

# Fuel Cell Technology at MAHLE

IAA Transportation 2022



**MAHLE**



# Fuel Cell System Approach

## Air Management



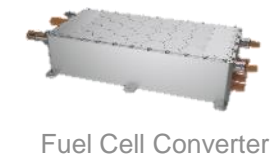
## System Approach

- ▶ System simulation & architecture
- ▶ FuelCell test rig
- ▶ BALLARD Alliance

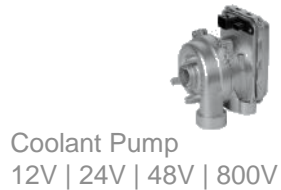
## Vehicle Peripherals



## Electronics



## Thermal Management



**MAHLE provides the full portfolio of BoP components embedded in a strong system approach**

# Development Competences

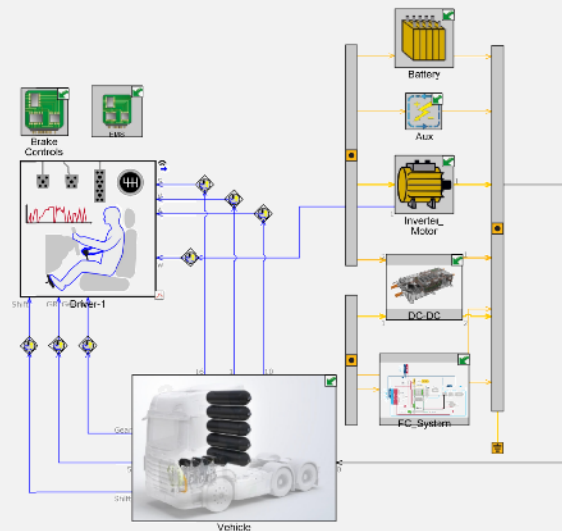


# Interlinked disciplines of development

Our development teams cover the full bandwidth of required disciplines from early concept to the final optimization

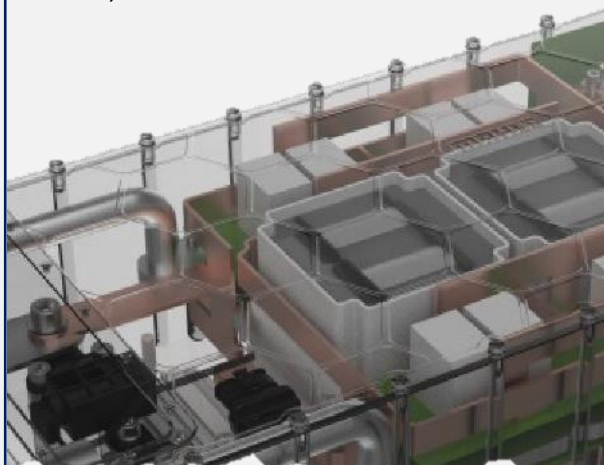
## System Engineering and Simulation

- Full functional system simulation (digital twin)
- Full system architecture, design and optimization



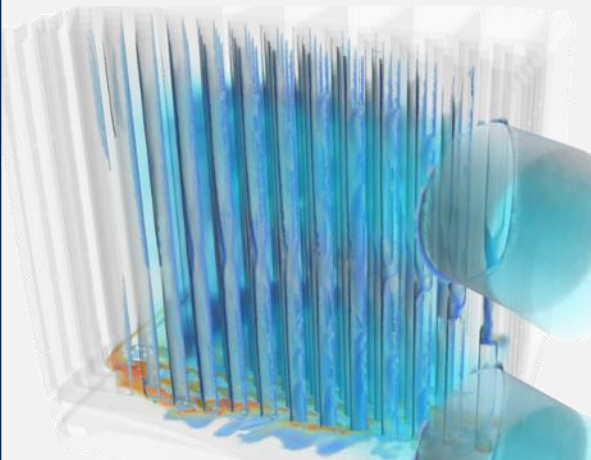
## Concept, Design and Thermal Simulation of Electronics

- State of the art HW design tools with circuit verification and design rule checks
- State of the art simulation tools for electrical, magnetic, thermal and mechanical simulation
- Rapid prototyping environment for design verification (MABX, P-HiL, S-HiL)



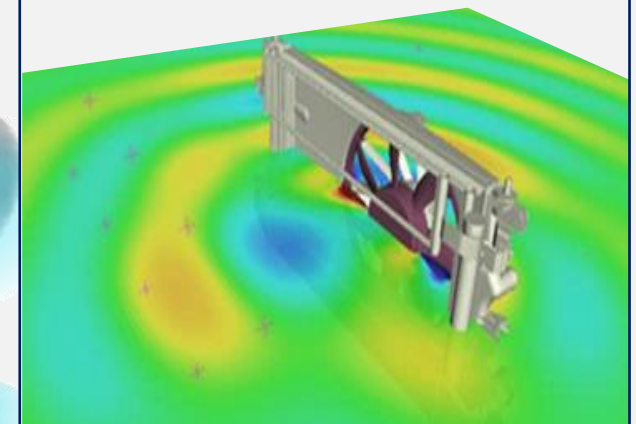
## Full Air path CFD Analysis and optimization

- Advanced aero- and thermodynamic simulation (pressure drops, flow field analysis)
- Water Separation: detailed simulation facilitate geometry optimization to achieve best water separation efficiency

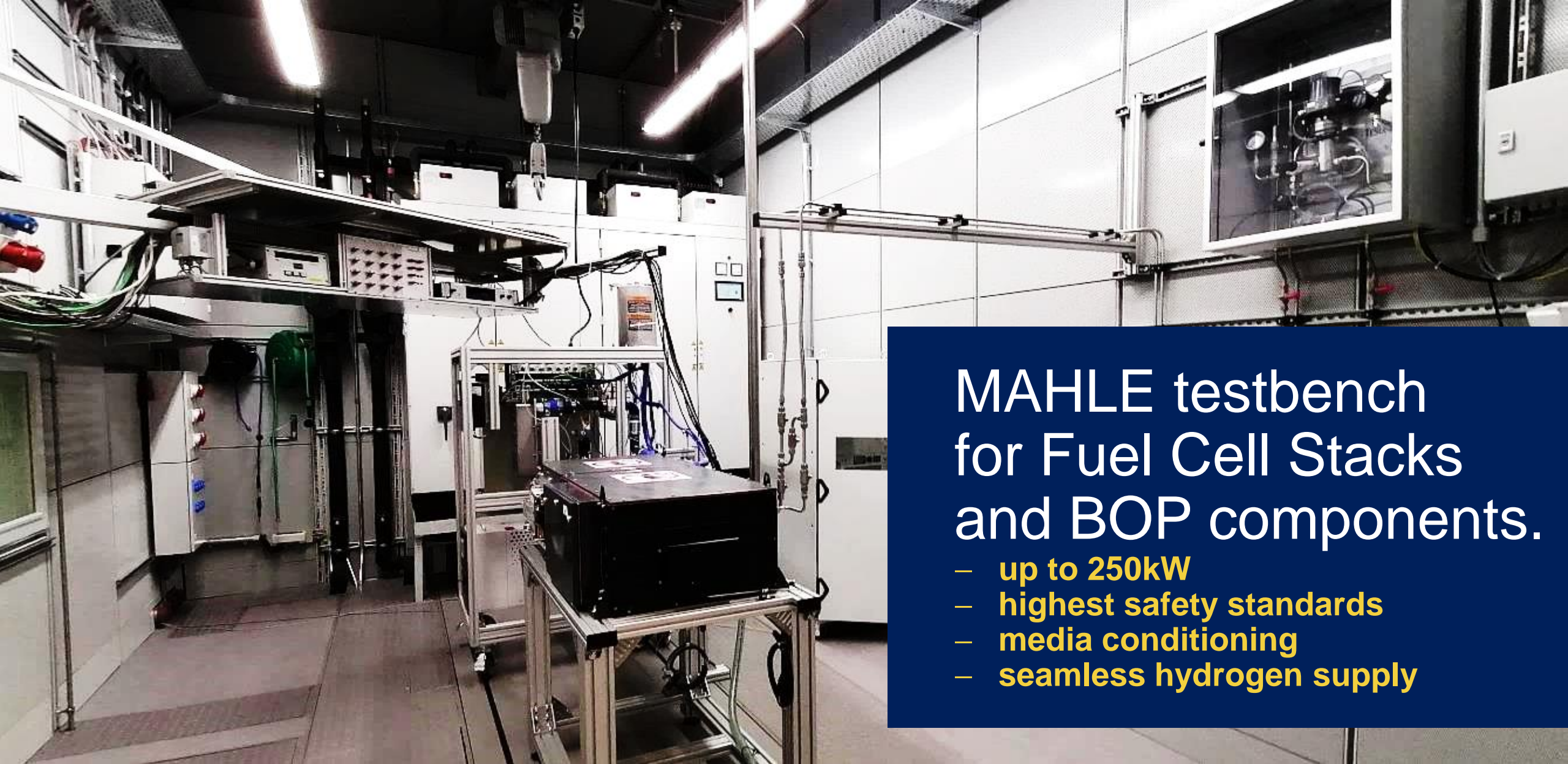


## Flow field & performance optimization on module level

- Advanced aero- and thermodynamic simulation
- Airflow evaluation and/or validation including heat rejection calculation for each heat exchanger
- Advanced aeroacoustics simulation (for modules)
- Geometry optimization of ducts and supporting geometry







# MAHLE testbench for Fuel Cell Stacks and BOP components.

- up to 250kW
- highest safety standards
- media conditioning
- seamless hydrogen supply

# MAHLE Fuel Cell Components



# Air Path System

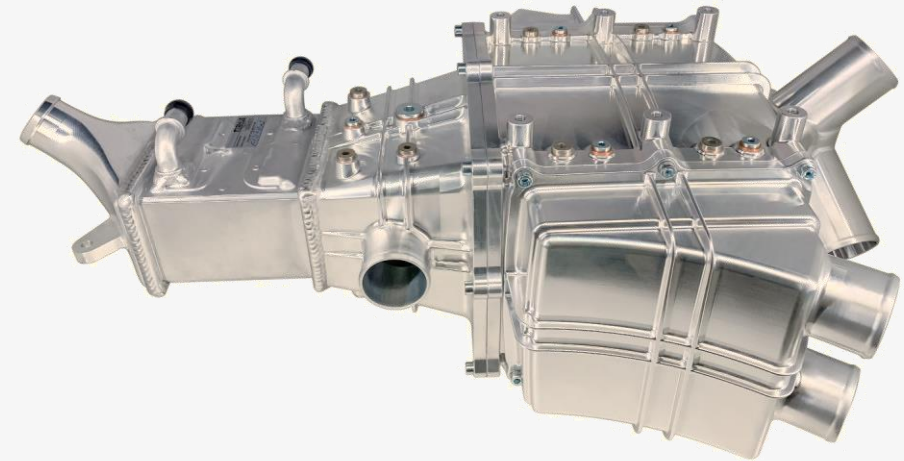
**The integrated cathode module provides the full air conditioning**

The sub module contains the following products

- Charge Air Cooler
- Humidifier
- Water Separation
- Air Flap Valves

The first available unit is designed for a module of about 120kW.  
Further variants will follow.

Prototypes available from Q4/2022



# Charge Air Cooler

## Compact heat exchanger to reduce compressed air temperature

- Scalable design ensures perfect fit from LV to HD application.
- Mature product based on technology already proven on light vehicle fuel cell applications
- Cost efficient design thanks to synergies with high volume charge air cooler applications
- Patented passivation process to meet stringent fuel cell conductivity requirements
- Parts available, full validation for HD applications in 2021





# Flat Membrane Humidifier

## Humidifier with flat membranes for high performance and extended durability

- Using the humidity of the exhaust gas to protect the fuel cell stack from dry-out
- Stack of flat semi-permeable membranes
- Plastic housing with integrated functions (e.g. charge air cooler)
- Small package and low cost due to flat membrane concept
- Improved robustness compared to hollow fibers
- High temperature range (90...120 °C)
- Higher humidification efficiency



# Air Filter

## **Harmful gas absorption** (NO<sub>x</sub> SO<sub>2</sub> NH<sub>3</sub> H<sub>2</sub>S HC)

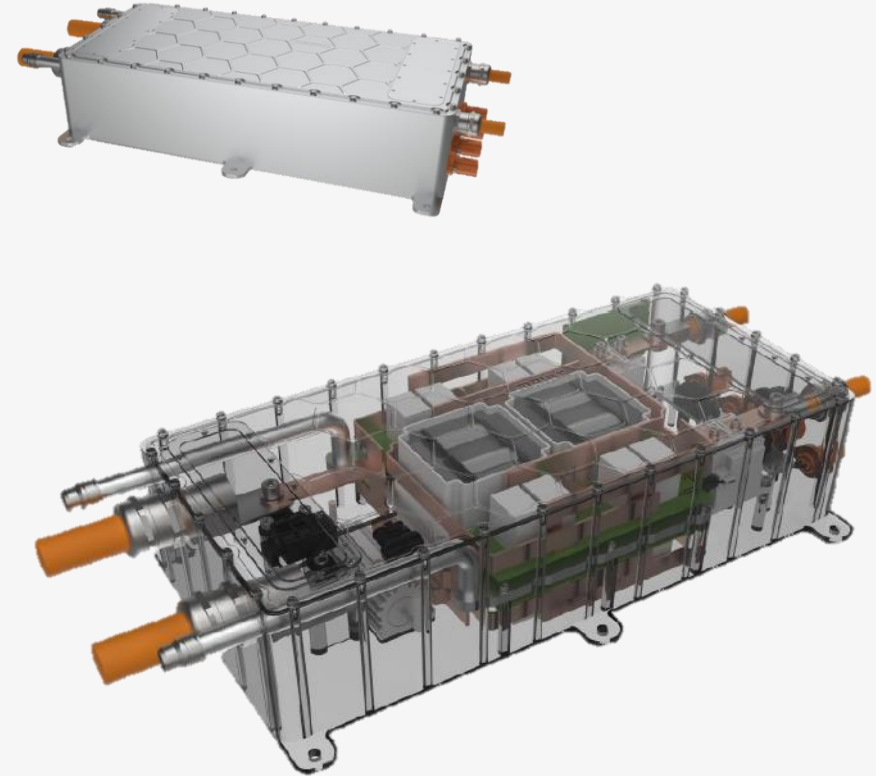
- High fractional filtration efficiencies for dust, soot and salt
- 'Off-the-shelf' solutions for stack size from 25 kW to 375 kW
- Filter housing in high volume production
- Protection and lifetime extension of the fuel cell stack
- High particle separation efficiency of > 99.9%
- Up to 45 g - SO<sub>2</sub>, 40 g - NH<sub>3</sub> and 16 g - NO<sub>x</sub> adsorption capacity
- Robust product concept by using proven filtration materials
- Service lifetime of 40.000km and above.



# Fuel Cell Converter

**The fuel cell converter ensures a constant voltage level towards the vehicle HV net up to 180 kW**

- 180 kW non galvanic isolated DC/DC-Converter
- Boost operation (Buck optional)
- Input current control with input and output voltage limitation
- Input voltage range: 50 - 515 V
- Output voltage range: 520 - 850 V
- Max. input current 600 A (scalable in 200A steps)
- SiC MOSFET semiconductors for a high system efficiency >97 %
- Integration of additional components possible, e.g. contactors, ...
  
- High power density of 6.5 kW/l
- ASIL-capable  $\mu$ C to ensure functional Safety accoring ISO 26262
- Low input ripple due to multiphase design
  
- Power electronics functionality proven on testbench
- First prototypes for customer testing in Q1/2022





# Coolant Pump High Voltage

## A coolant pump for medium and heavy duty vehicle applications

- Voltage range up to 850V, Electric Power 1,0 - 2,5 kW
- Volume flow 300 l/min @ 2.5 bar delta pressure
- Lifetime 40.000 h / 1.2mil km mileage
- Low ion emission materials
- Sensorless control algorithm
- ASIL B level on rpm (medium flow)
- CAN J1939 (optional LIN)
- Diagnostic functions / fault detection capability
- Functional samples from Q3/22
- SOP 2026



# Coolant Pump Low Voltage

## A coolant pump for medium and heavy duty vehicle applications

- Modular design (12V / 24V / 48V) with wet runner concept
- Flow of 7 lpm to 250 lpm (by-pass possible)
- Up to 650 / 850 / 1200W el. and 6250 rpm
- Fluid: Ethylene Glycol
- Pump Efficiency > 50% across wide working point range
- Temperature Fluid: -40 to +115°C Ambient: -40 to +100°C
- Noise <80 dB (A)
- Lifetime >45k hours
- Pump Weight <2,5kg
- Communication Protocol: LIN, PWM and CAN
- SOP: Q4/2023



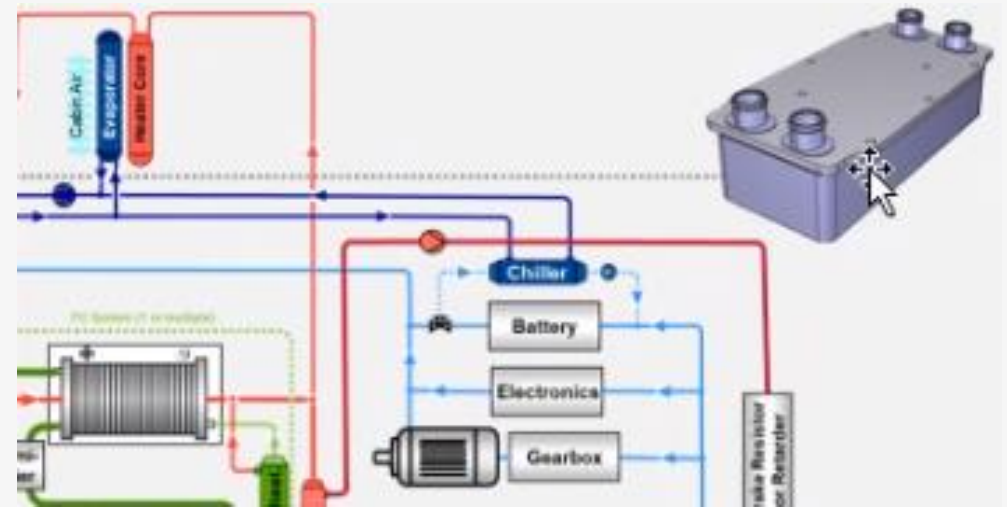
# Coolant-to-Coolant Heat Exchanger

## Description

- High performance coolant to coolant heat exchanger for Fuel Cell circuit
- Enables separation of Fuel Cell (high cleanliness requirement) from the rest of the cooling circuit
- Extended portfolio to fit to Fuel Cell cooling requirements: big plate for Stack indirect cooling, medium plate for brake resistor and retarder cooling

## Benefits

- Reduced need for passivation of components of the cooling circuit
- Improved fuel cell protection
- Enable cooling synergies on HT-Loop





# Cooling Module

## **Complete cooling modules will provide thermal stability to FC Systems up to heavy duty sizes**

- High maturity level through use of ICE-proven design and components
- Easy to integrate into existing vehicle architecture
- 3 Layer Cooling Module to cool fuel cell stack, E-Powertrain and brake retarder
- Based on existing series components
- Fuel Cell radiator passivated to achieve coolant conductivity requirements
- Specific application for FCEV



# Electrical Fans

## Description

- 5...10...15kW E-fan Family
- 800V Fan drive with integrated inverter
- Can be arranged in single fan or dual fan configuration -> up to 30kW

## Benefits

- High performance
- Compact packaging with integrated inverter

## Milestones (10kW motor)

- First customer samples: Q1-2022
- First SOP: Q1-2024

