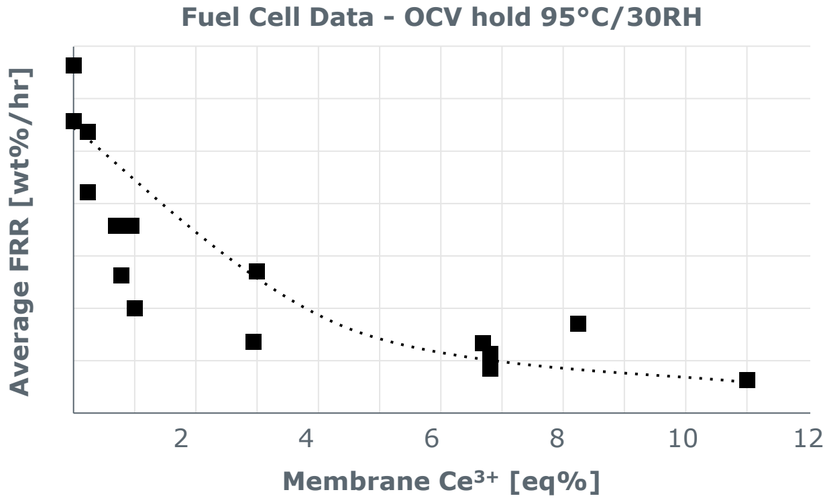


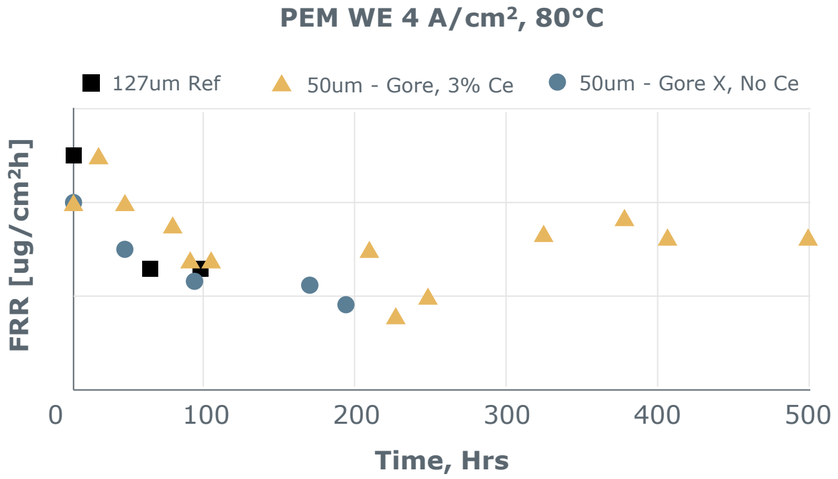


Gore RC technology shows effectiveness at mitigating H_2 in O_2 safety concerns.

Enables high system utilization and efficiency through a wide operating range.

Leveraging additives for chemical durability





Cerium (Ce) is a known radical scavenger and an effective mitigation strategy to improve chemical durability in FC systems

Tradeoffs

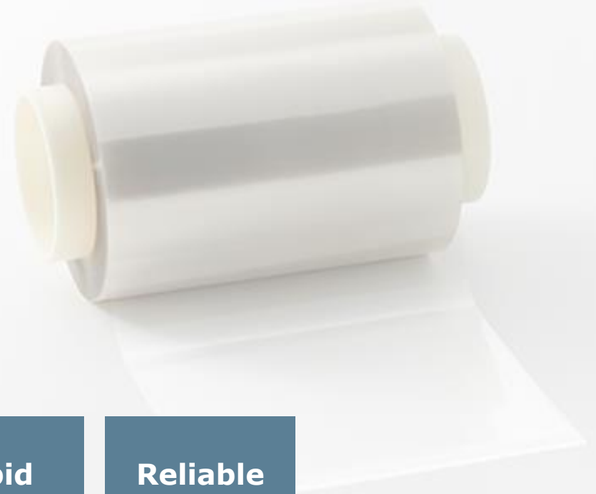
- Mobile, moves under current and can reduce iV performance
- Ion exchange-able, can wash out with reconditioning acid flushes

Electrode and PEM design interact

Optimal MEA design requires partnership

Creating value for a cleaner environment

Reinforced composite membranes enable higher-performing systems for OEMs and lower levelized cost of hydrogen for end-users.



Benefit to Customer

Lower LCOH

Lower CAPEX | **Lower OPEX**

High H^+ Conductance / High Power and Voltage Efficiency | **Durable/ Longevity** | **Low H_2 in O_2 and Permeance / High Efficiency** | **Rapid Scale-Up** | **Reliable Supply**

Gore Capabilities

Reinforced Composite Membrane Technology + **Large Portfolio Predictive Model** + **High Capacity Strong Brand Secure Supply Chain**

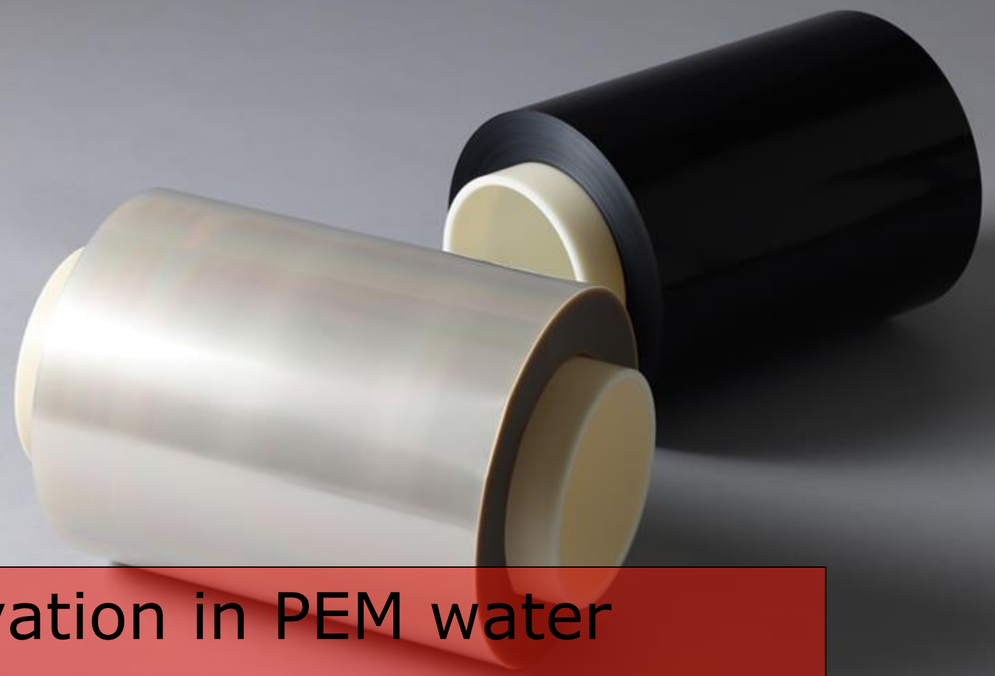
Summary

Gore’s core technology is engineering polymers and polymer composites into unique structures.

LCOH is influenced by many factors and close collaboration is paramount.

Trade-offs in membrane design can be mitigated through advanced technology from Gore.

- Track record of delivering high performance materials
- Proven, high-quality, high-volume PEM manufacturing
- Ability to break the “performance/ durability” trade-offs to enable lower LCOH



Engage with us to further innovation in PEM water electrolysis!

Scan the QR Code on your handout for exclusive content.

Thank You!

Questions?

Together, improving life