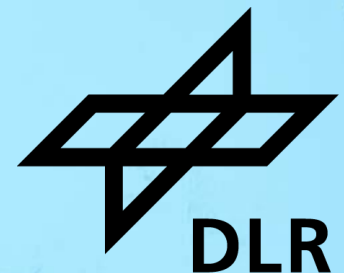


# HEAT PIPE–ASSISTED THERMAL MANAGEMENT OF FUEL CELLS IN AVIATION

Numerical determination of geometry-specific heat transfer coefficients



# Overview



Section 01

**Motivation**

Section 02

**State of the Art**

Section 03

**Methodology**

Section 04

**Results**

Section 05

**Conclusion**

Section 06

**Outlook**

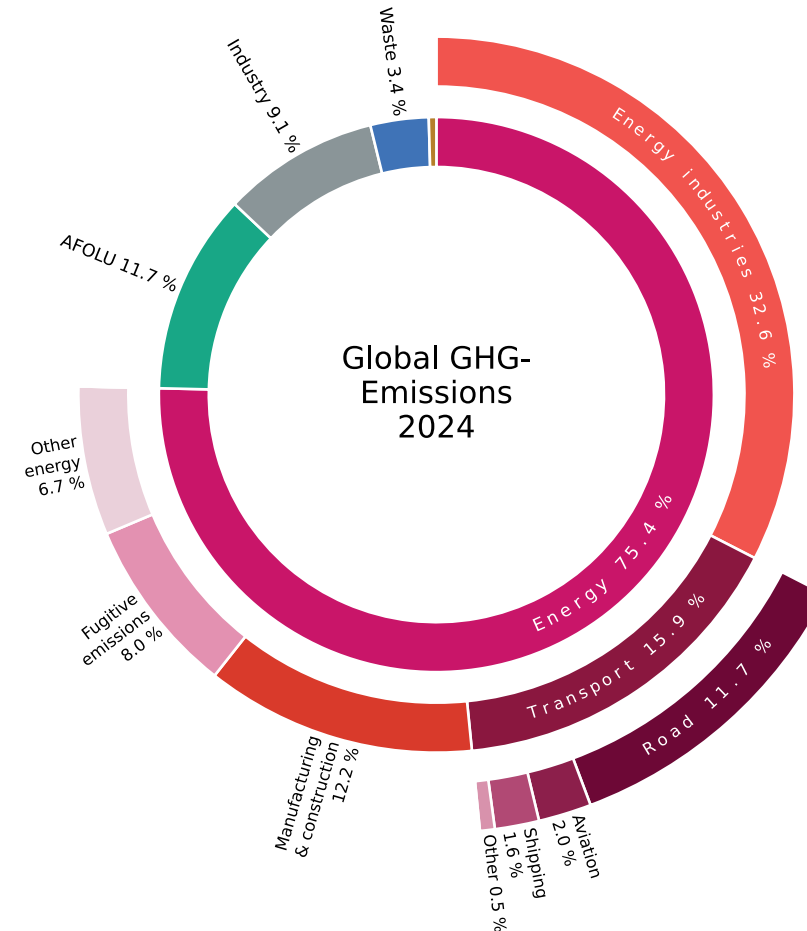


# Motivation – Global Developments in the Aviation Sector



## Global Greenhouse Gas Emissions in 2024

Total:	53,2	Billion tons of CO2 eq.
Aviation:	1,0	Billion tons of CO2 eq.



Global greenhouse gas emissions by sector; 2024 [1]

# Motivation – Global Developments in the Aviation Sector

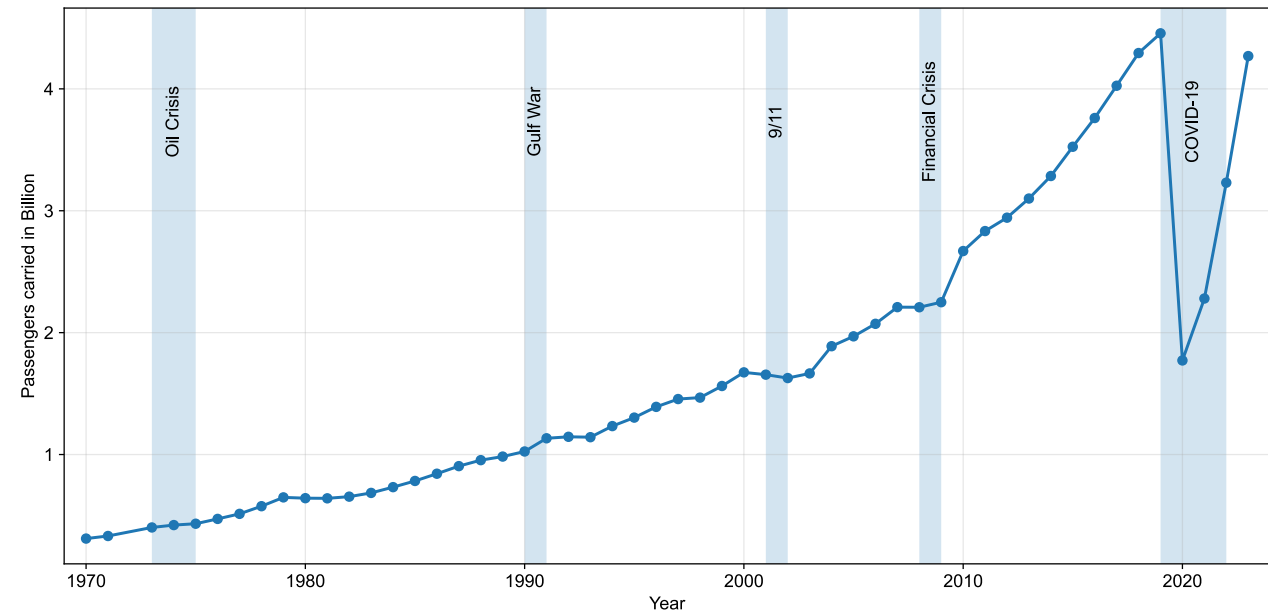


## Global Greenhouse Gas Emissions in 2024

Total: 53,2 Billion tons of CO2 eq.  
Aviation: 1,0 Billion tons of CO2 eq.

## Development

Air traffic doubles every 15 to 20 years  
Recovery of air traffic to pre-COVID-19 levels  
Reductions in other sectors



Worldwide development of the passengers carried in billions from 1970-2023; [2]

# Motivation – Innovations for GHG reduction



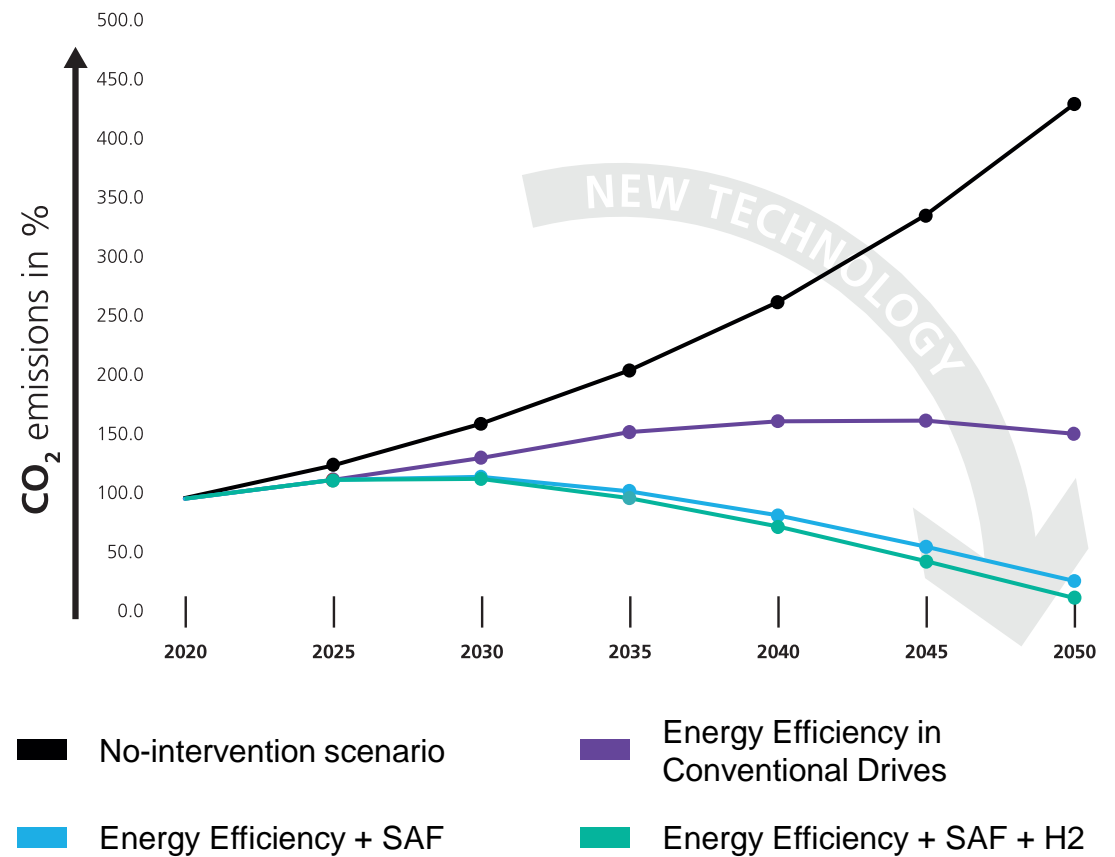
## Goals

75% reduction in CO<sub>2</sub> emissions per passenger kilometer compared to year-2000 aircraft [3]

Decoupling air traffic growth from emissions

## Reduction methods

- Further development of conventional technologies
- Optimization of traffic management
- Minimizing non-CO<sub>2</sub> effects
- Sustainable aviation fuel (SAF)
- Innovative aircraft designs based on alternative energy sources



Strategies for Reducing CO<sub>2</sub> Emissions in the Aviation Sector, [4]

# Motivation – DLR's aviation strategy

Low-emission aviation engines

Energy-efficient aircraft

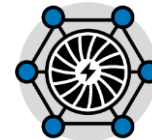
Climate-friendly air transport system

Digitalization

## Institute of Electrified Aero Engines



Komponententechnologien



Architektur und Integration des Antriebssystems



Luftfahrtanforderungen und Antriebsregelung



Umweltwirkungen und Sensorik



Versuchseinrichtungen und Infrastruktur

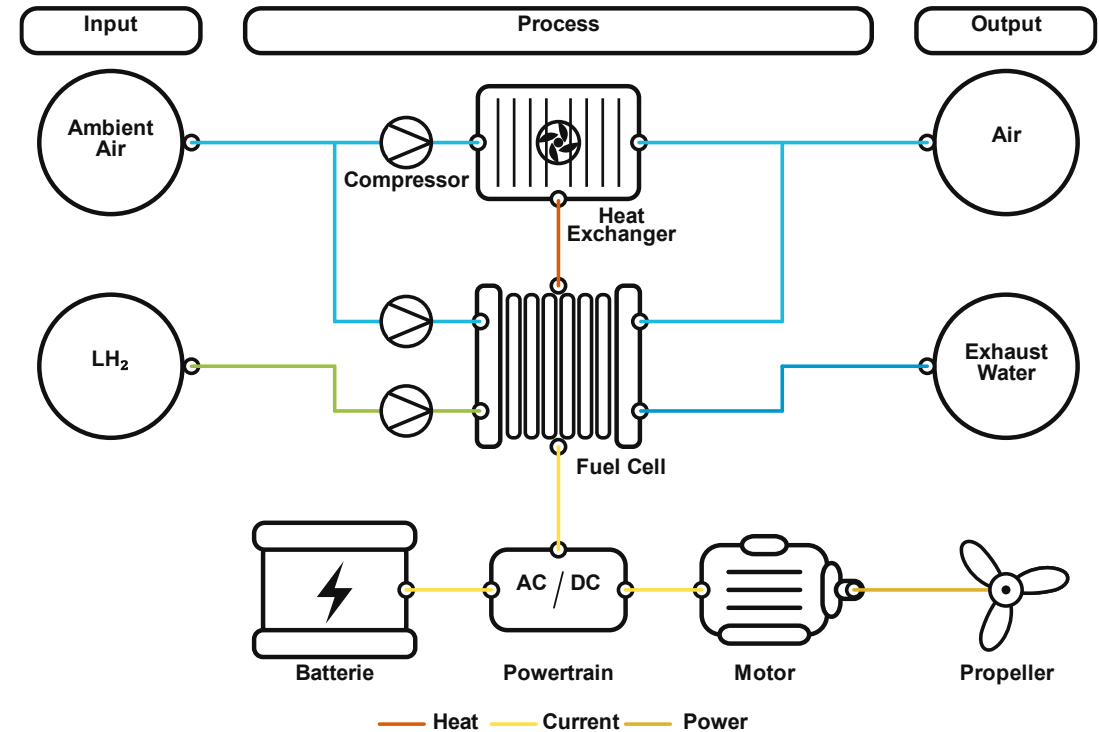
# State of the Art – Abstraction of an electric drive

## Conventional drive systems

Jet engines generate energy via thermal cycle  
Kerosin is used as fuel (high energy density)  
Efficiency is limited by the carnot efficiency

## Electric drive systems

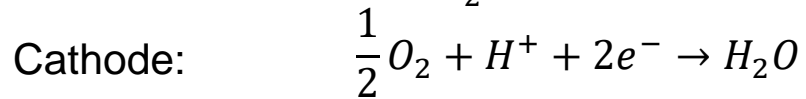
Fuel cells convert chemical to electrical energy  
Hydrogen is used as fuel (high specific energy)



Schematic of an electric drive system using fuel cells [5]

# State of the Art – High-temperature polymer electrolyte membrane fuel cells (HT-PEMFC)

## Chemical Process



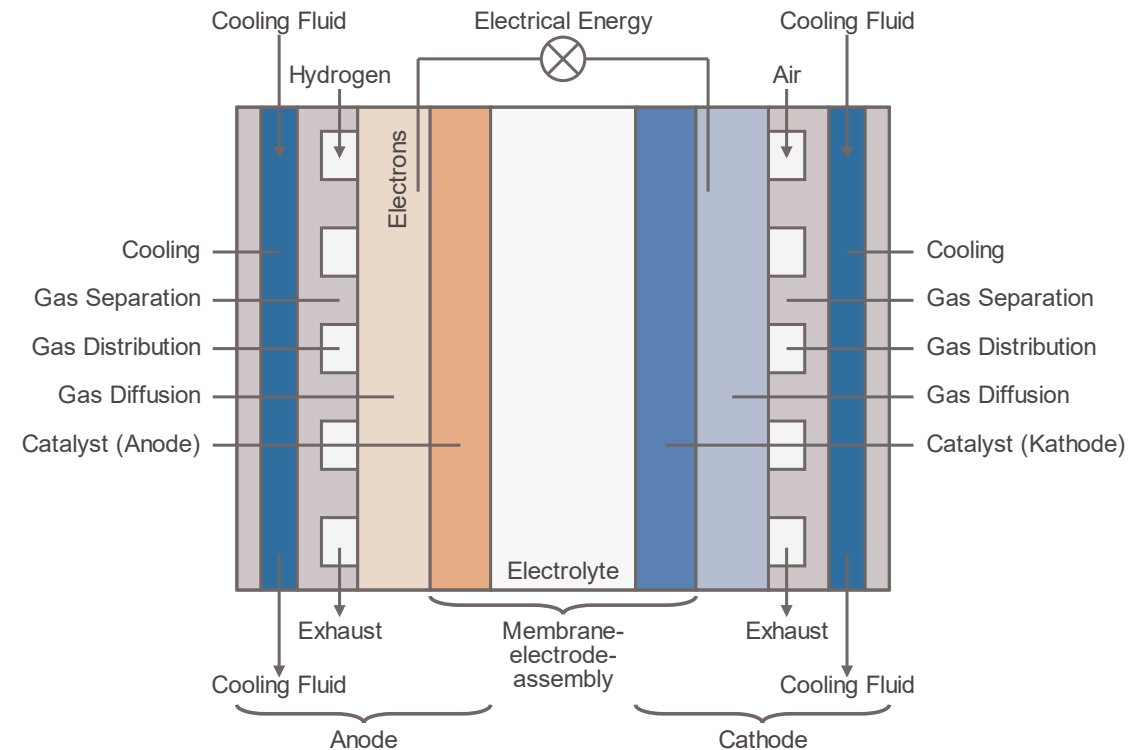
Standard electromotive force is 1.229 V [6]

## HT-PEMFC

Operating temperatures between 130 - 180°C

Simplified thermal management

Higher power density



Schematic of a fuel cell [7]

# State of the Art – Thermal Management of a HT-PEMFC

## Heat Generation

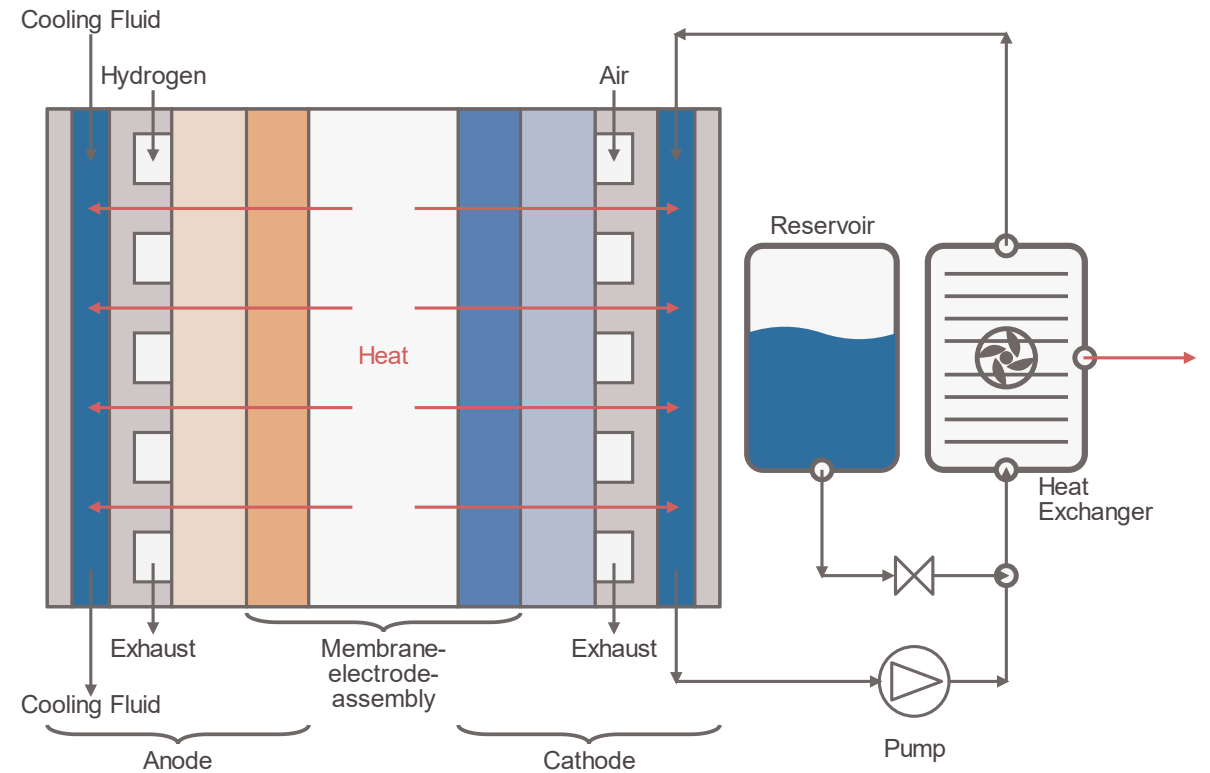
≈50% of Hydrogen's energy converts to heat in the catalyst layer [8]

Heat must be absorbed and rejected to the environment

## Liquid Cooling

State-of-the-Art Concept

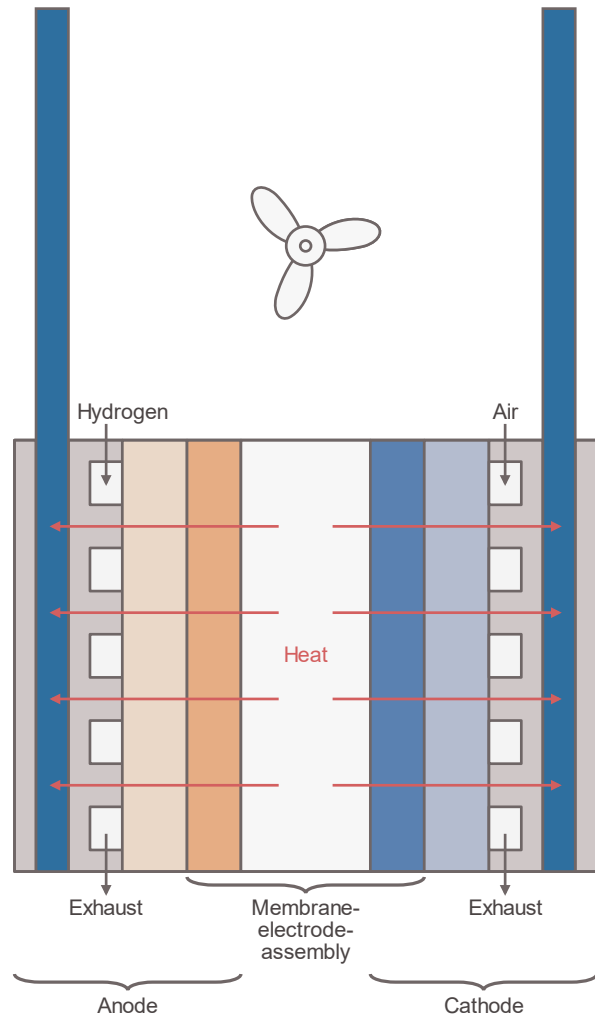
Liquid cooling channels are installed in the bipolar plates



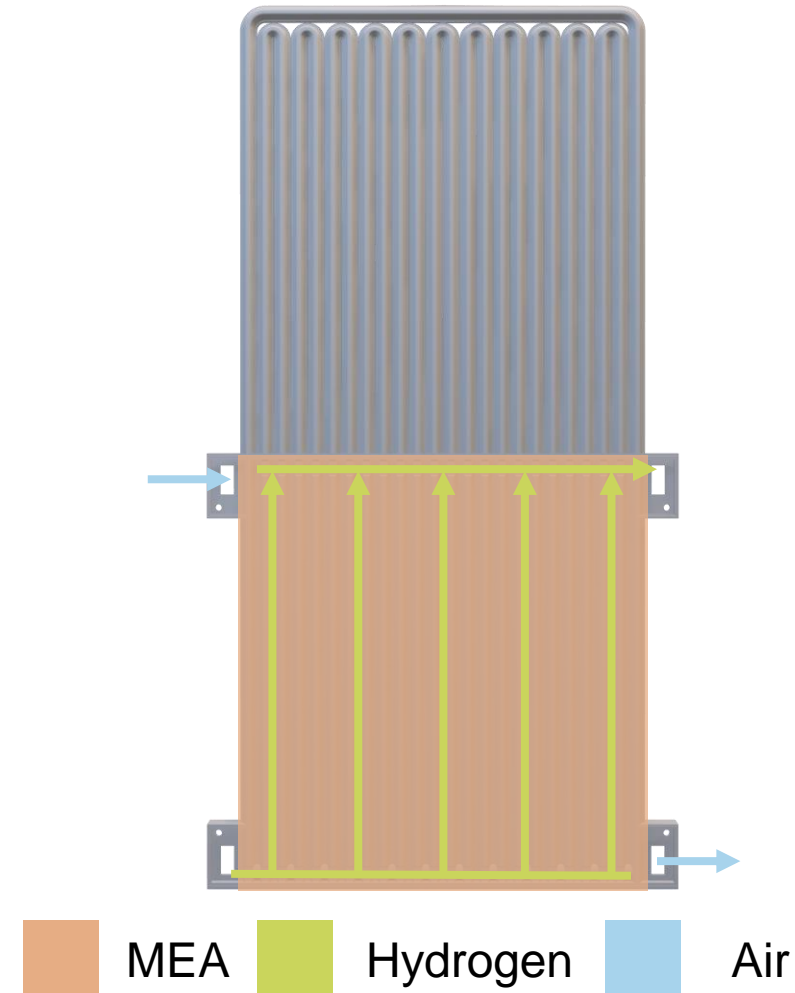
Conventional thermal management system for HT-PEMFC

# Methodology – Thermal Management of a HT-PEMFC

## Conductive Cooling

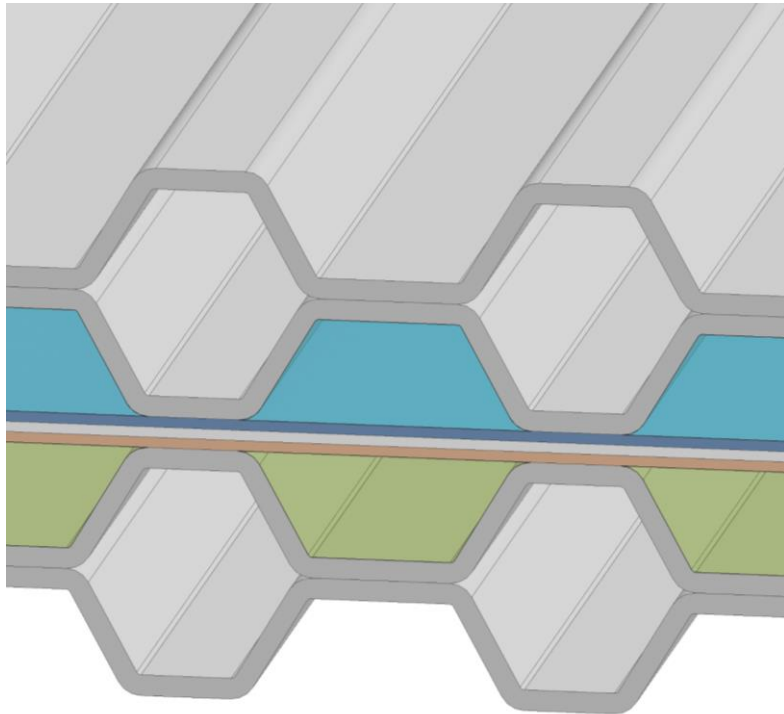


## PHP-Integrated Bipolar Plates

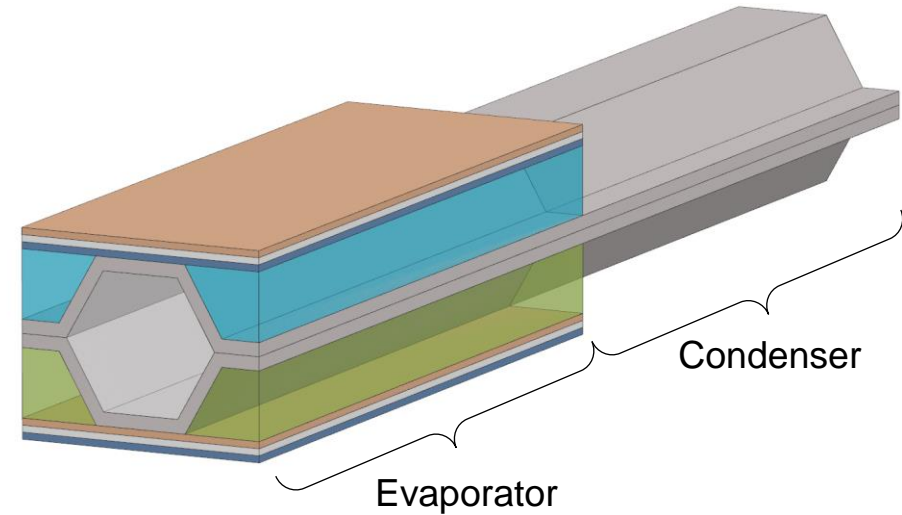







# Methodology – Analysis of the Geometry

Crosssection



Simplified model

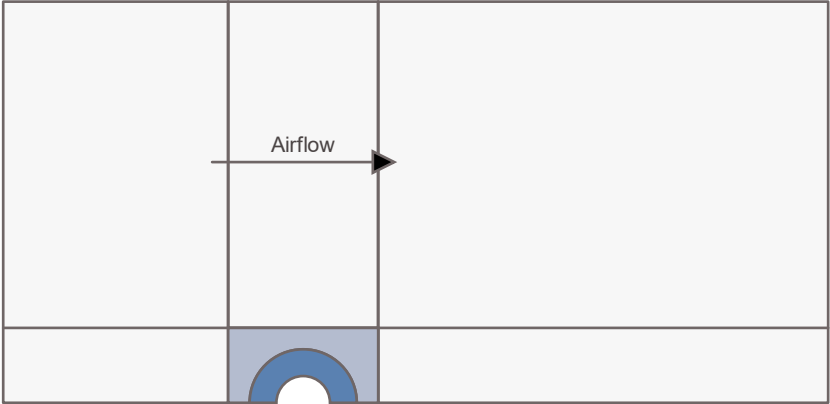


	Catalyst (Anode)		Electrolyte		Catalyst (Cathode)
	Air		Hydrogen		

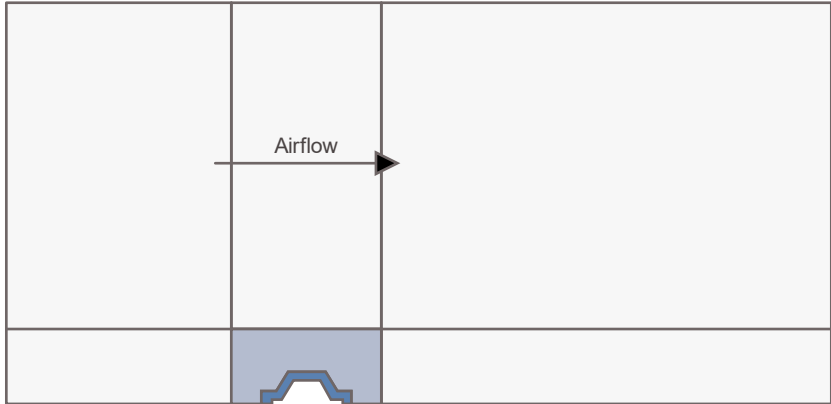
# Methodology – Abstraction of a 2D Simulation



Validation via circle

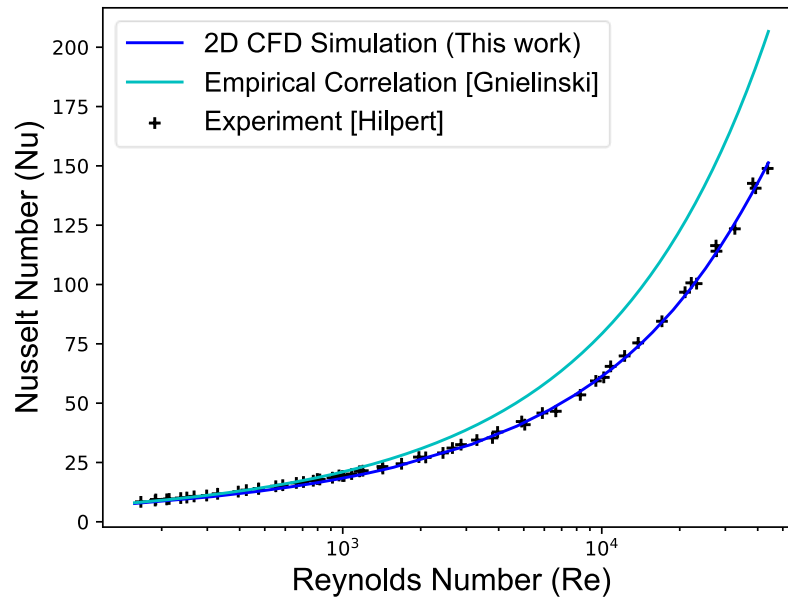
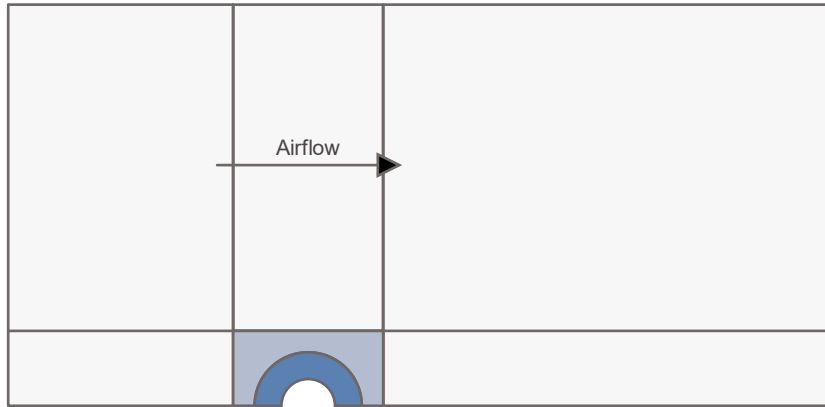


Conversion to hexagonal geometry

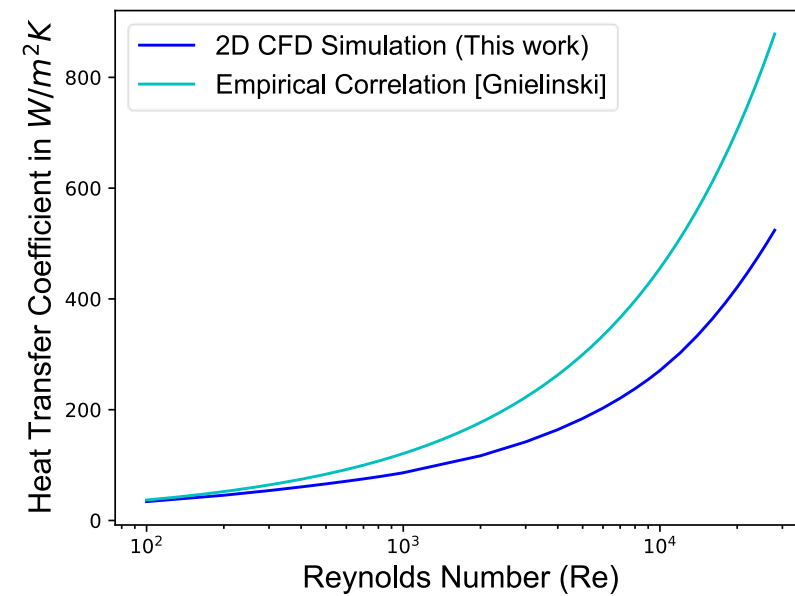
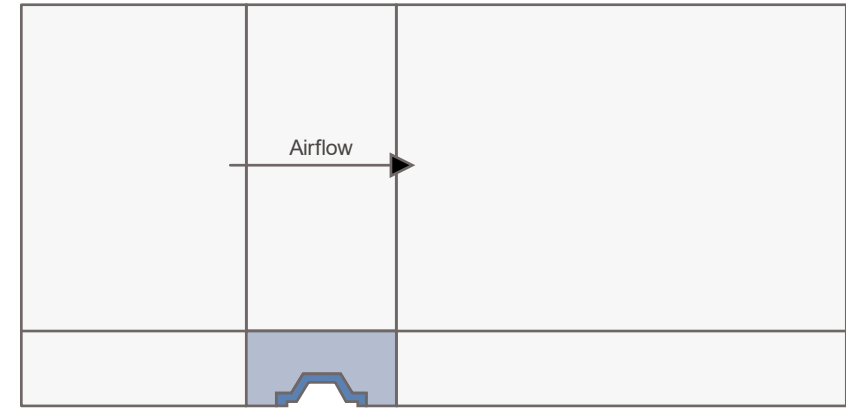


# Results – Abstraction of a 2D Simulation

## Validation via circle

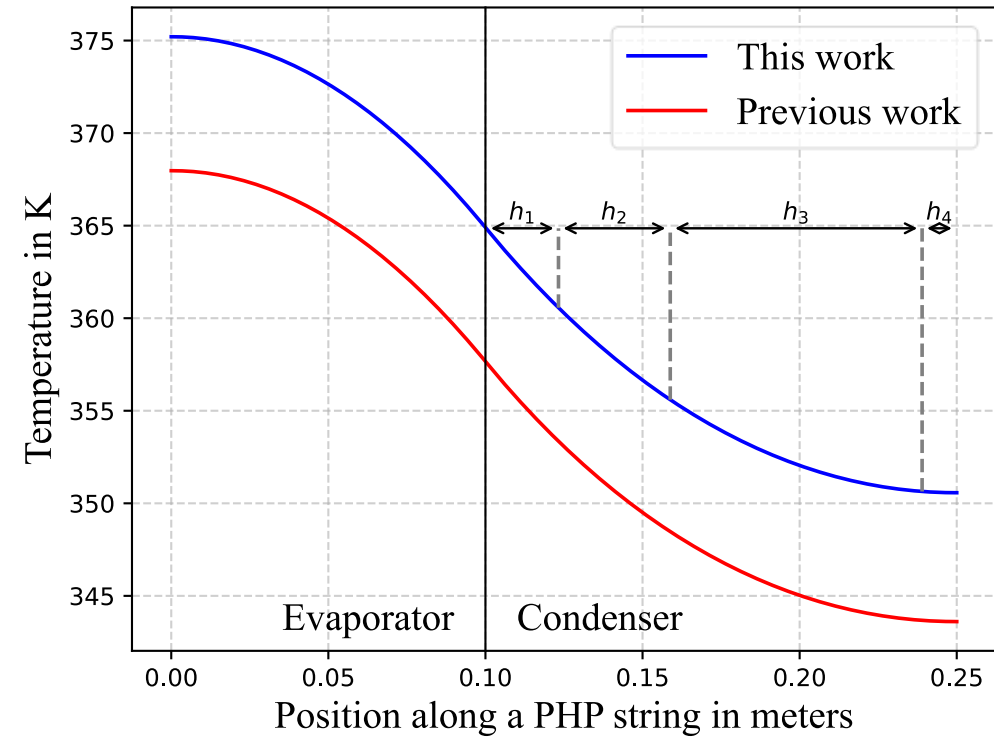
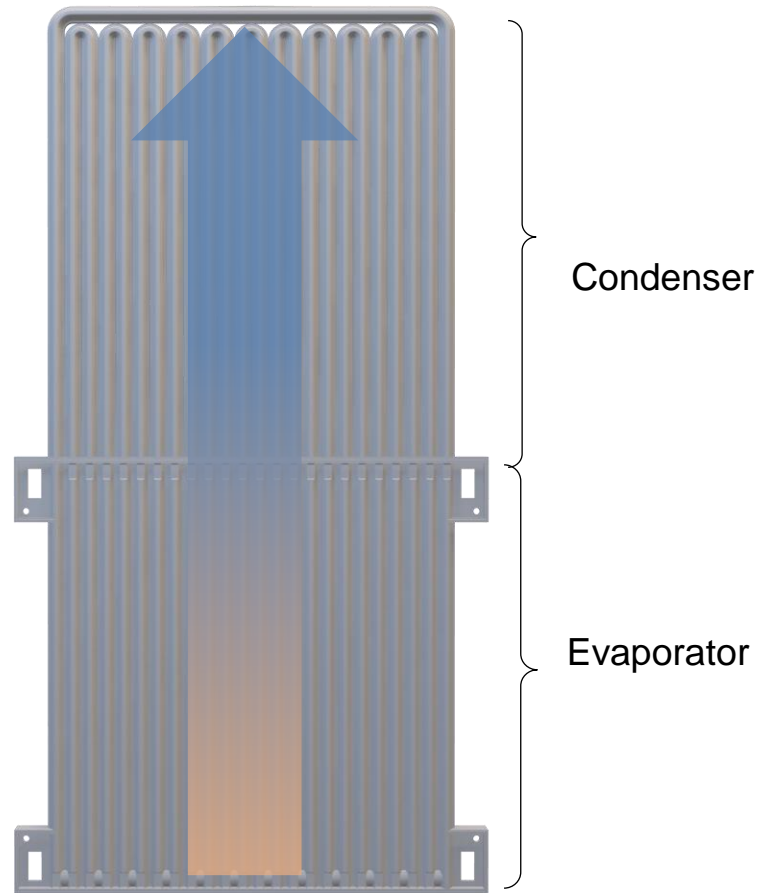


## Conversion to hexagonal geometry



# Results – Modification of the 1D model

Temperature distribution



Temperature distribution for  $\lambda_{eq} = 3300 \frac{W}{mK}$ ; [9]

External air speed  $v_{air} = 3 \frac{m}{s}$ ,  $T_{air} = 323.15K$

# Conclusion – Assessment of the Geometry

## Heat pipe air cooling for fuel cells

Concept to integrate PHP into fuel cells

Potential for higher simplicity and efficiency

## Model

Single-pipe temperature distribution calculated

2D CFD for geometry-specific heat transfer

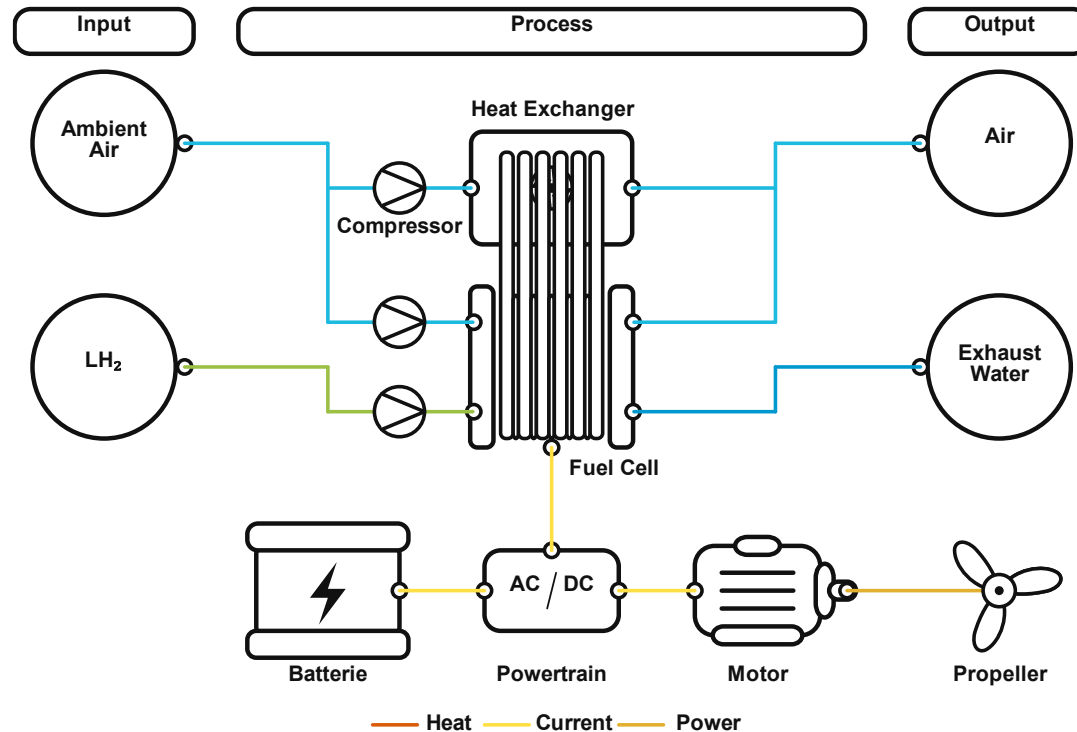
## Results

Higher Temp. via geometry-specific heat transfer

Thermal conditions confirm FC cooling feasibility



# Outlook – Rapid prototyping



Schematic of electric drive with proposed thermal management

## Manufacturing of hexagonal PHP

Prototype design and iterative refinement  
Evaluation of manufacturing and filling methods

## Testing

Construction of a PHP test stand  
Prototypes, operating conditions and measurement techniques varied

## Scaling and integration

Evaluation of thermal behavior in full PHP and FC stack  
Determination of impact on fuel cell operation

# References



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- [9] Ayel, Vincent; Slobodeniuk, Maksym; Bertossi, Rémi; Romestant, Cyril; Bertin, Yves: Flat plate pulsating heat pipes: A review on the thermohydraulic principles, thermal performances and open issues; DOI: 10.1016/j.applthermaleng.2021.117200

**Thank you for listening!**

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# Impressum



Thema: Modellierung einer Heat-Pipe-gestützten Thermalregulierung von HT-PEM-Brennstoffzellen in der Luftfahrt - Numerische Bestimmung geometriespezifischer Wärmeübergangskoeffizienten

Datum: 2026-05-07

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