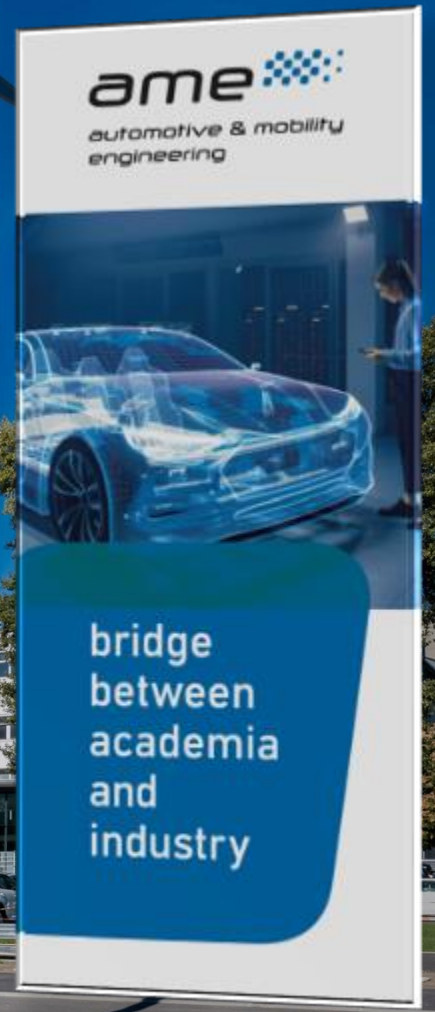
# Antriebstechnologien der Zukunft

## Optimierung durch Thermalmanagement




Univ. Prof. Dr. Uwe D. Grebe

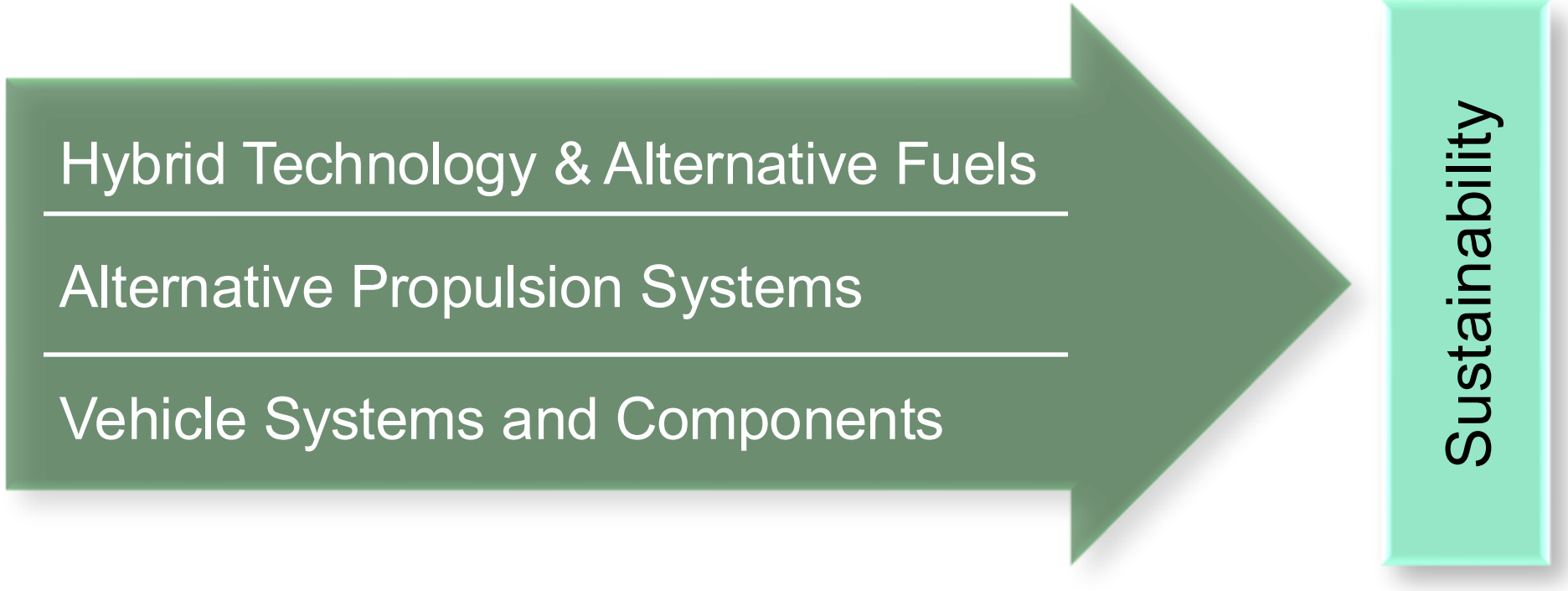
TU Wien / ame GmbH

A3PS Eco-Mobility Konferenz
13. November 2025

# Mission of institute and ame GmbH

IFA
Institute of Powertrain
& Automotive Technology

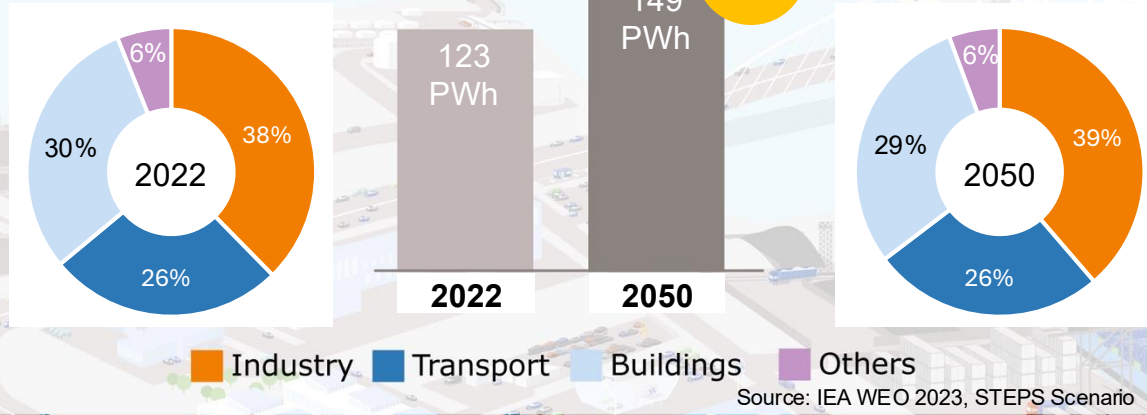
ame
automotive & mobility
engineering




*Collaboration between academia and industry to enable future mobility solutions with technological openness*

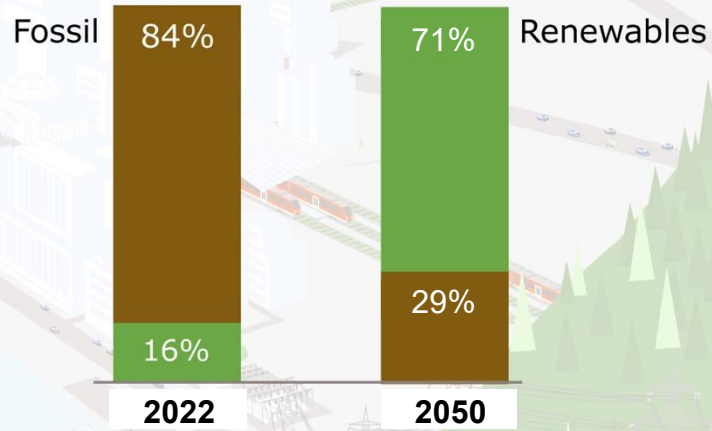
# Global primary energy supply and demand

**Consumption** increases
**Sector Share** unchanged




Source: IEA WEO 2023, STEPS Scenario

**Supply** shifts to Renewables

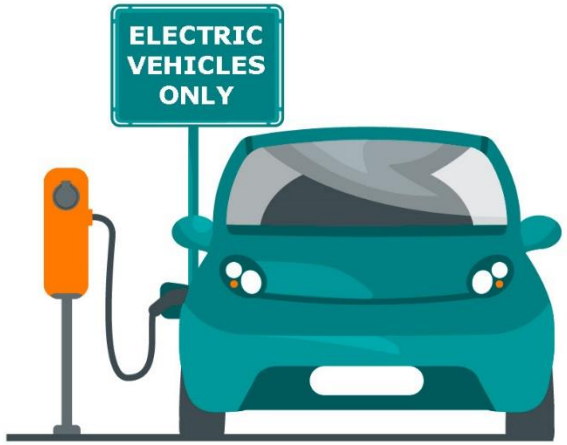



Source: IEA WEO 2023, NetZero Scenario

Source: AVL

de-fossilization
of the entire (!)
primary energy supply

# Effective $CO_2$ reduction?

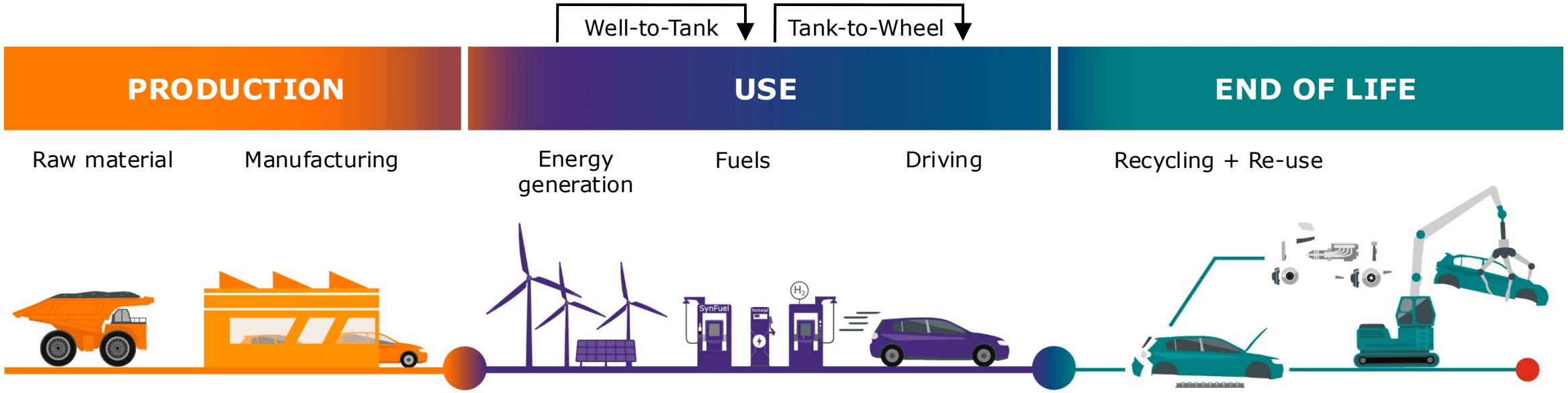

Vision for the future:
Carbon neutral mobility through renewable energy in production and use-phase of the vehicle accompanied by zero $CO_2$ infrastructure.

Source: AVL

# BEV is a major part of the solution

BEV is a major part
of the solution
when sustainable energy
is in dominant position

# Carbon neutrality in the entire product life cycle




Example: Compact passenger car –
Battery electric vs mild hybrid vehicle

2024 with current energy mix in EU

| | | | |
|---|---|---|---|
| 11 -20 t $CO_2$e | BEV | 2 - 15 t $CO_2$e | 0.4 – 1 t $CO_2$e |
| 7 t $CO_2$e | MHEV | 24 t $CO_2$e | |

Assumptions: C-segment | HEV: Propulsion 110 kW, Gasoline 85 kW, Battery 1.2 kWh, 5.6L/100km, 20% $CO_2$ from WtT, Fossil Fuel
BEV: Propulsion 150 kW, Battery 60 kWh (330 km range) | lifetime 180,000 km
Electricity mix for production & in-use phase ranges from 105 g$CO_2$e (France) to 980 g$CO_2$e (Poland)

The assessment of the propulsion system needs to reflect the entire product life cycle for the vehicle and the energy carrier.

Source: AVL

# $CO_2$ impact of different technology approaches applied to the European market

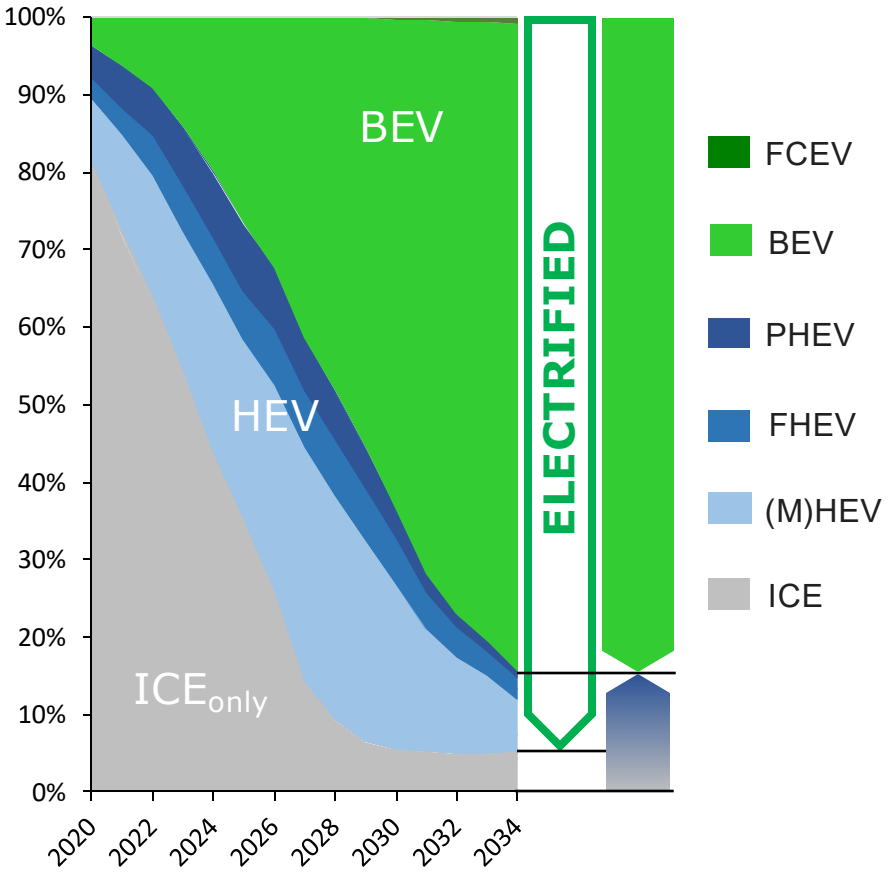
Tank-to-Wheel focus

Tank

Wheel

BEV Dogma

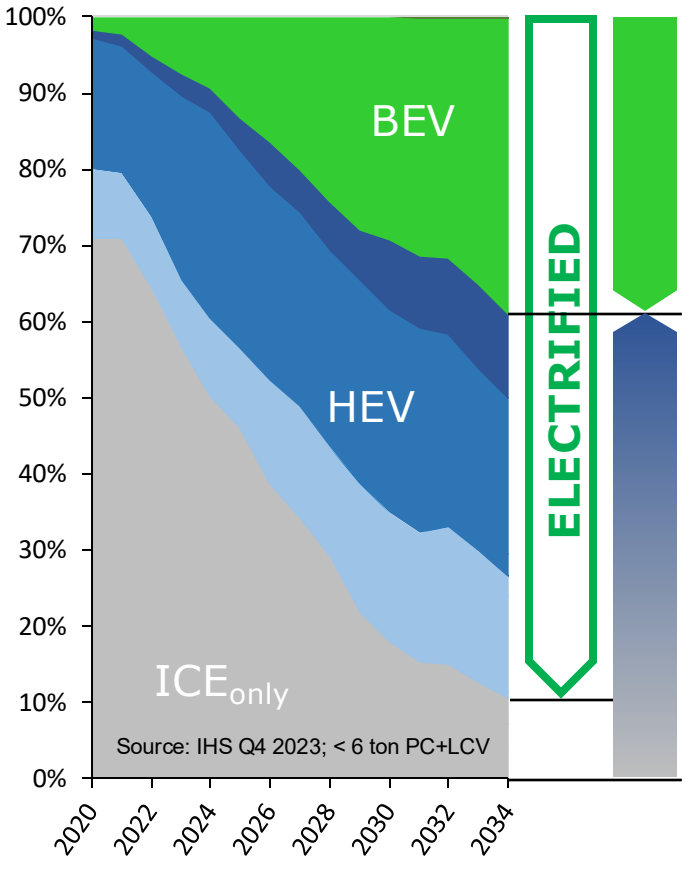
New registrations Europe



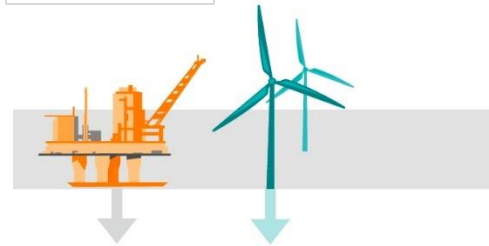


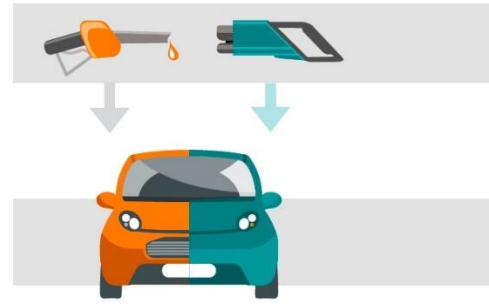


New registrations with Japanese technology mix




Well-to-Wheel focus



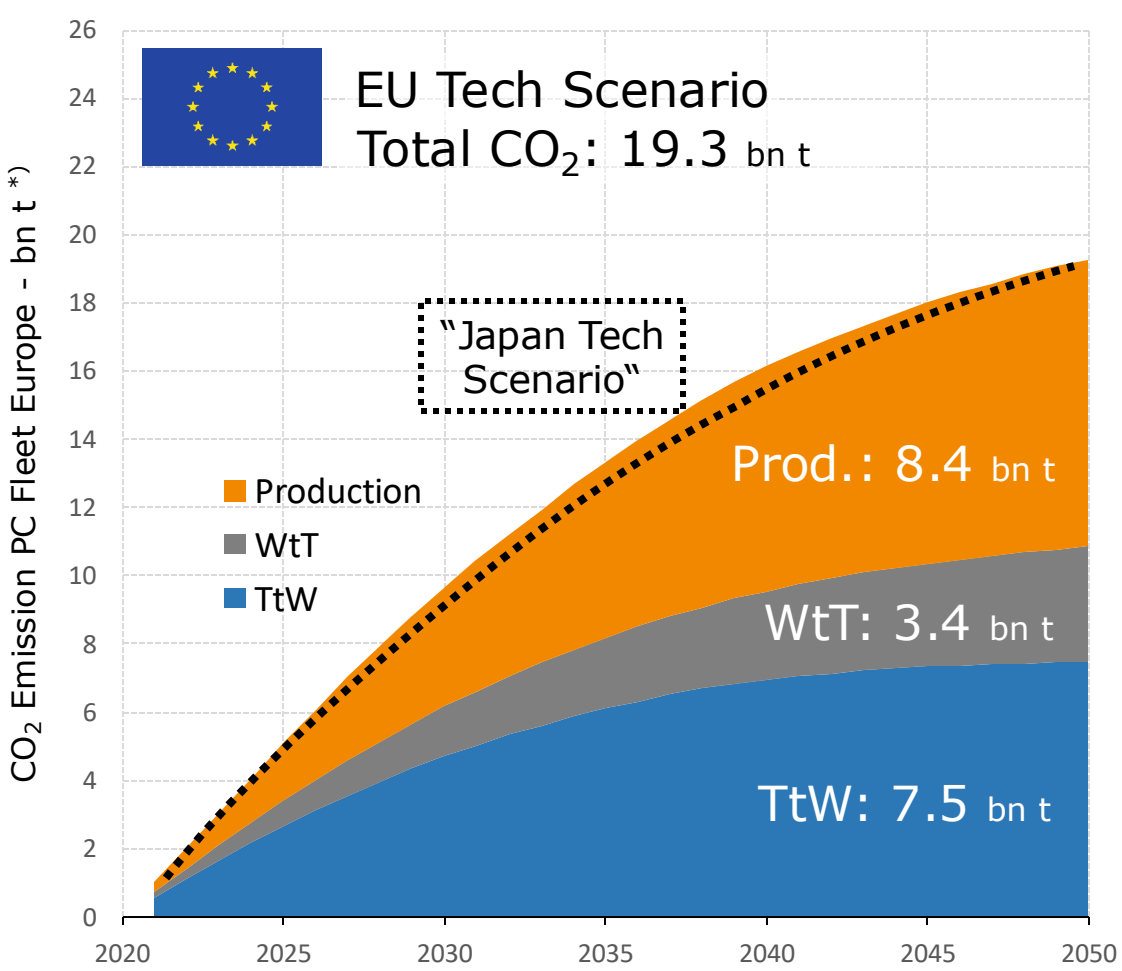


Technology openness

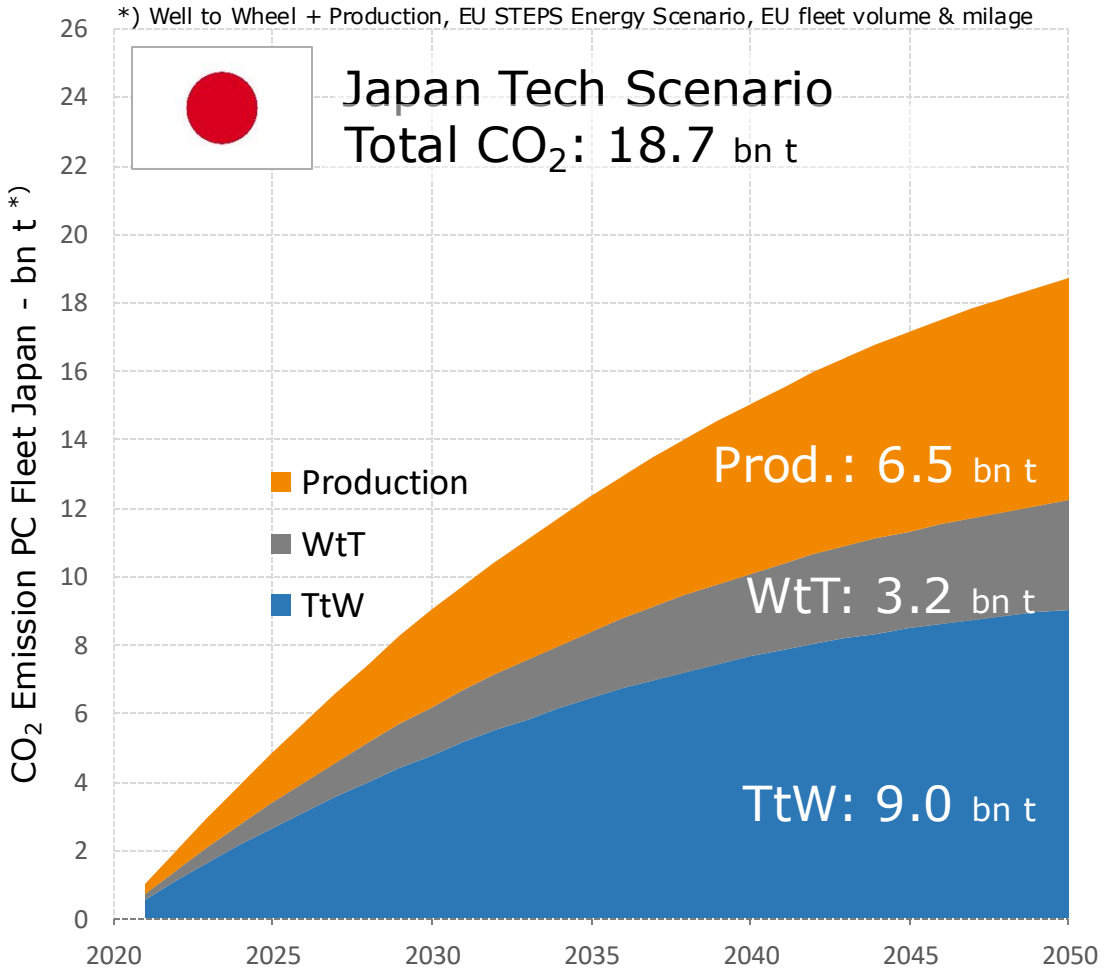
$CO_2$ legislation (“Tank-to-Wheel” or “Well-to-Wheel”) influences the solution set.

Source: AVL

# Cumulative total $CO_2$ emission*) of new registrations European passenger car in EU vs. Japan technology scenario



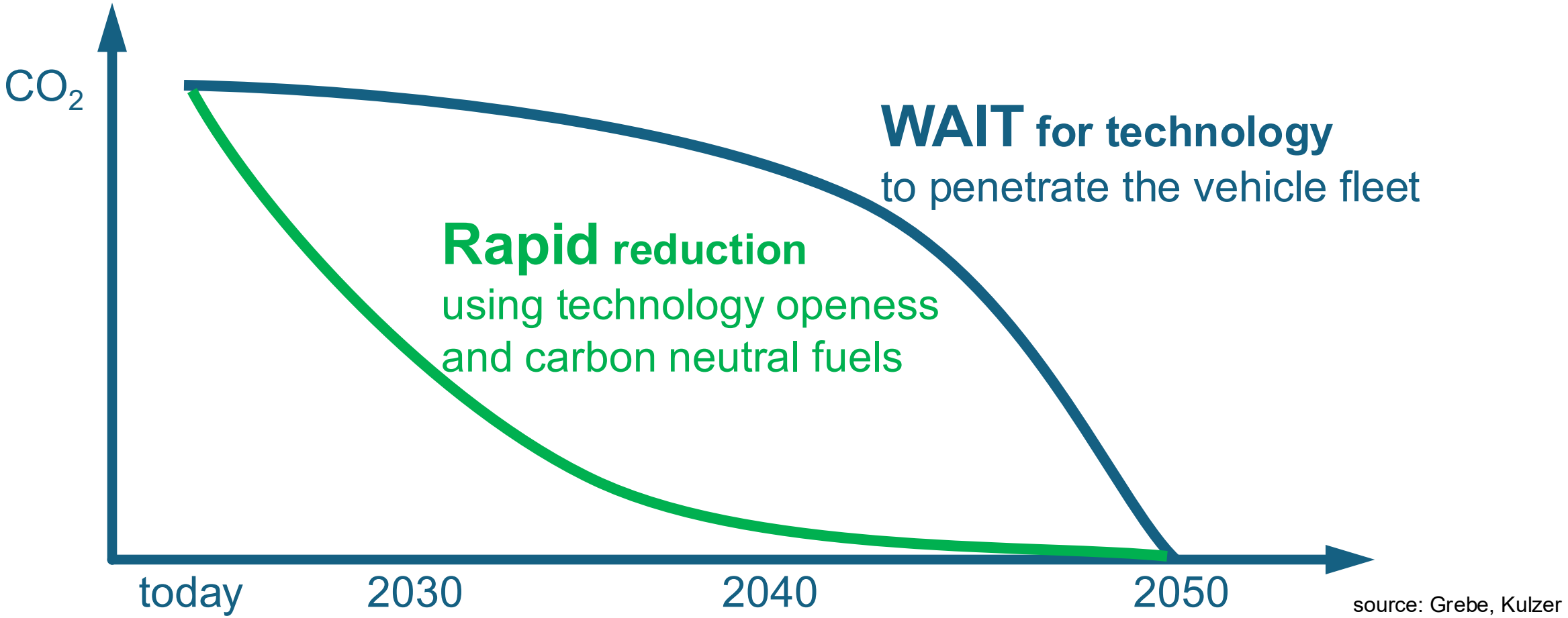

*) Well to Wheel + Production, EU STEPS Energy Scenario, EU fleet volume & milage




With "EU $CO_2$ footprint of the Energy Mix", a "Japan Tech Scenario" would offer similar total $CO_2$, however, at significantly lower cost.


„Wenn wir in Japan neun Millionen Elektroautos (BEVs) gebaut hätten, hätten sich die $CO_2$-Emissionen tatsächlich erhöht – nicht verringert.“
– Akio Toyoda

# Pathways to carbon-neutrality

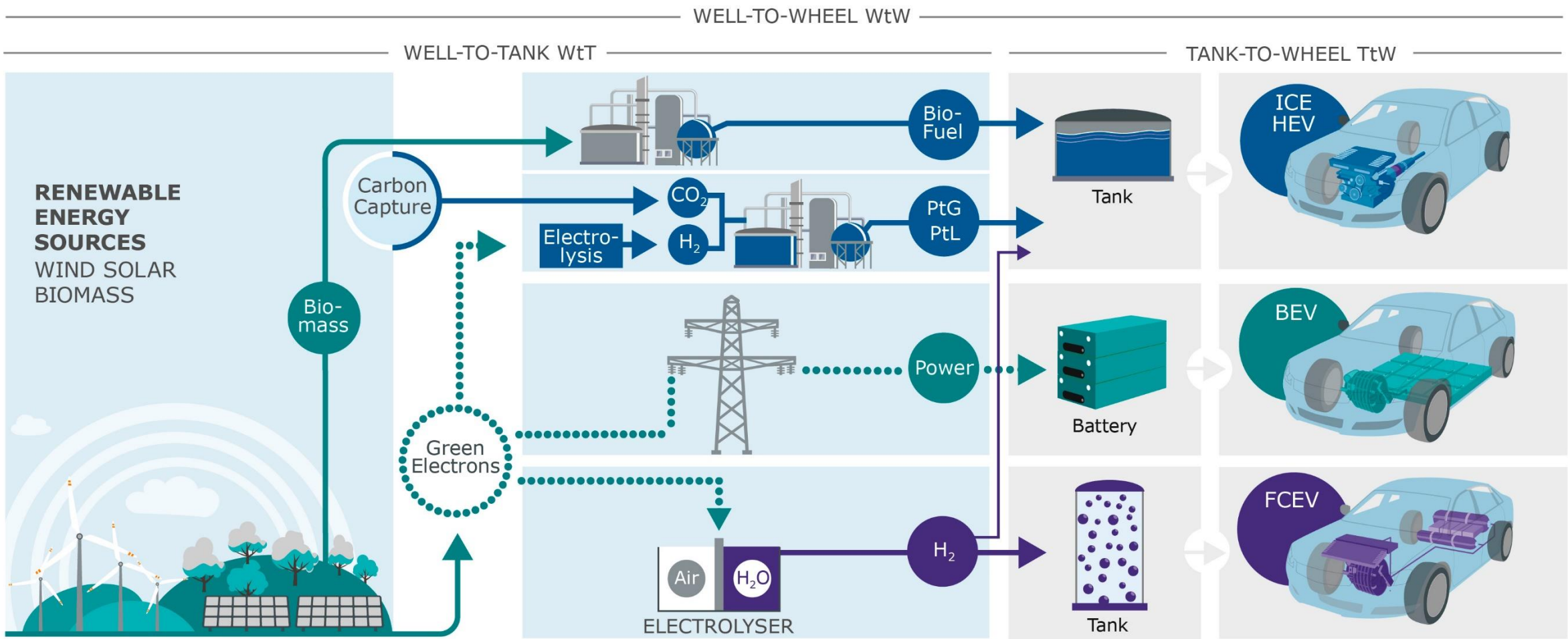



source: Grebe, Kulzer

A fast eFuel roll out offers the opportunity of immediate contribution to $CO_2$ reduction!

Reduce the
lifecycle $CO_2$ emission
of every newly
produced vehicle

# Pathways to clean and sustainable propulsion systems

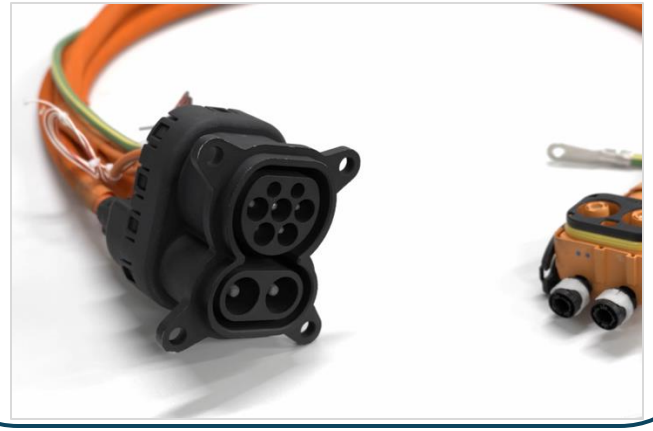



The energy source for automotive will be 100% green. All will involve electric motors, inverters and batteries!

Source: AVL

# Selection of research activities at IFA institute and ame GmbH

FFG Forschung wirkt. Megawattladen



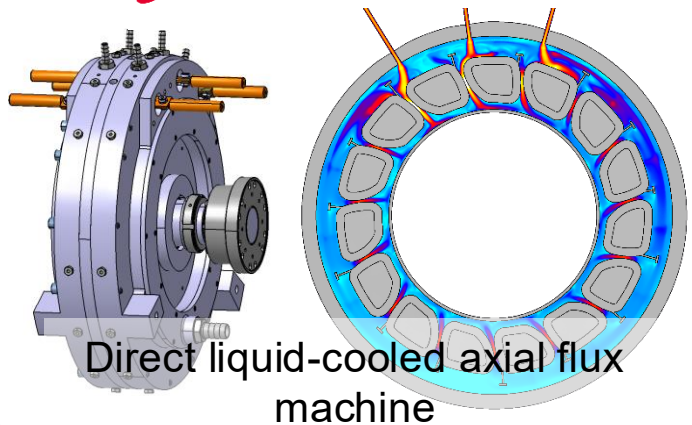
**Thermal management**
research activities for

- Performance increase
- Efficiency improvement
- Durability improvement
- Package improvement
- …

MINDED

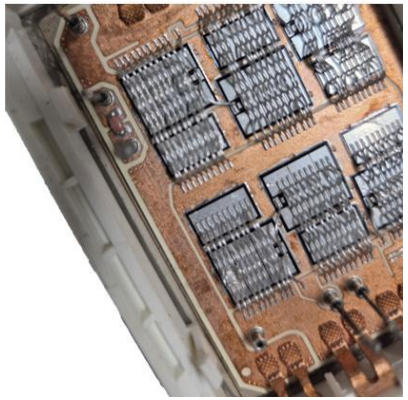
EV thermal management

FFG Forschung wirkt. CoolAFM



Direct liquid-cooled axial flux machine

Immersion-cooled inverter



# MINDED

MINDED

Funded by the European Union

- Development of **predictive thermal management** strategies for **cabin, powertrain** and **battery**

- **Measurements** on a climate-controlled 4-wheel chassis dynamometer

TU WIEN TECHNISCHE UNIVERSITÄT WIEN

IFA Institut für Fahrzeugantriebe & Automobiltechnik

Villinger research & development

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

RIMAC TECHNOLOGY

IVECO

Applus IDIADA

Garrett ADVANCING MOTION

TECHNISCHE UNIVERSITÄT DARMSTADT

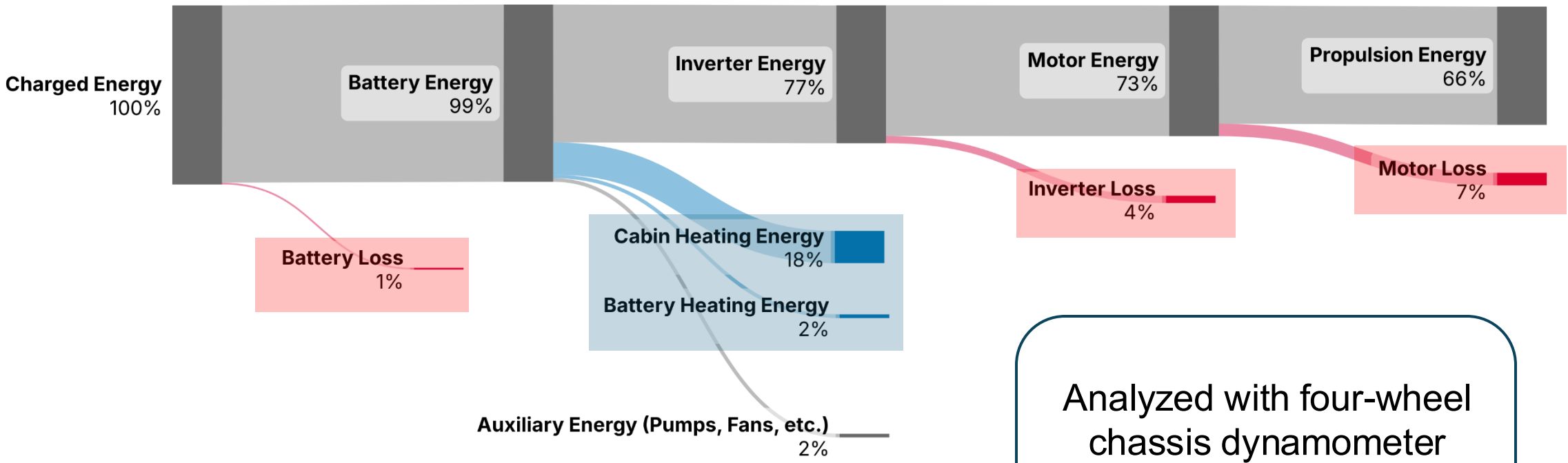
LEAD TECH Integrated Logistic Support

FSB University of Zagreb Faculty of Mechanical Engineering and Naval Architecture


Project goal: 20% range increase at 0°C ambient temperature for an electric minibus

ame

# Energy consumption of an electric minibus in WTLC test cycle




Analyzed with four-wheel chassis dynamometer

WLTC @ $T_{amb}$ = 0°C

Significant amount of energy (~20%) is consumed for cabin and battery heating

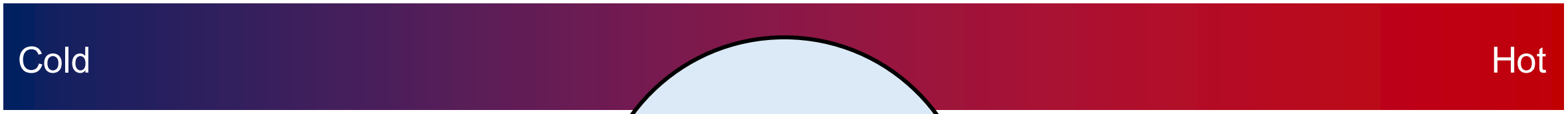
# Comparison of waste heat and required heat

Waste heat for const. speed driving @ 85 km/h

HV battery 0.6 kW

Inverter 1.5 kW

eMotor 3.3 kW




Required heat to maintain cabin temperature @ $T_{amb}$ = 0°C

Cabin heating 6.2 kW

Advanced thermal management system (*heat pump, coolant circuit architecture*) is necessary to match heat requirements to waste heat

# Measures for improvement

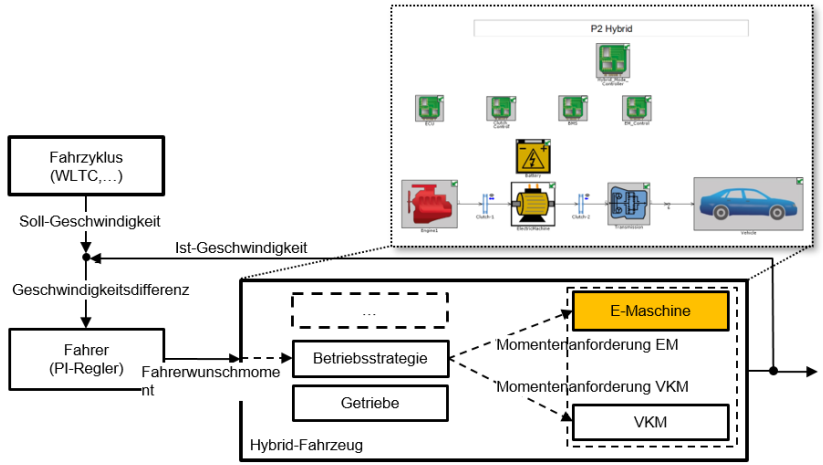
- Smart waste heat recirculation
- Heat pump
- Tailored passenger heating using infrared panels
- Predictive strategies for cabin, battery and powertrain thermal management
- Optimal heat rejection by **immersion cooling**

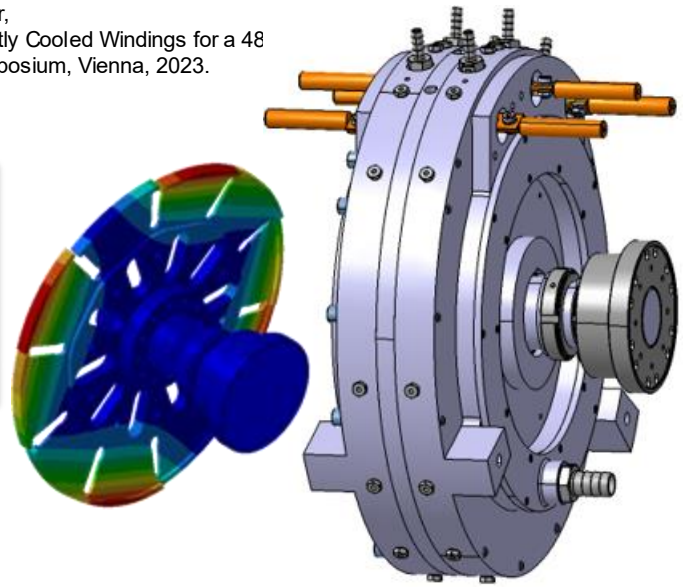
# Cooling concepts for axial-flux electric motor
## FFG project CoolAFM

- Development of an **axial-flux permanent magnet machine** with d**irectly cooled windings** for a 48V-Mild-Hybrid powertrain.

- Development, optimization and validation of an operating strategy with simulation models and test bench measurements.

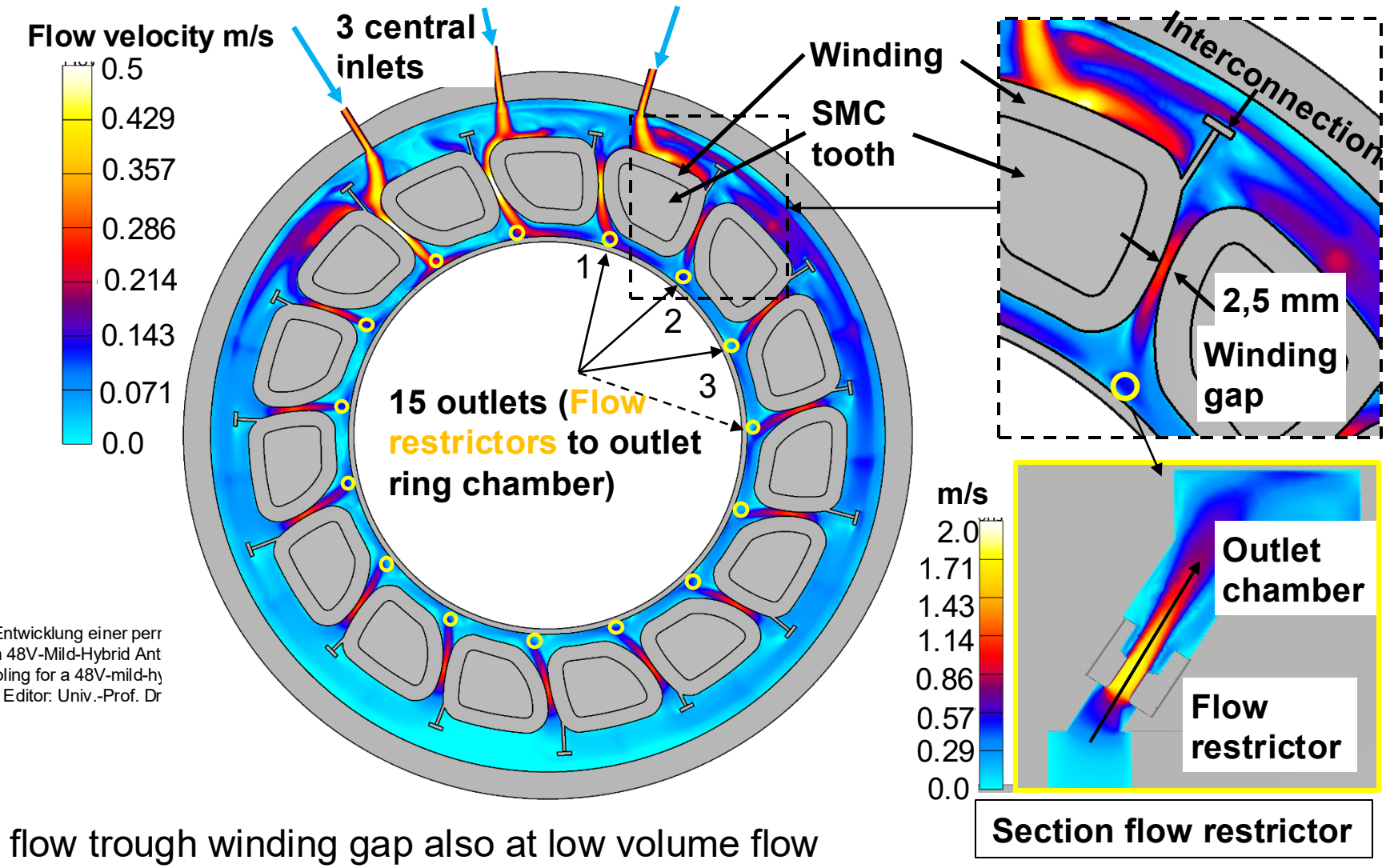
Publikation:
C. Schwella, P. Hofmann, R. Morawetz, D. Andessner and C. Sandner,
„Development of an Axial-Flux Permanent Magnet Machine with Directly Cooled Windings for a 48
in Conference Proceedings of the 44. International Vienna Motor Symposium, Vienna, 2023.



# Cooling concepts for axial-flux electric motor

- ☐ Example at 5 l/min
- ☐ Uniform flow through winding gap

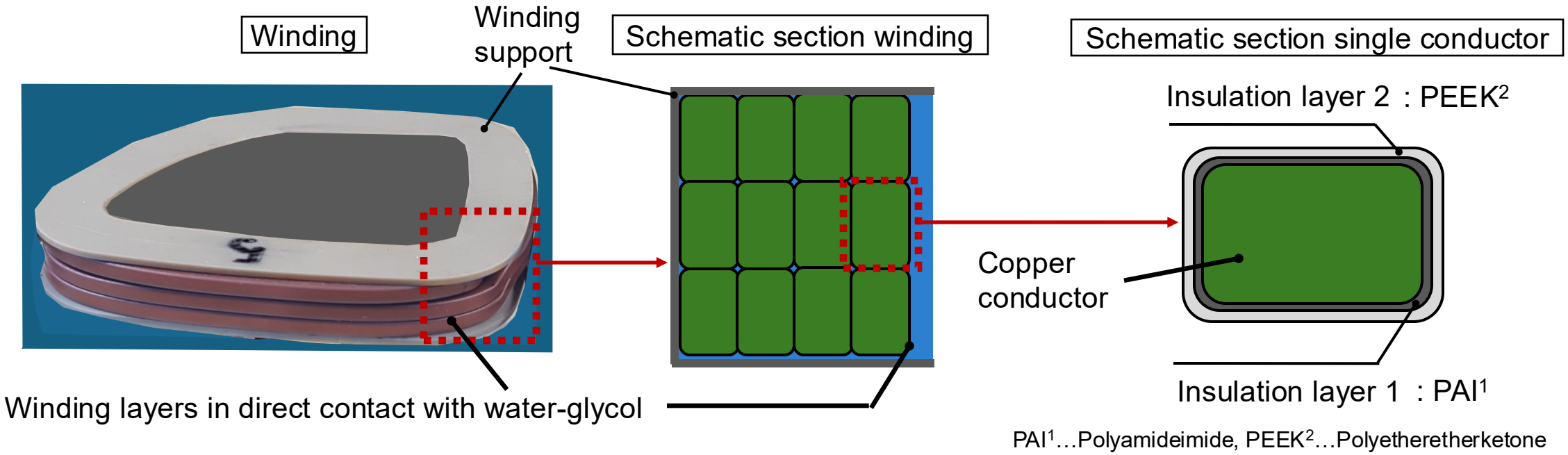



[Schwella, C.; Hofmann, P.; Andessner, D.; Sandner, C.: Entwicklung einer perr
Axialflussmaschine mit direkter Wicklungskühlung für einen 48V-Mild-Hybrid Ant
permanently excited axial flux motor with direct winding cooling for a 48V-mild-hy
International Vienna Motor Symposium. 26 - 28 April 2023. Editor: Univ.-Prof. Dr
3-9504969-2-5.]

➡ Homogenous flow trough winding gap also at low volume flow

# Winding for axial-flux electric motor

- Winding in direct contact with water-glycol
- Insulated wires aged for 90 days at 90 °C in a water-glycol immersion
- Electrical breakdown test (max. test voltage 2300 V) to evaluate their aging condition

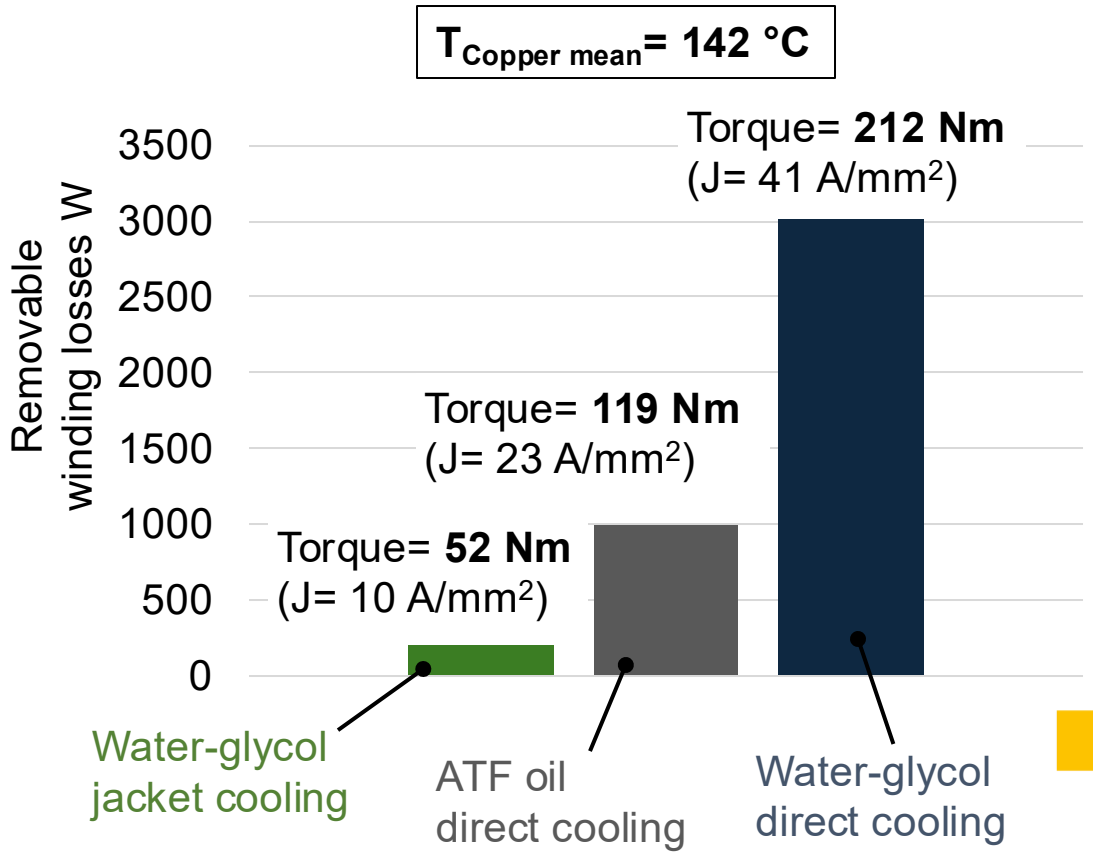


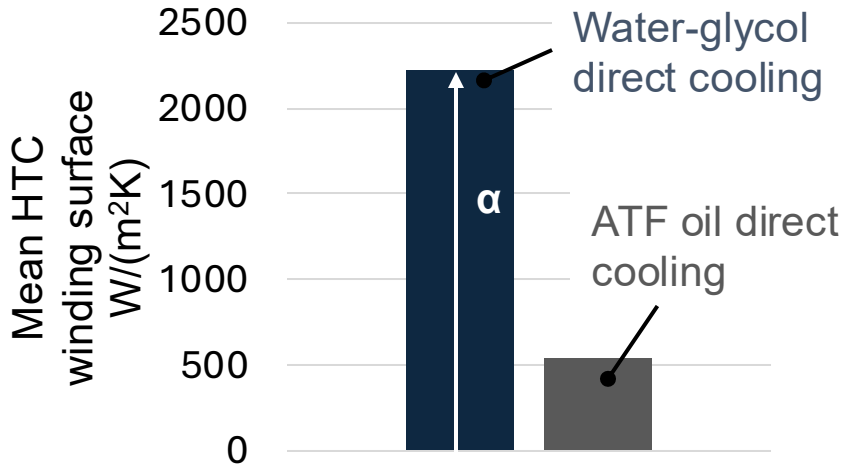

Resistant copper wire uses PEEK insulation with exeptional chemical resistance to glycol and excellent hydrolysis resistance

[Schwella, C.; Hofmann, P.; Andessner, D.; Sandner, C.: Entwicklung einer permanenterregten Axialflussmaschine mit direkter Wicklungskühlung für einen 48V-Mild-Hybrid Antriebsstrang. Development of a permanently excited axial flux motor with direct winding cooling for a 48V-mild-hybrid powertrain. 44th International Vienna Motor Symposium. 26 - 28 April 2023. Editor: Univ.-Prof. Dr. Bernhard Geringer ISBN: 978-3-9504969-2-5.]

# Cooling concepts for electric drives

- Fluid inlet temperature 90 °C, $\dot{V}$= 10 l/min
- Maximum heat flux at same temperature




Compared with ATF oil up to 3 times more heat loss can be dissipated and up to 15 times more in comparison with conventional jacket cooling

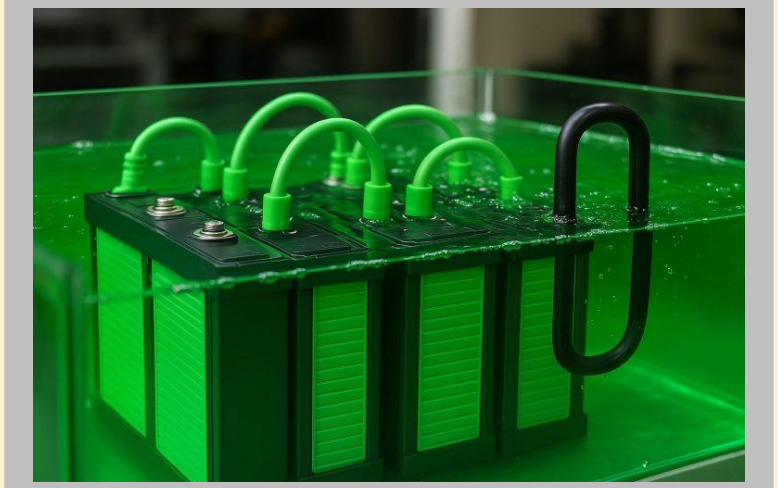
[Schwella, C.; Hofmann, P.; Andessner, D.; Sandner, C.: Entwicklung einer permanenterregten Axialflussmaschine mit direkter Wicklungskühlung für einen 48V-Mild-Hybrid Antriebsstrang. Development of a permanently excited axial flux motor with direct winding cooling for a 48V-mild-hybrid powertrain. 44th International Vienna Motor Symposium. 26 - 28 April 2023. Editor: Univ.-Prof. Dr. Bernhard Geringer ISBN: 978-3-9504969-2-5.]

# Current and developing fields for immersion cooling

**Immersion cooling: Components are submerged in dielectric coolant**

Data Center

Battery cooling



Immersion cooling is for **thermal management**

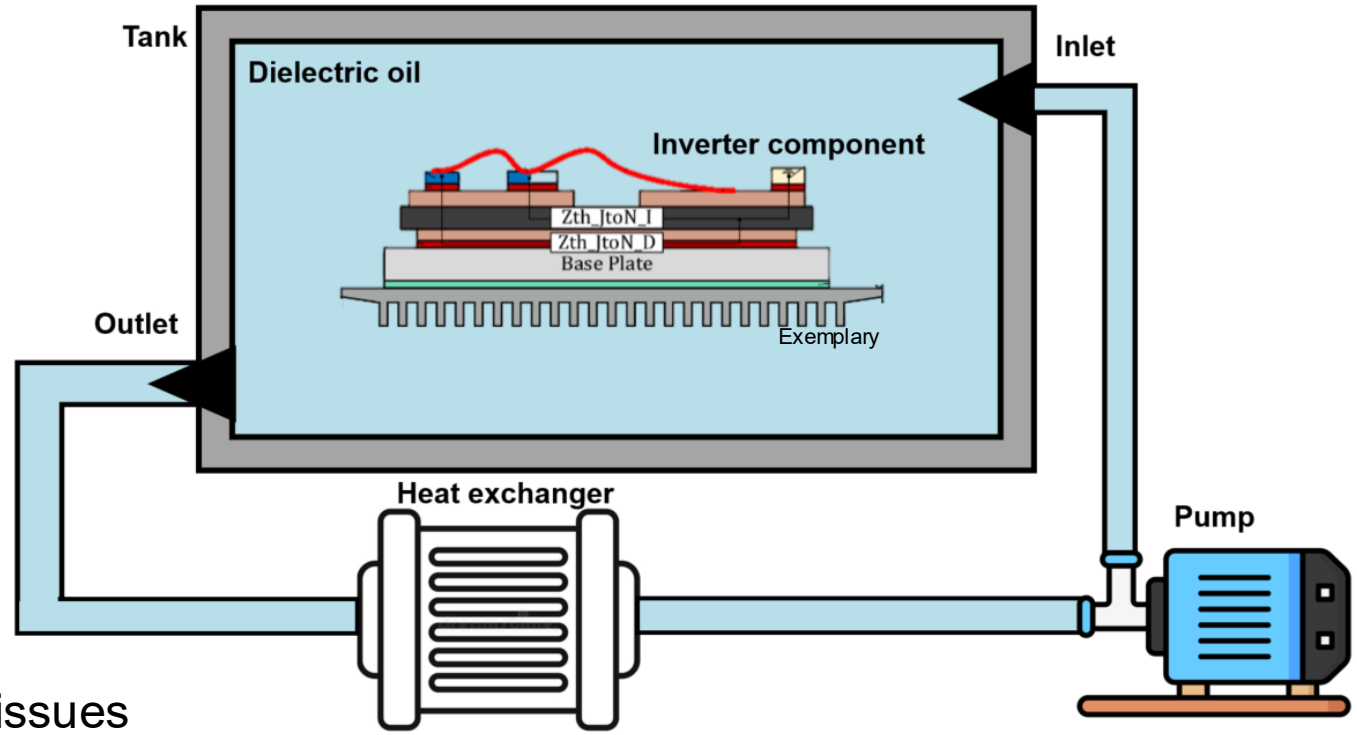
Developing fields: Immersion cooling for **Power electronics by EV**

Source: https://www.upsite.com/blog/immersion-cooling-the-good-the-bad-and-the-ugly/
Source: https://www.archimede-energia.com/en/immersion-cooling-lithium-battery/

# Immersion cooling in EV Inverter

**Advantage of immersion cooling**

- Lower thermal resistances
- More uniform temperatures
- Longer lifetime
- Compact design
- No corrosion / electrical conduction issues



# Immersion cooling in EV Inverter by IFA

**Our Current Research Focus**

- Fluid analysis (thermal properties)
- Flow / geometry optimization
- Digital electro-thermal modelling
- HiL system validation

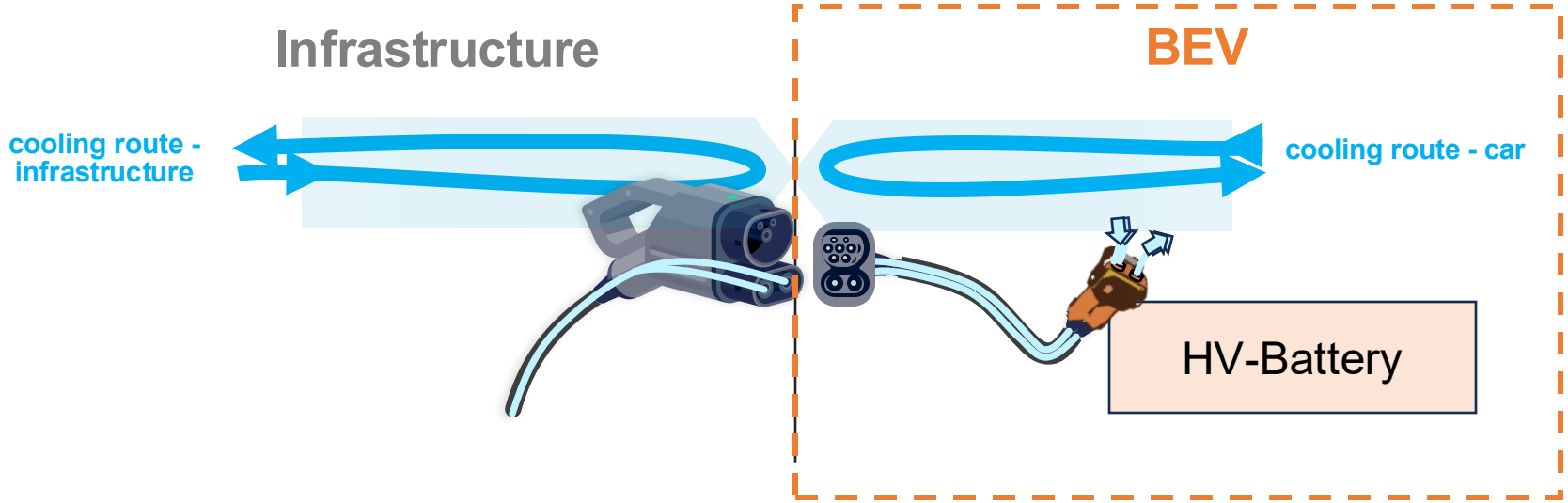
**Vision**

- Immersion cooling for: Next-gen EV inverter with higher power density & lifetime

# Megawatt-Charging

Liquid-cooled BEV Megawatt-Charging System:

- Charging duration below 5 minutes
- Reduction of HV-wire cross-section
- Smart utilization of waste heat

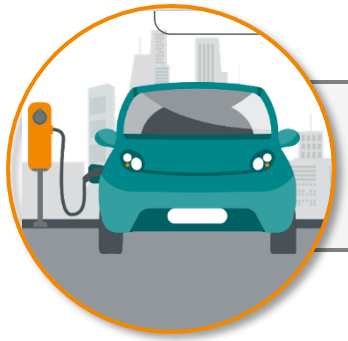



Gebauer & Griller

OEM
(Supporting Partner)

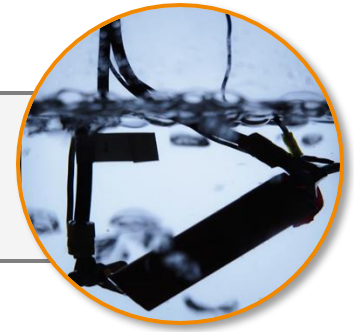
FFG
Forschung wirkt.

# Summary



**Driven by $CO_2$ emission regulations: E-Mobility is a given!**

**Thermomanagement is key for future improvements in performance, package, durability and efficiency/range**




**Technology Openness – improving $CO_2$ emissions in everything development step is crucial!**

# Thank you for your attention