Bundesministerium Innovation, Mobilität und Infrastruktur

Bundesministerium Wirtschaft, Energie und Tourismus

Potential of AEM Fuel Cells

Simulation as an enabler

Speaker:

Samuele Cappelli, MSc BSc

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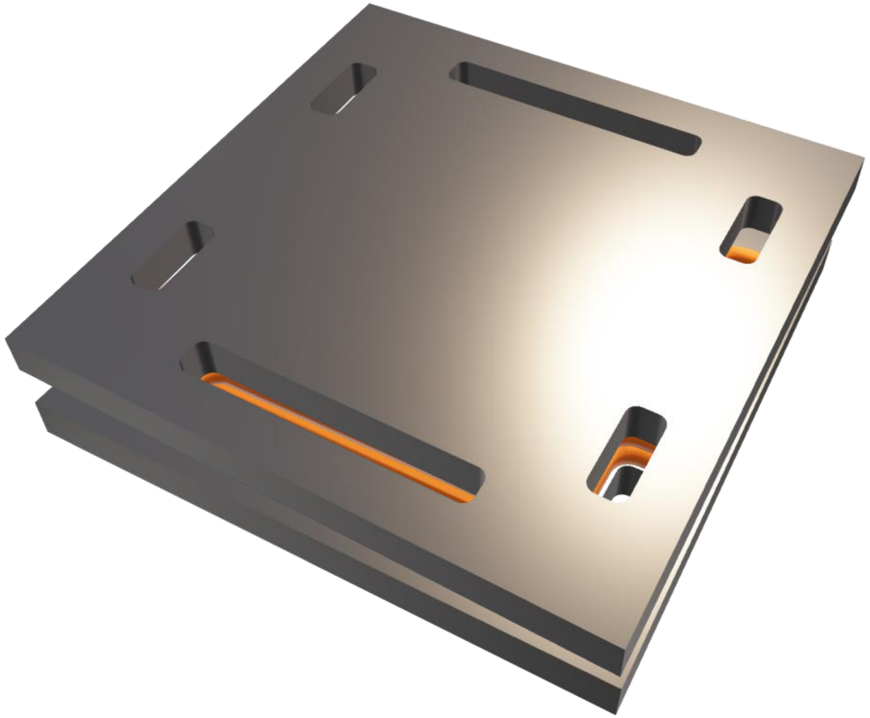
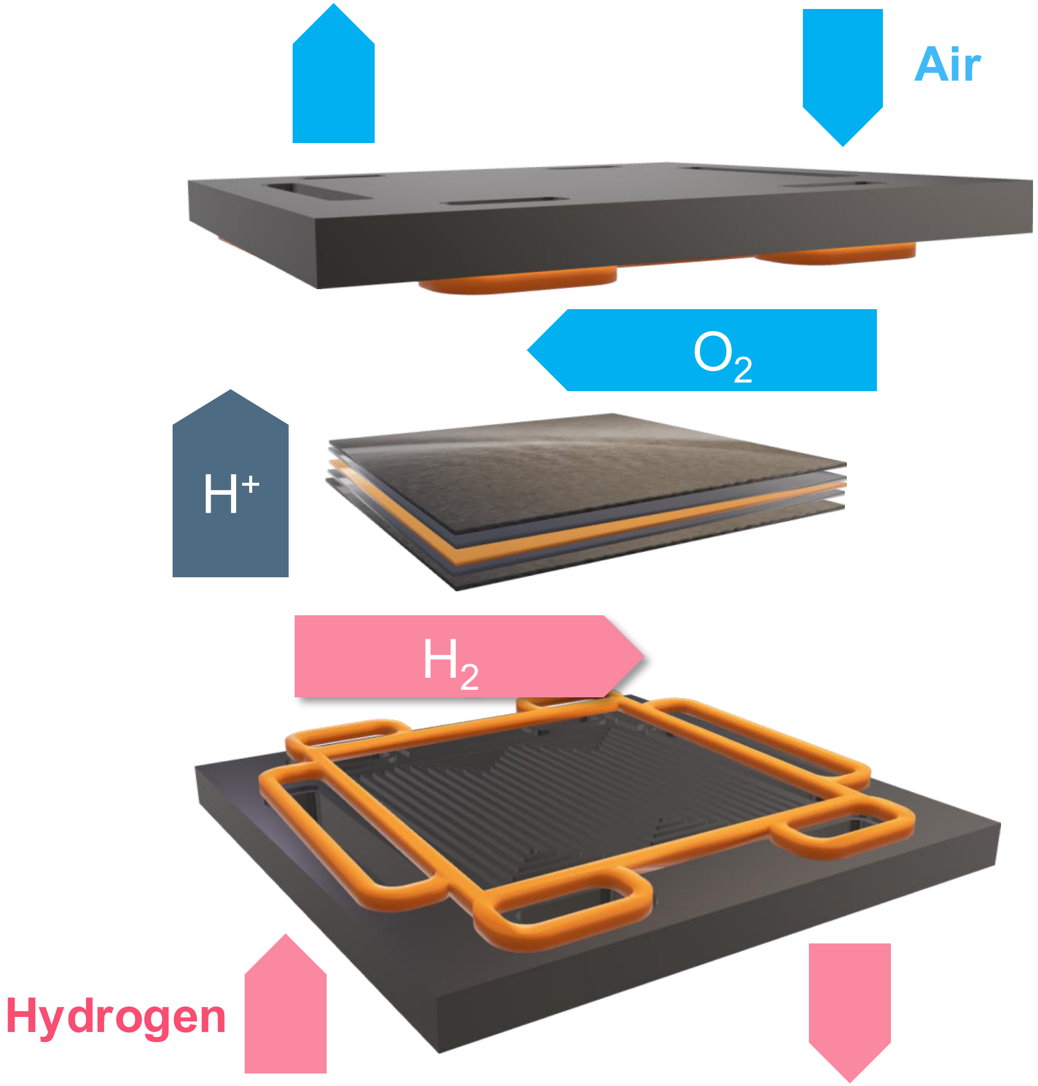
FC technology



PEMFC technology



PEMFC operation

Cathode

$1/2\,O_2 + 2H^+ + 2e^- \rightleftharpoons H_2O \qquad E^0_{SHE} = 1.229\,V$

FC overall reaction

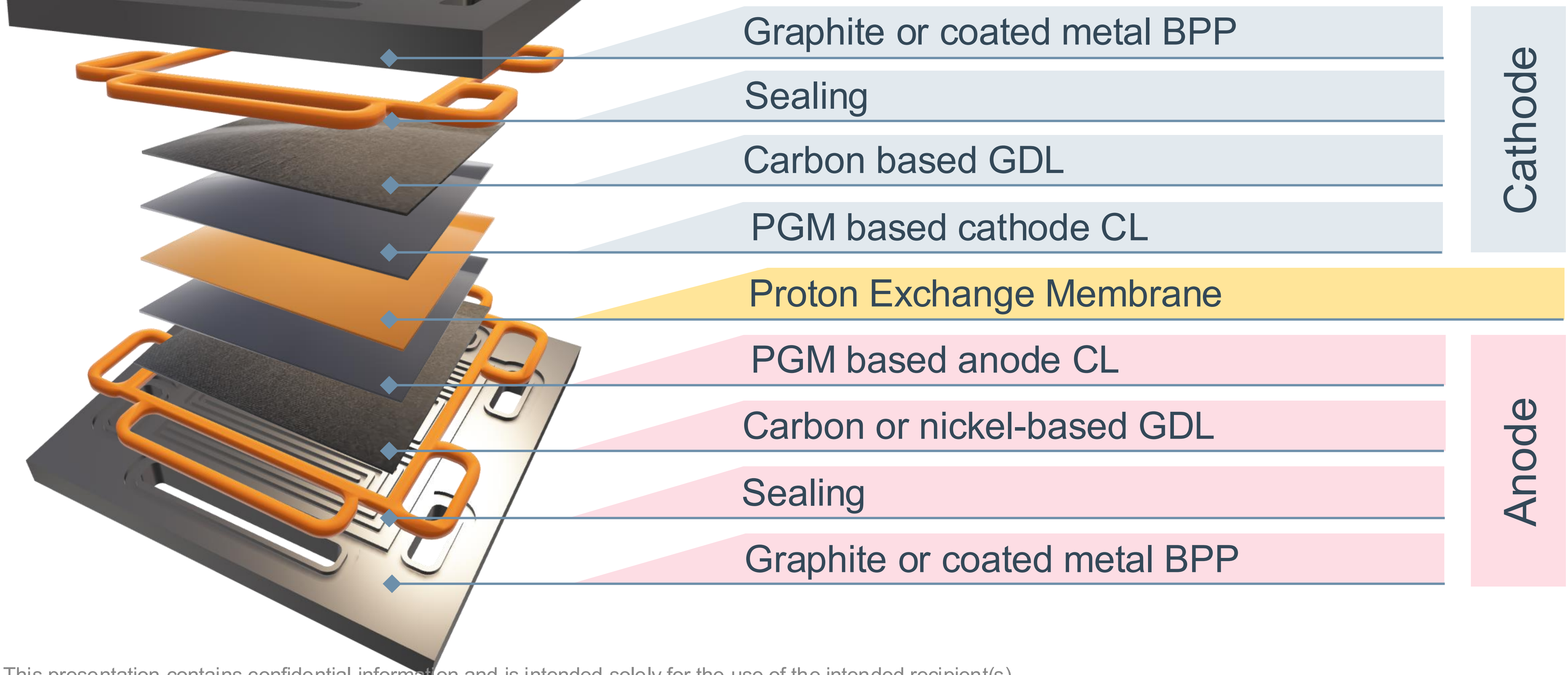
$H_2 + 1/2\,O_2 \rightleftharpoons H_2O \qquad E^0_{SHE} = 1.229\,V$

Anode

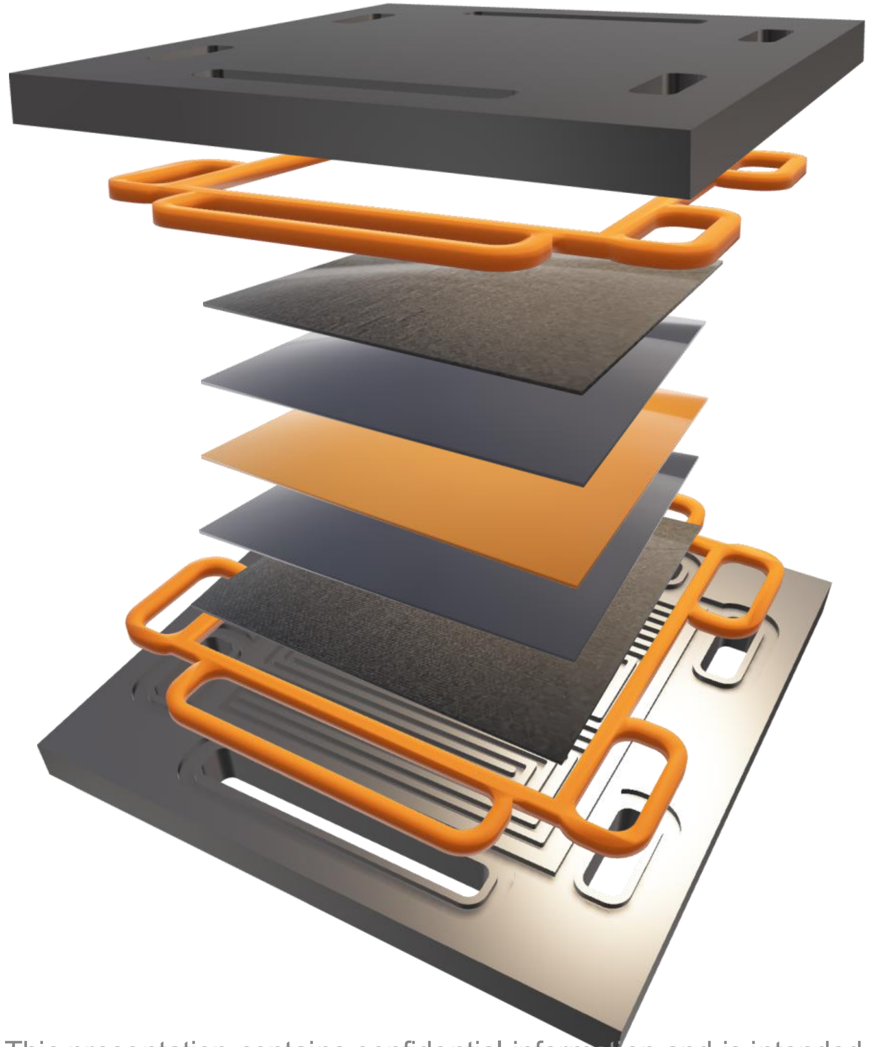
$H_2 \rightleftharpoons 2H^+ + 2e^- \qquad E^0_{SHE} = 0.000\,V$

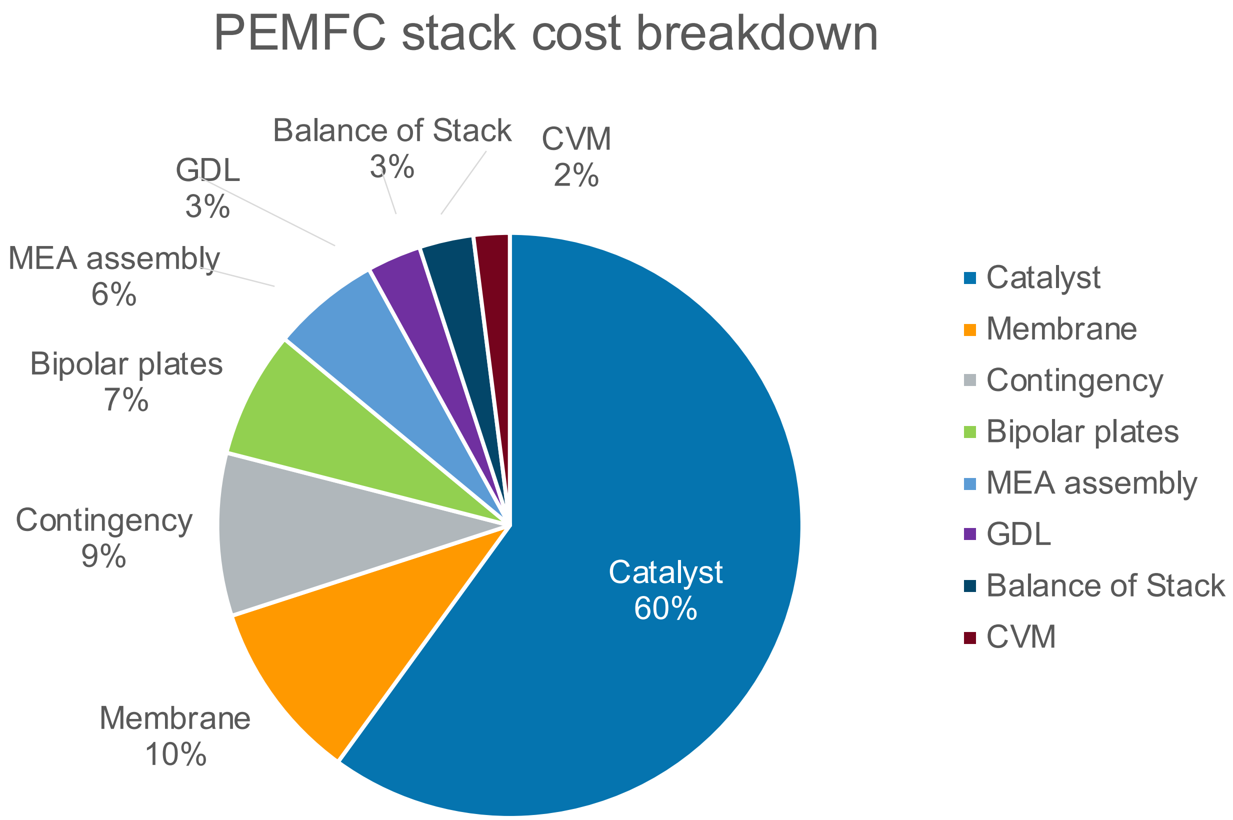
PEMFC technology

PEMFC cell structure



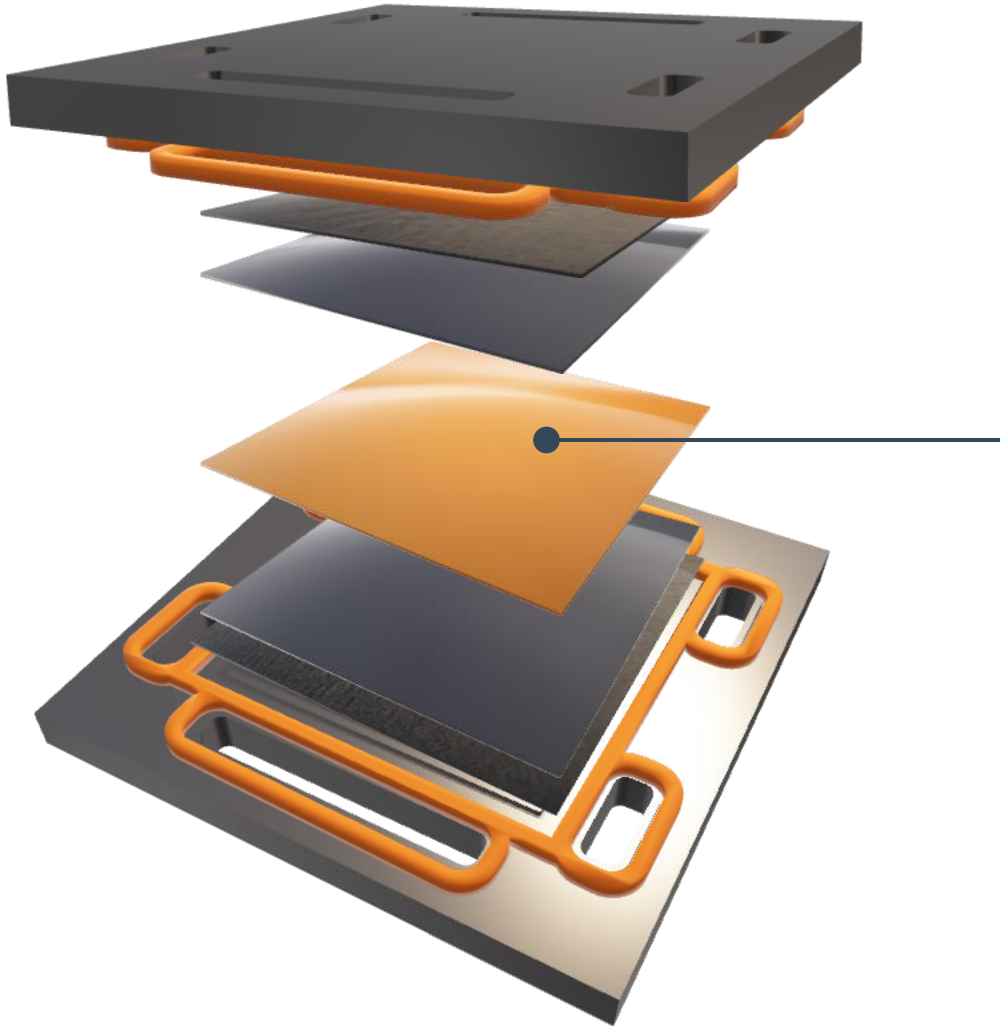
PEMFC technology



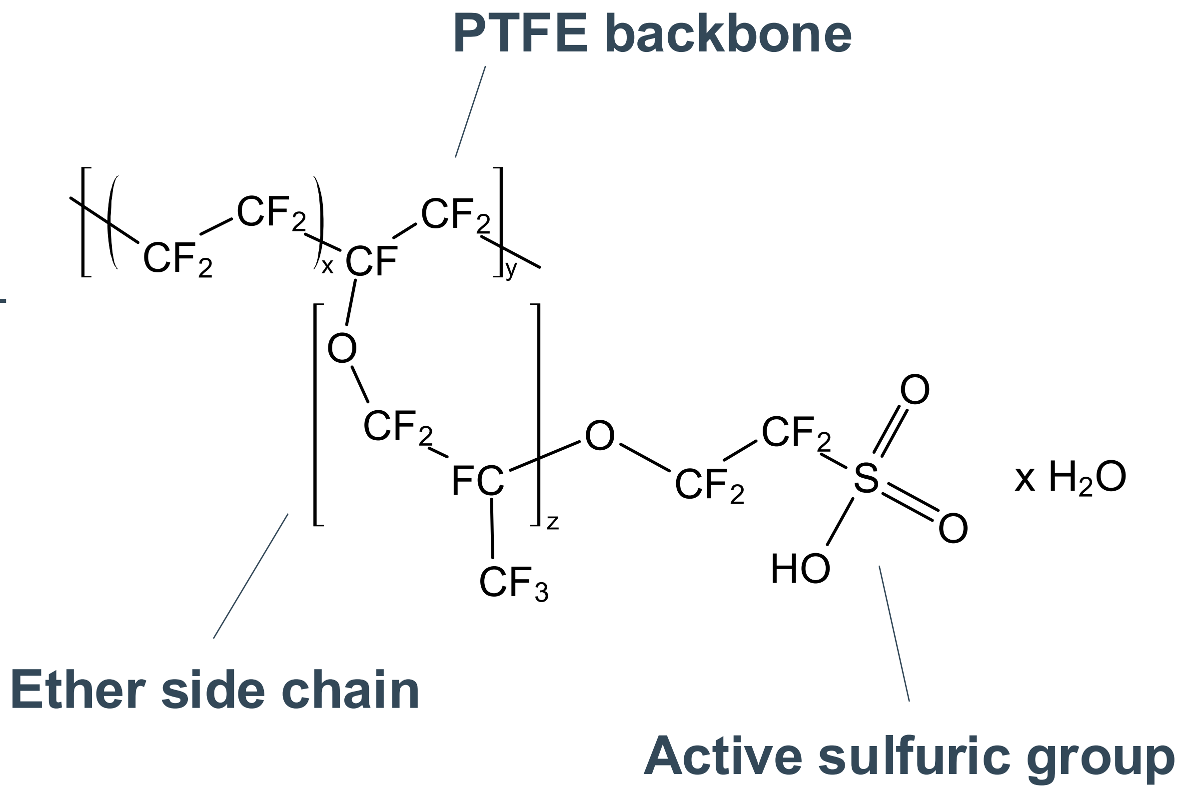


Source: Heavy-Duty Fuel Cell System Cost – 2023

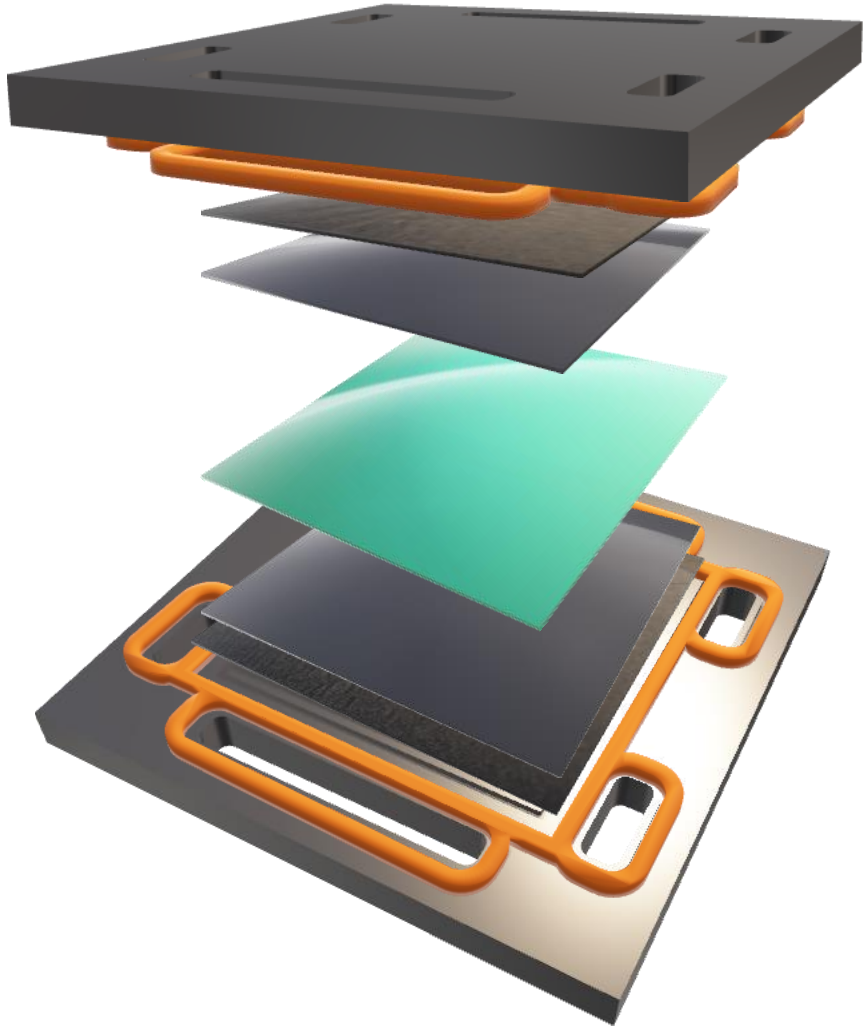
PEMFC technology



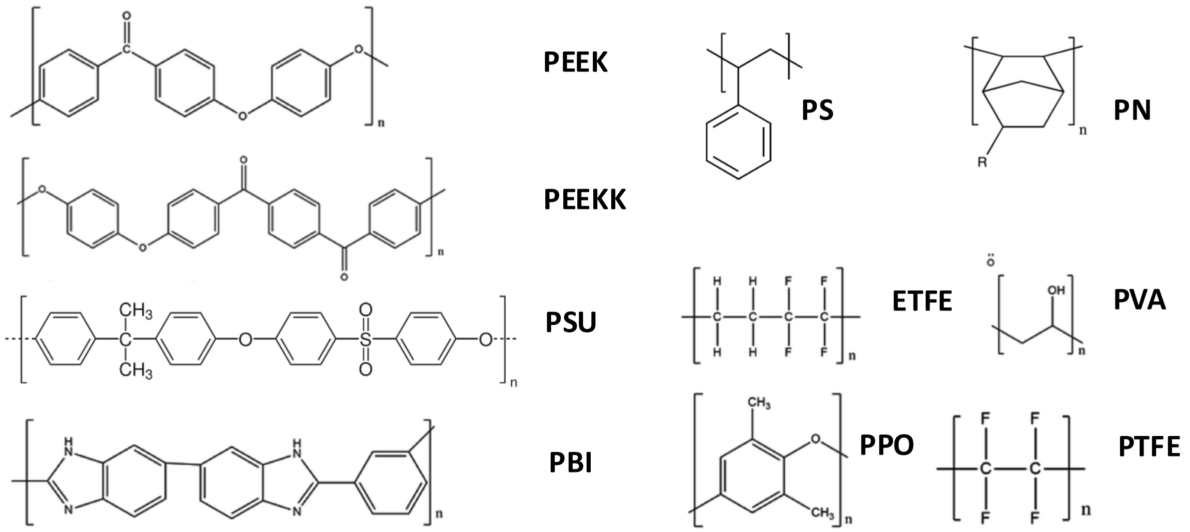
Nafion membrane



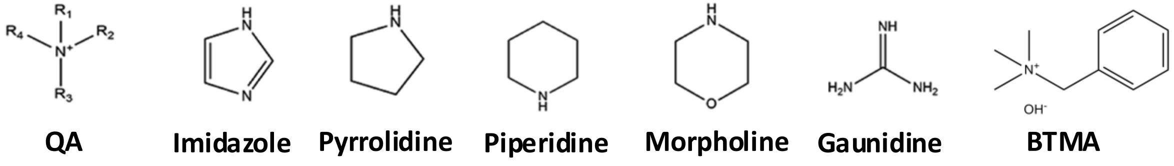
AEMFC technology



Anion Exchange Membrane

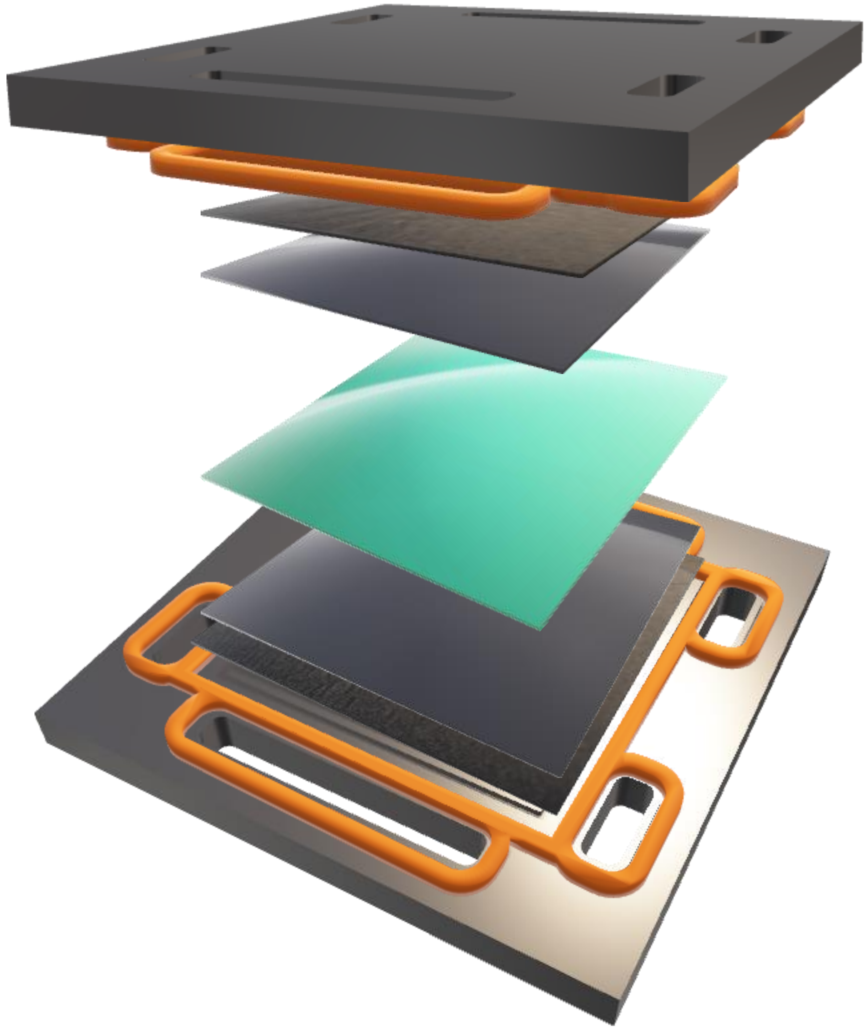


Polymeric backbones



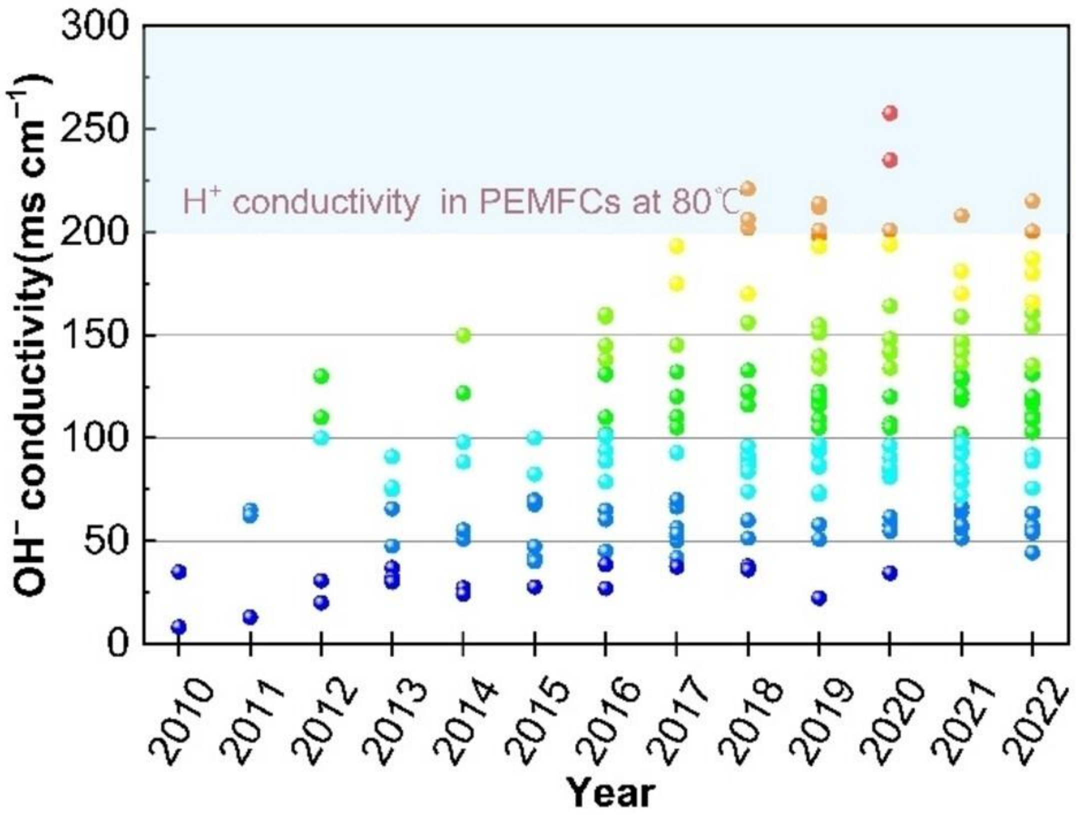
Functional groups

AEMFC technology



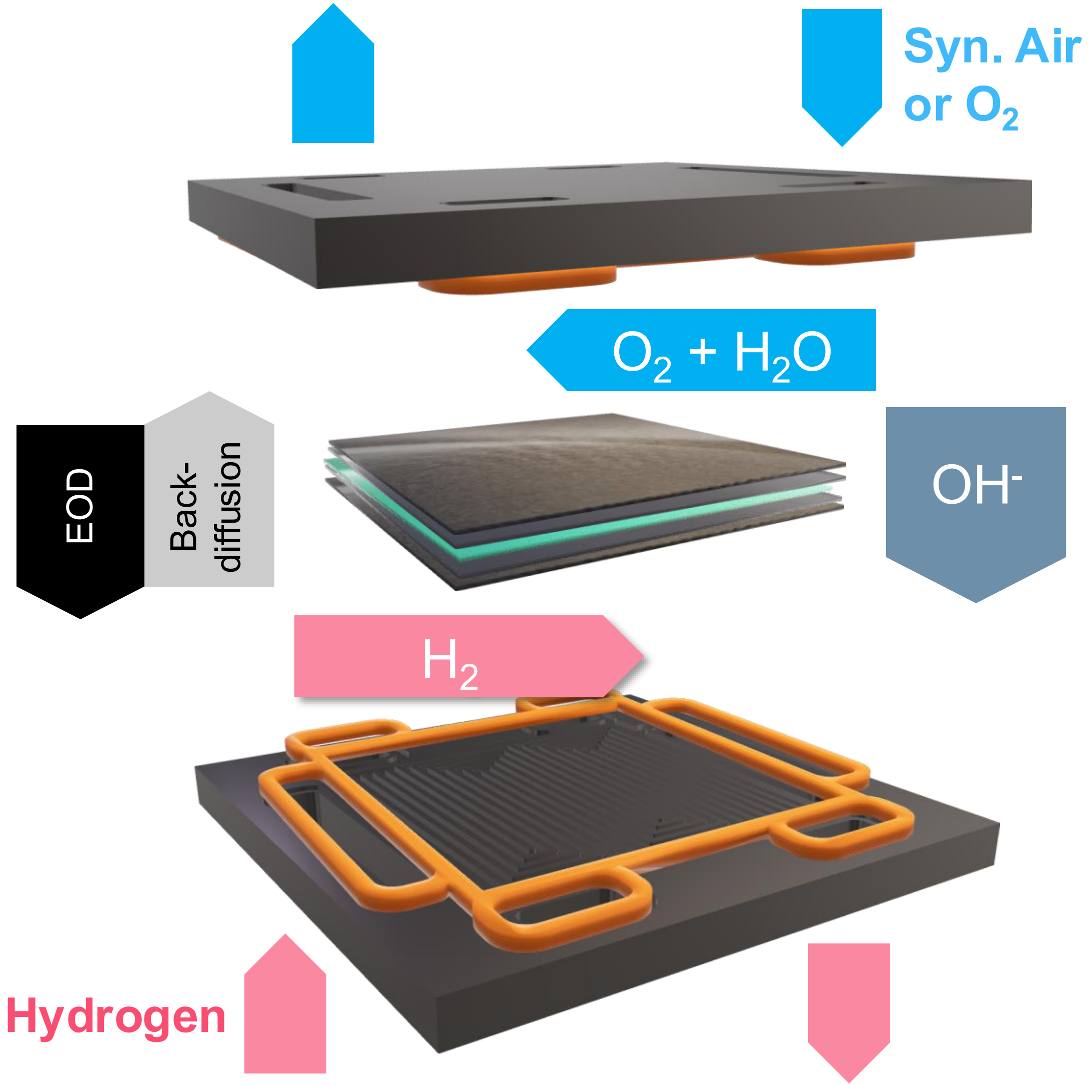
Anion Exchange Membrane

High ion conductivity (>200 mS cm-1 @ 80°C)



Source: Recent Development of Anion Exchange Membrane Fuel Cells and Performance Optimization Strategies: A Review

AEMFC technology



AEMFC operation

Cathode

$$O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^- \qquad E^0_{SHE} = 0.4010\ \mathrm{V}$$

Advantage: high ORR activity in alkaline environment

$$H_2 + 1/2\,O_2 \rightleftharpoons H_2O \qquad E^0_{SHE} = 1.2291\ \mathrm{V}$$

Challenge: difficult water management due to water consumption at cathode and high EOD

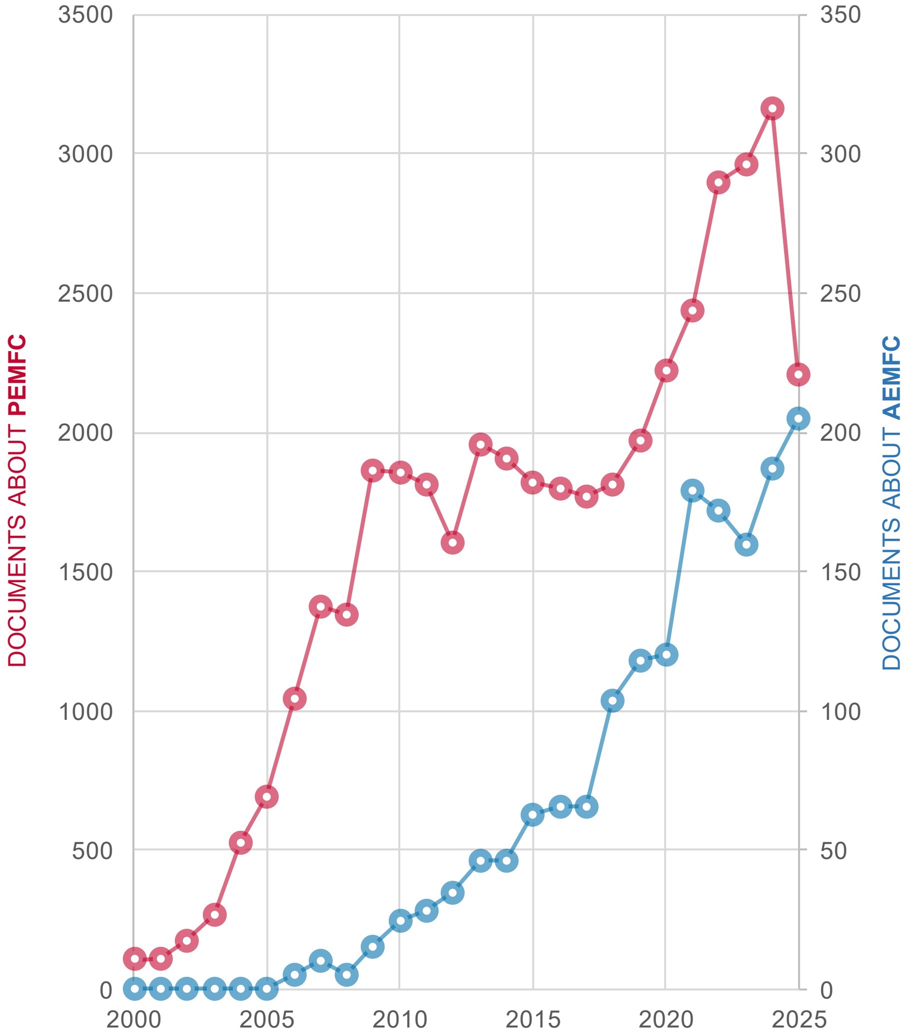
Anode

$$H_2 + 2OH^- \rightleftharpoons 2H_2O + 2e^- \qquad E^0_{SHE} = -0.8281\ \mathrm{V}$$

Advantage: wide range of available fuels

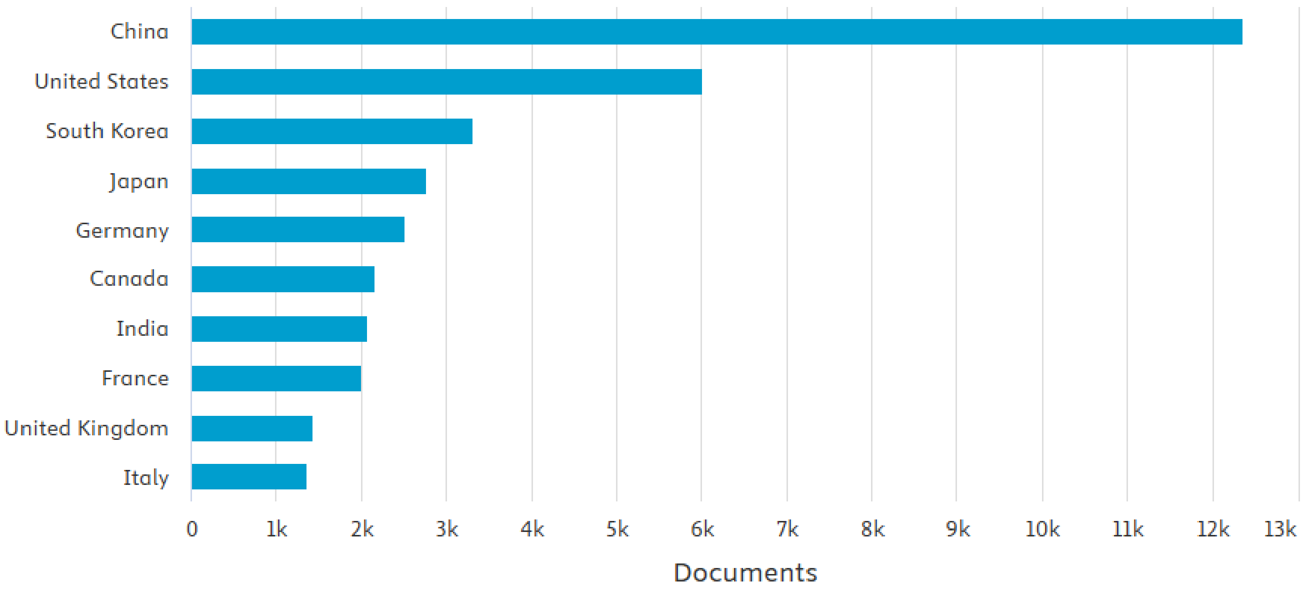
AEMFC - Current R&D efforts

Documents per year



Documents by country or territory

Compare the document counts for up to 15 countries/territories

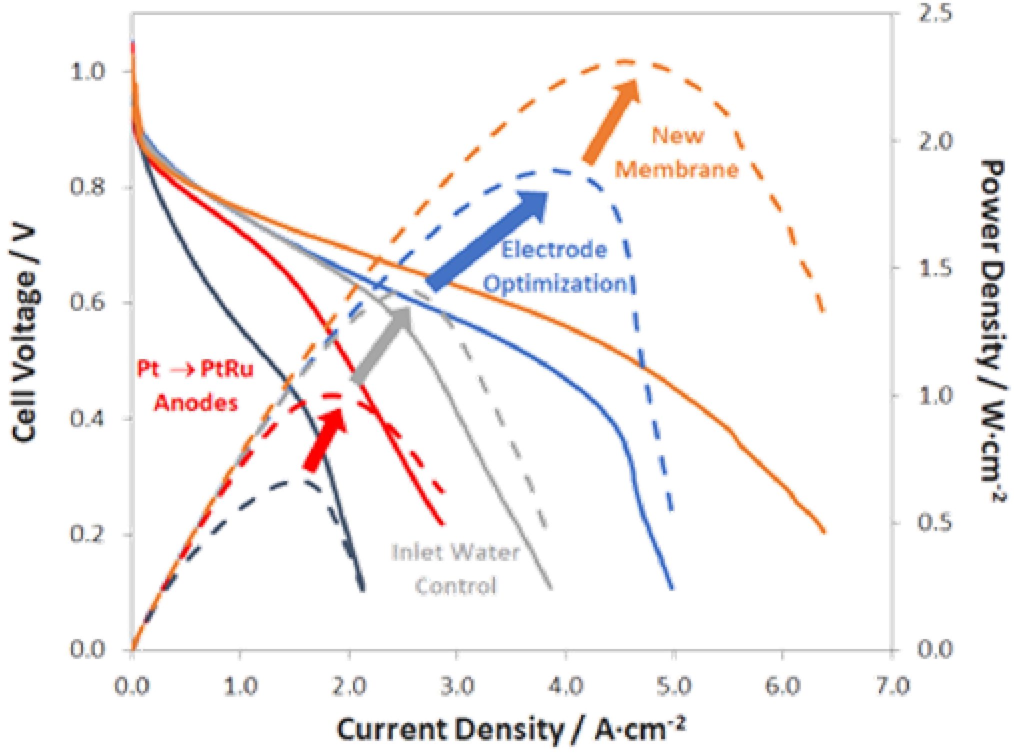


Chronology of publications about PEMFC and AEMFC. Source: http://www.scopus.com; search settings: 1) pemfc 2) aemfc, anion exchange membrane fuel cell, alkaline membrane fuel cell, hydroxide exchange membrane fuel cell; limited to Article, Review, Conference Paper (accessed November 2025).

AEMFC – Present R&D trends

Specific performances

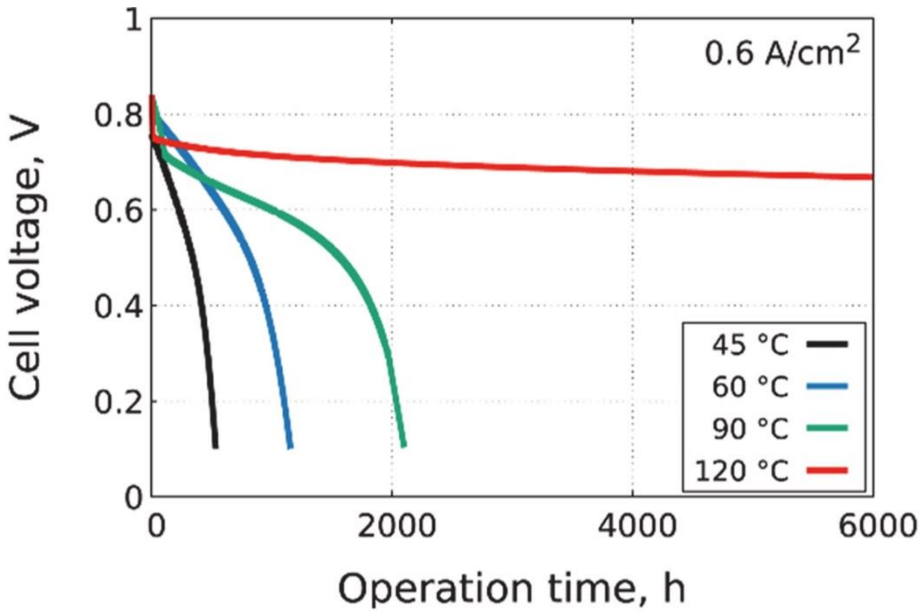
Performances with pure oxygen feed



Source: Understanding how high-performance anion exchange membrane fuel cells were achieved: Component, interfacial, and cell-level factors
William E. Mustain, 2018, https://doi.org/10.1016/j.coelec.2018.11.010

Durability / Lifetime

Galvanostatic stability



Source: A surprising relation between operating temperature and stability of anion exchange membrane fuel cells
Karam Yassin et al., 2021, https://doi.org/10.1016/j.powera.2021.100066

COMET Project GAMBIT

Goal: Assessment of AEMFC technology potential for the application in the mobility sector (heavy-duty, rail, maritime)

Focus on:

- HC-based membrane
- **Zero or extremely low PGM loading**
- Multi-fuel capability (e.g. ammonia, methanol)
- Power density optimization
- Hygrothermal management
- **Degradation mitigation strategies**

Methodology:

- Simulation in virtual environments
- Experimental analysis

Company partners

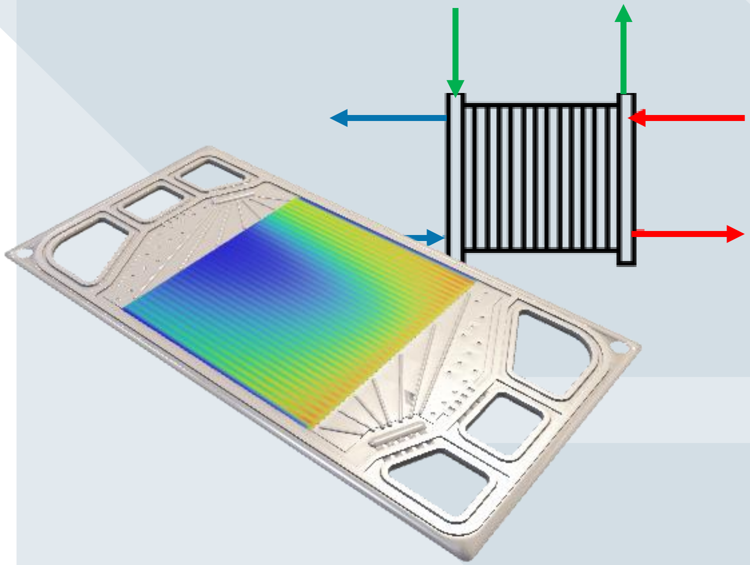
Heraeus INNOMR INNOVATIONS, AVL

Scientific partners

SFU Simon Fraser University, Chalmers University of Technology, CEET, iTnA

Simulation as enabler

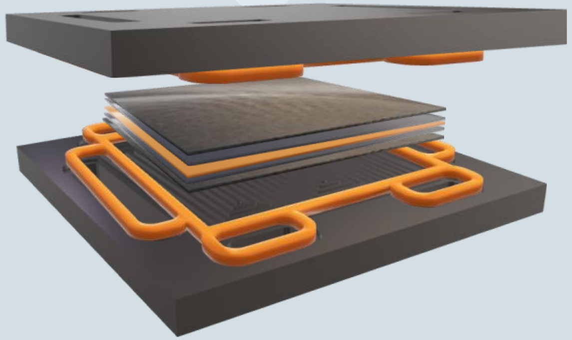
Simulation



- Research on AEMFC
- Simulation 0D, 1D, 3D

Implementation

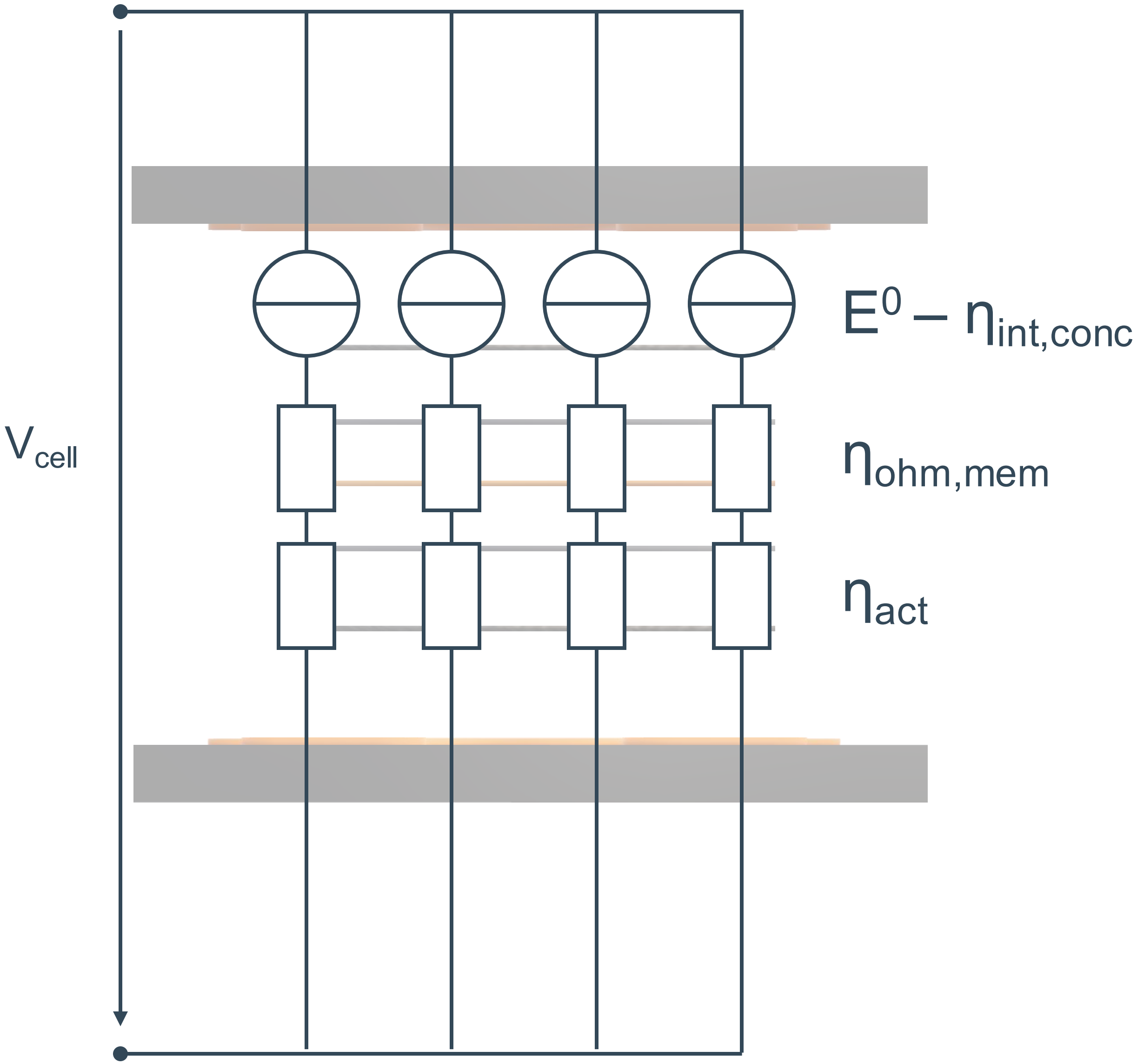
- **PEMFC-Model can not be used**
- **No commercially available AEMFC Model**



Validation

- **Single-cell testing**

Along-the-channel AEMFC model

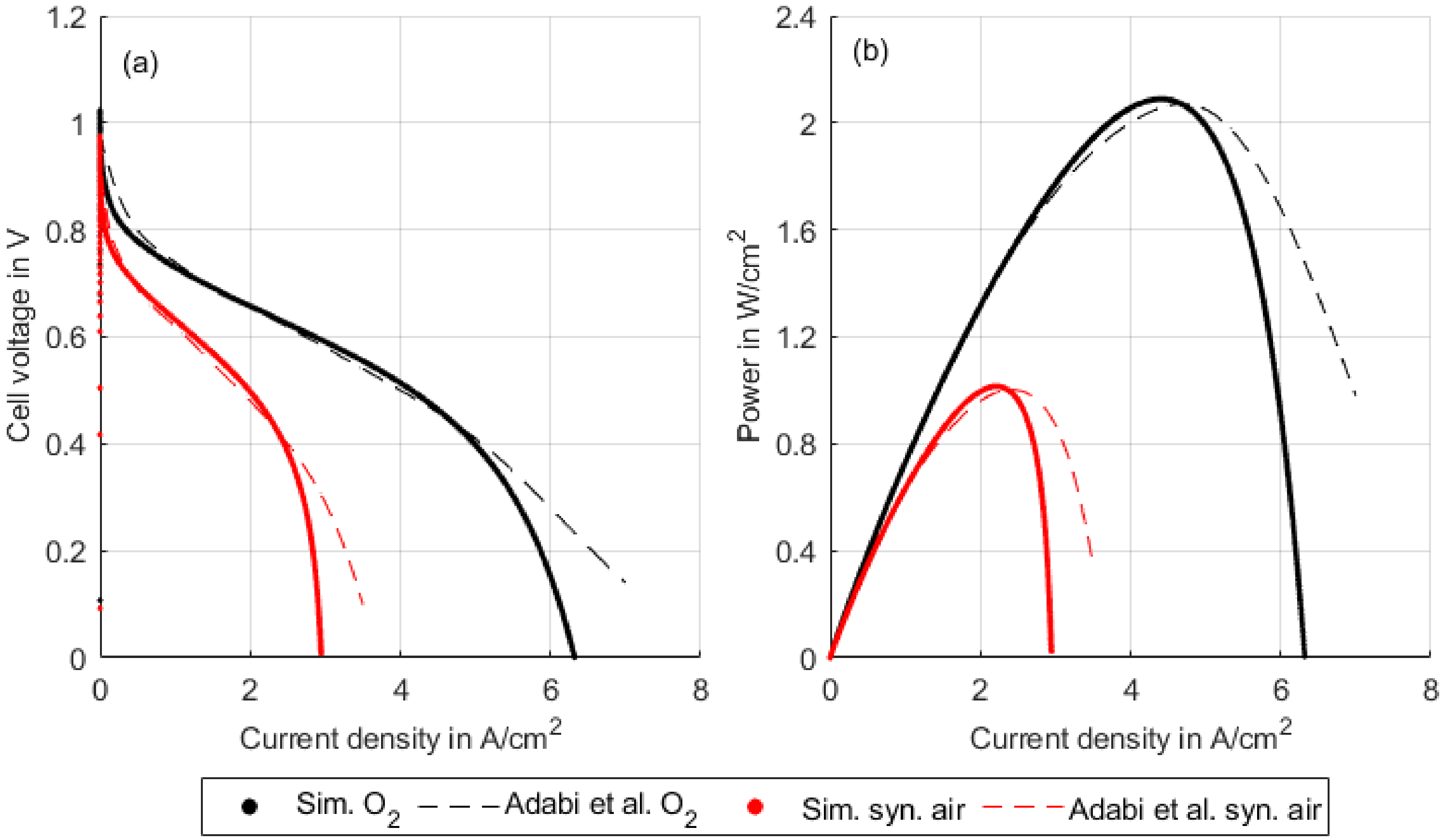


Voltage model

- Cell discretized along the Gas Flow Channel (GFC) leading to a so-called pseudo-1D model
- Segments connected in parallel
- Possibility to further discretize each segment across the MEA to reach a pseudo-2D model
- Cell voltage equal to the reversible cell potential minus all overvoltages
- Segment current calculated via explicit finite difference equations
- Coded in Matlab/Simulink

Model validation vs. literature

AEMFC (a) **polarization curve** and (b) **power curve** with simulation results feeding pure oxygen (O_2) and synthetic air (syn. air.) from this work and experimental results adapted from Adabi et al.



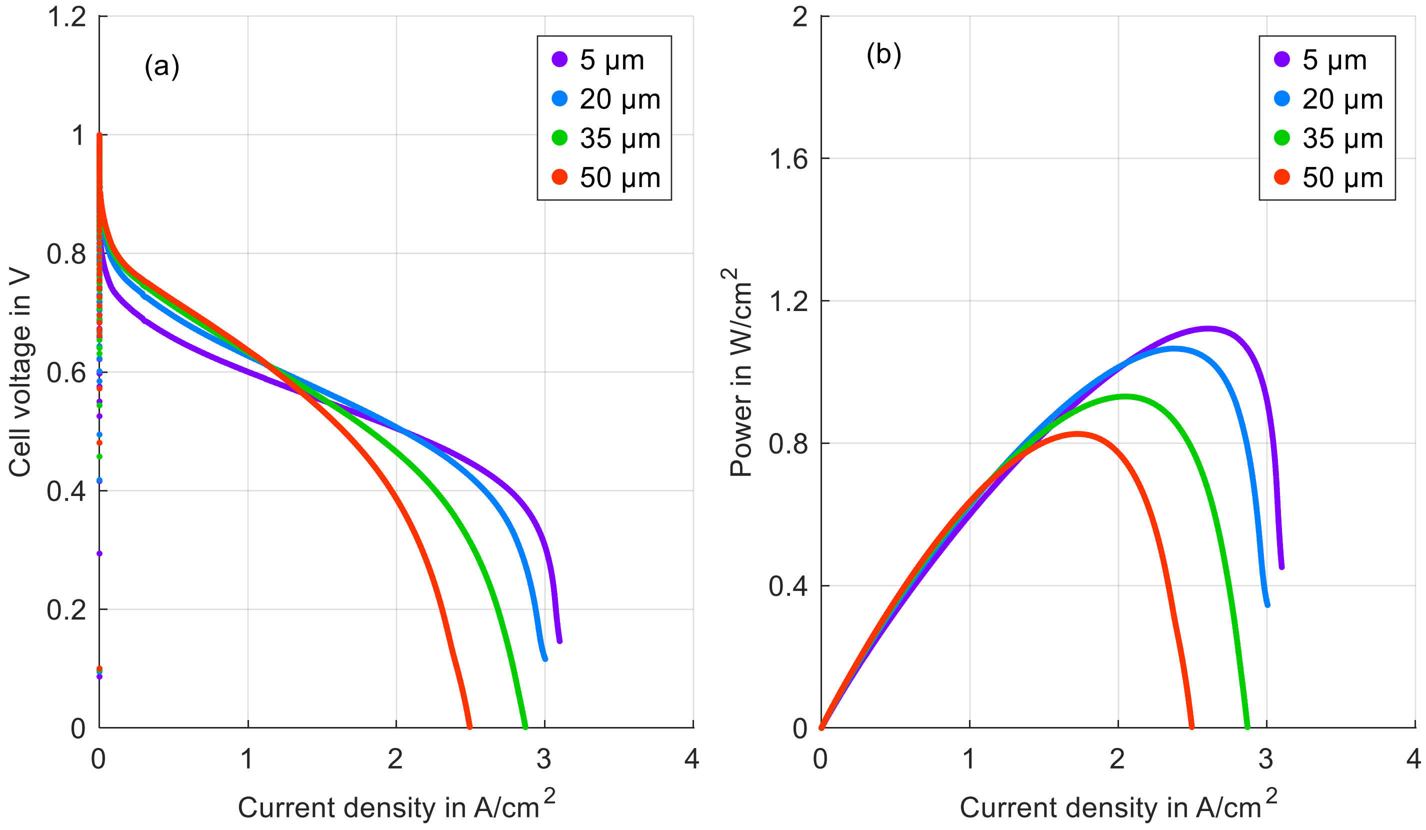
Simulation inputs:

- 20 µm membrane thickness
- inlet temperature for all media at 80°C
- 250 cm2 active area
- RH cathode/anode 75%/25%
- Operating pressure steady at 2.0bar(a) on both anode and cathode

Experimental reference:
H. Adabi et al., "*High-performing commercial Fe–N–C cathode electrocatalyst for anion-exchange membrane fuel cells*," Nature energy, vol. 6, pp. 834-843, 2021.

Membrane thickness variation

AEMFC (a) **polarization curve** and (b) **power curve** with simulation results feeding synthetic air to cells parametrised with varying **membrane thickness**



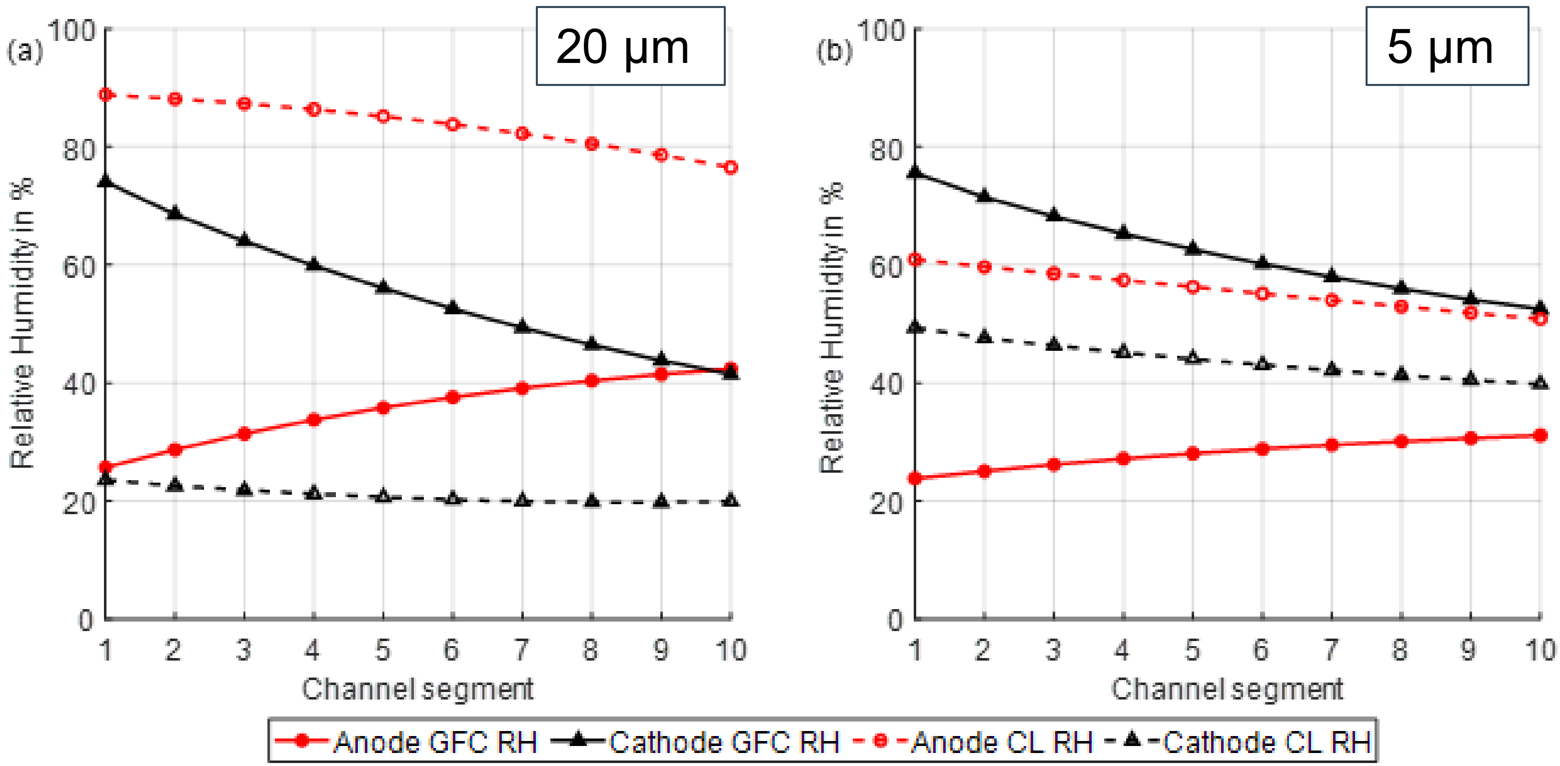
Simulation inputs:

- membrane thickness variation between 5 and 50 µm
- cathode fed with synthetic air
- inlet temperature for all media at 80°C
- 250 cm2 active area
- RH cathode/anode 80%/25%
- Operating pressure steady at 2.0bar(a) on both anode and cathode

Along-the-channel AEMFC model

HyCentA HYDROGEN CENTER AUSTRIA

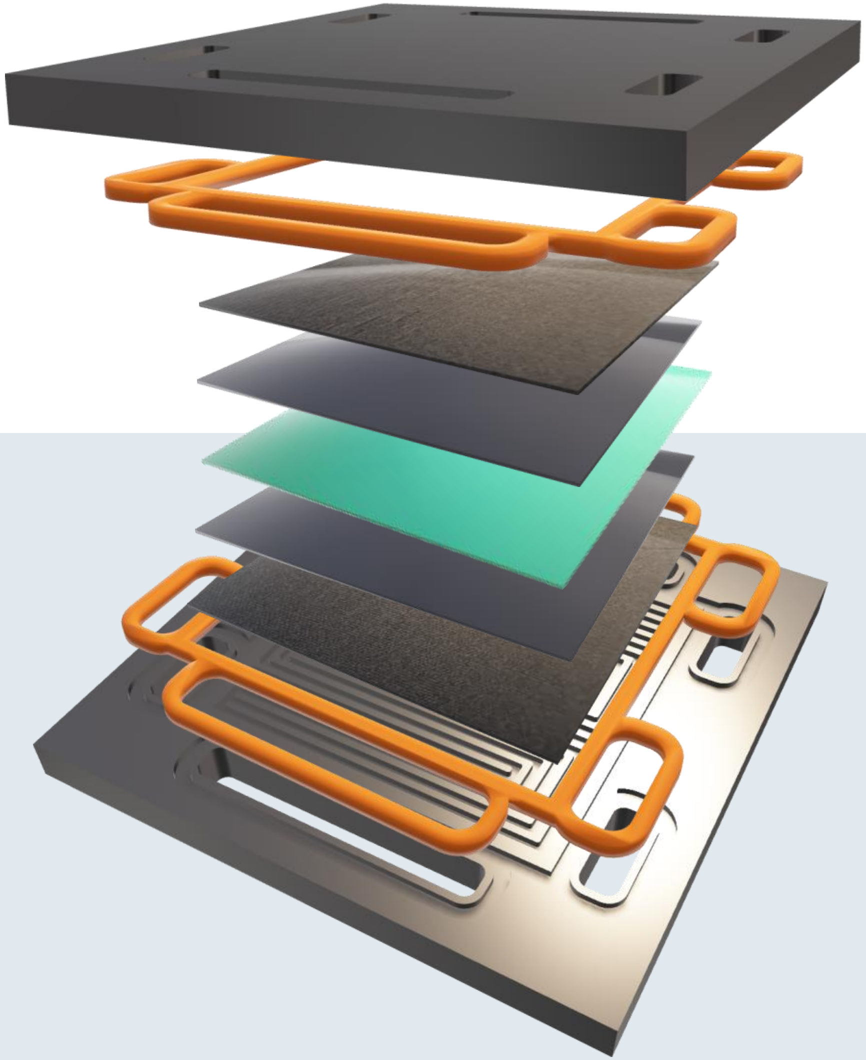
Sensitivity analysis of membrane thickness on water management. RH is plot for both anode and cathode with (a) 20 µm and (b) 5 µm thick membrane, at GFC and CL



Simulation inputs:

- H2/syn.air on Anode/Cathode
- Inlet temperature for all media at 80°C
- 250 cm^2 active area
- RH cathode/anode 90% / 20%
- Current density at 2 A/cm^2

Along-the-channel AEMFC model



Advantages

- Use of non-precious metal catalysts
- Cost effectiveness
- high ORR activity in alkaline environment
- wide range of available fuels

Challenges:

- Water management
- Carbonation
- Upscaling

COMET Phase 2

Further catalysts, stack

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Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie

FFG Forschung wirkt.

Das Land Steiermark