# PEM – Science for E-Mobility Production

Chair of Production Engineering of E-Mobility Components (PEM)
of RWTH Aachen University

Introduction

Aachen

PEM | RWTH AACHEN UNIVERSITY

# Our origin
## Production Engineering is a major research area at RWTH Aachen University



**Production Engineering of E-Mobility Components** of **RWTH Aachen University**

| | |
|---|---|
| Founded in 2014 | Founded in 1870 |
| 107 full-time employees: 75 scientists, 32 non-scientists* | Highest third-party funds in Germany |
| 130+ student assistants* | One of 11 Universities of Excellence |
| New location at “Avantis European Science and Business Park” | 10.250 employees**, 47.269 students*** |
| 700 $m^2$ office space and 2.000 $m^2$ production space | 70+ institutes in Mechanical Engineering |

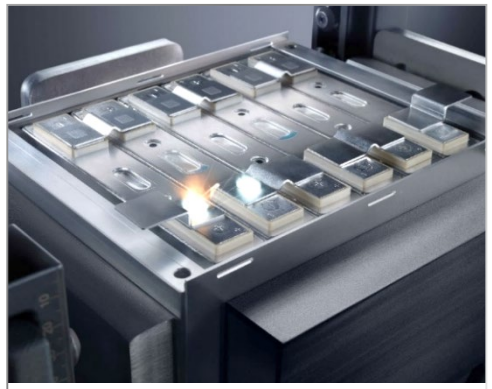
*as of September 2022; **official statistics from 2021; ***as of winter semester 2020/2021



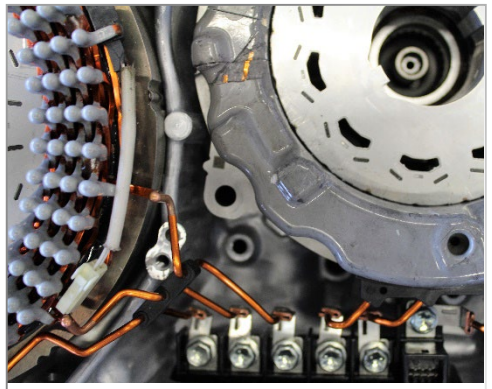
PEM | RWTH AACHEN UNIVERSITY

# Our core topics
## We offer product and production solutions for the electric drivetrain

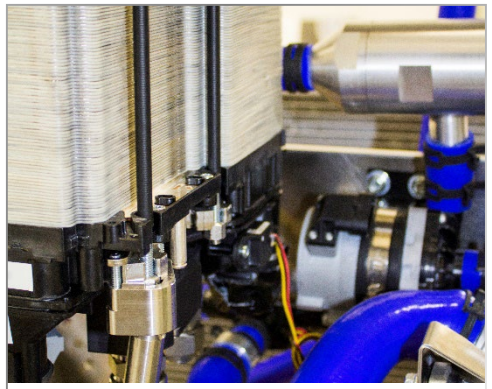
### Key components



**Battery**

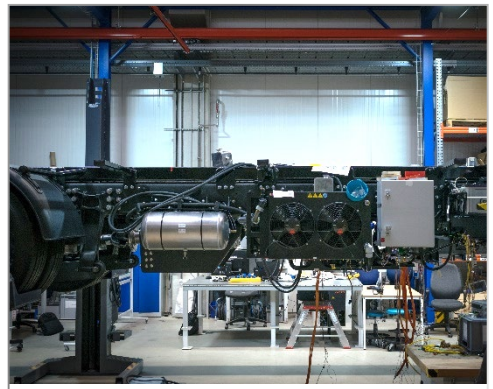


**Electric Drive**



**Fuel Cell**

### Integration



**Commercial Vehicles**

We develop pioneering **products** for sustainable manufacturing of electrified drivetrains

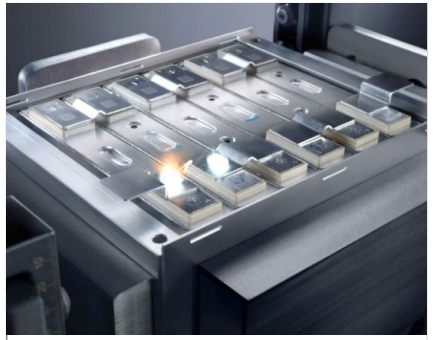
+

We focus on **production** processes and innovations for a cost-efficient realization of these products



PEM | RWTH AACHEN UNIVERSITY

# Our core topic “Battery”
# Energizing cost-efficient and sustainable battery electric drivetrains



**Battery**

Fluxlicon

BattNutzung SimBAS

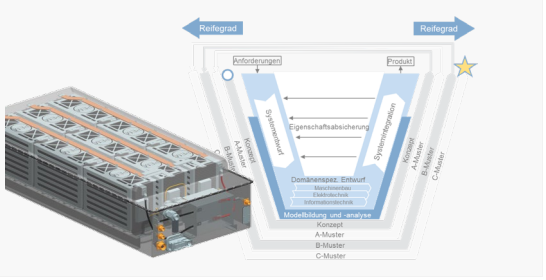
## Our long-term mission

Application-oriented research and development to **increase quality, performance, and sustainability** while **reducing costs** of battery cells, modules, and systems

## Our focus activities along the value chain contributing to reach the long-term mission

### Battery Components & Recycling

- Battery components supplier overview and benchmark analysis
- Material evaluation and battery components development
- Re-X, testing and disassembly of EoL batteries




### Battery Engineering & Safety

- Design for manufacturing of modules and battery systems (e.g. Cell-to-Pack)
- Cell design and requirement analysis
- Construction of battery system C-samples

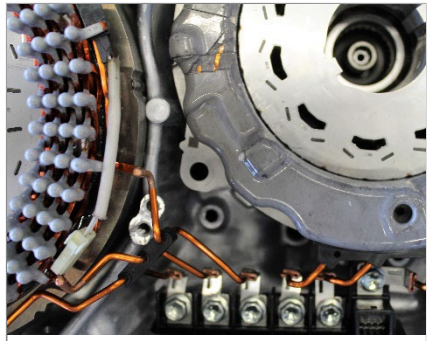
### Battery Production

- Methodological planning of battery cell, module and pack production lines
- Technology and cost analysis
- Safety & technical cleanliness concept development
- Battery cell prototyping



PEM | RWTH AACHEN UNIVERSITY

# Our core topic “Electric Drive”
## Helping shape the production of today’s electric drives



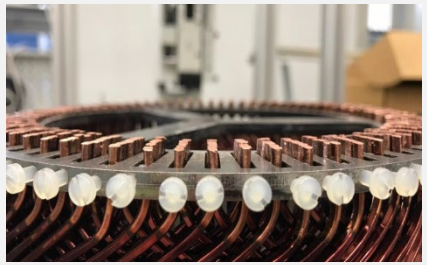
Electric Drive

HaPiPro²

### Our long-term mission

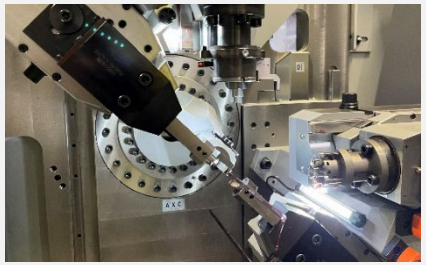
We are helping to make the production of electric drives **cost-efficient, flexible in terms of variants, future-oriented and sustainable**, and are **working on challenges along the entire value chain** – from the **semi-finished product** to the finished **e-drive** and from the **individual process** to the **holistic consideration** of interdependencies in the process chain.

### Our focus activities within the research group “Electric Drive Production”



**Prototyping of stators and rotors**

- Assembly of stators and rotors as functional prototypes in small batches
- Process development, implementation and testing in laboratory environment



**Feasibility studies & validation**

- Parameter development and test execution
- Comparison of individual components and processes with current products available on the market

**Production planning and optimization**

- Production (concept) planning and requirements management
- Process and layout planning
- Cost analysis and planning
- Value chain analysis

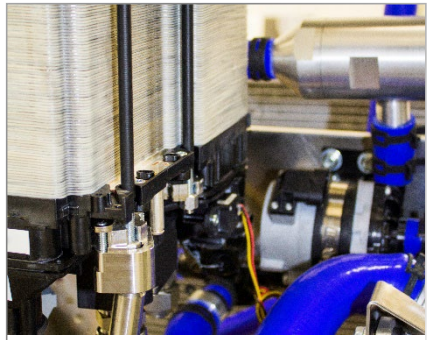
**Ramp-up support & root cause analysis**

- Supplier management
- Trouble shooting, root cause and interdependency analysis
- Coordination of plant modifications



PEM | RWTH AACHEN UNIVERSITY

# Our core topic “Fuel Cell”
## Dedicated to a constant optimization of fuel cell manufacturing



Fuel Cell

FCPP

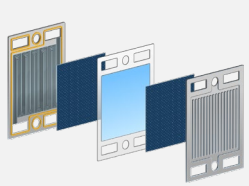
Zukunftscluster $H_2$ Wasserstoff

$H_2$Revier

### Our long-term mission

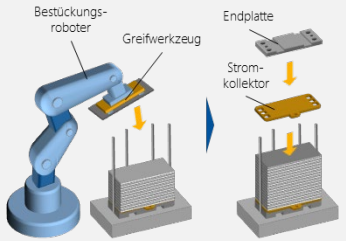
Enabling the production of fuel cells with **innovative technologies** in **large quantities** at **reduced cost**

### Our focus activities along the value chain contributing to reach the long-term mission



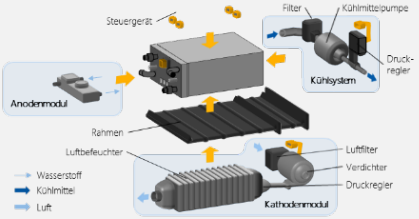
**I. Stack Component Production**

- Process innovations for MEA production
- Inline quality control



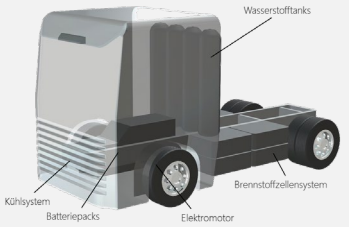

**II. Stack Assembly**

- Scalable stacking methods
- Incoming parts inspection
- Time-reduced conditioning




**III. System Assembly**

- Efficient assembly chains for Balance-of-Plant
- End-of-line testing of full systems



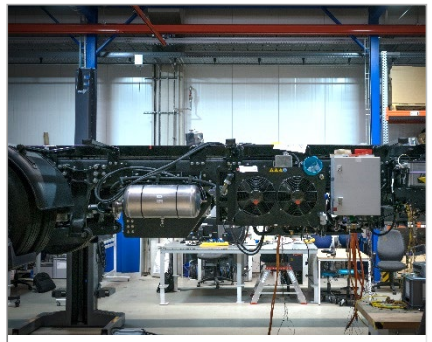

**IV. Vehicle Integration**

- Installation of the complete system in the vehicle drivetrain
- Initial operation of the vehicle with fuel cell



PEM | RWTH AACHEN UNIVERSITY

# Our core topic “Commercial Vehicles”
# Developing the modular drivetrain of the future



**Commercial Vehicles**

LiVe

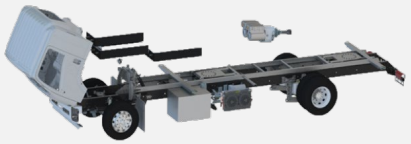
LiVePLuS

SeLv

## Our long-term mission

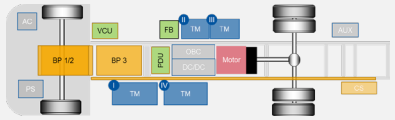
Innovative solutions in the field of **complete vehicle integration** of alternative drives and storages to enable TCO-optimized **modular-adaptable all-electric** and **hydrogen-based drivetrains** for **commercial vehicles**

## Our focus activities along the value chain contributing to reach the long-term mission



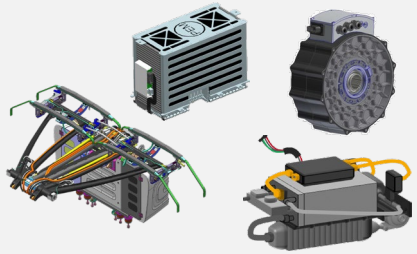
**Requirement Analysis & Vehicle Concept**

- Feasibility study
- Benchmarking
- Requirement management
- System architecture
- Homologation



**Drivetrain Design & Integration**

- Alternative drives
- Alternative storages
- Full vehicle thermal management
- Power electronics and auxiliaries



**Electrical Engineering & Power Management**

- Battery system
- Fuel cell system
- Pantograph system
- Electric drive system
- Control system and software


**Prototyping**

- Primotype
- Prototype
- Demonstrator
- Testing



PEM | RWTH AACHEN UNIVERSITY

# Science for e-mobility production in Aachen and Cologne
## Four locations complementing each other for an ideal environment

**Avantis *(main site)***

- Prototyping & full vehicle integration
- Machining & additive manufacturing
- Hydrogen infrastructure

**eLab**

- Joint project with 5 RWTH institutes
- Manufactory for battery components
- Testing & validation

**Rotter Bruch**

- Prototyping facilities
- Heavy duty drive-train integration
- Pantograph test bench

**HaPiPro² Area**

*Under construction*

- Prototyping facility for hairpin stators
- Welding, twisting, bending
- Impregnation, insulation

AACHEN

COLOGNE



PEM | RWTH AACHEN UNIVERSITY

# Our activities

## We are active in research, industry, and teaching along the value chain

The three disciplines our chair operates in are research projects, industry projects, and education.

### Industry

- Strategy development
- Technology consulting
- Production planning
- Ramp-up support
- Prototyping

### Research

- Production processes
- Machine equipment
- Materials
- Integration
- Demonstrators

### Education

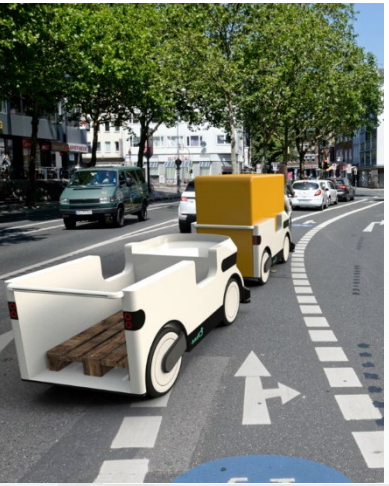
- Annual conference
- Industry seminars
- University lectures
- Publications

EPT ELEKTROMOBIL PRODUKTIONSTAGE



PEM | RWTH AACHEN UNIVERSITY

# Our value
## Transfer of innovation into demonstration and commercialization



### Demonstration in PEM ecosystem

PEM MOTION
OUCKTRAIN
velocity AACHEN
TRAILER DYNAMICS
AE ALTERNATIVE ENERGY DRIVEN SOLUTIONS
PRODUCTION|AC
FUTAVIS

### Innovation in academia

PEM | RWTH AACHEN UNIVERSITY

### Commercialization in industry

MARELLI
BENTELER makes it happen
Digatron power electronics
MARPOSS
GROB
KIEPE ELECTRIC
Stackpole International
GRUPO QUIMMCO
BST eltromat INTERNATIONAL
WPC WINKELMANN POWERTRAIN COMPONENTS
covestro
UNU
UK BATTERY INDUSTRIALISATION CENTRE
LILIUM
berylls
Ford
WAFIOS
VOLVO
BMW
wieland



PEM | RWTH AACHEN UNIVERSITY

# Our value
## Technology push of future products today

### Professionalization in development

PEM MOTION

TRL 1 2 3 4 5 6 7 8 9

### Innovations from science

PEM | RWTH AACHEN UNIVERSITY

TRL 1 2 3 4 5 6 7 8 9

### Demonstration in the PEM ecosystem

FUTAVIS · DUCKTRAIN · TRAILER DYNAMICS · PRODUCTION|AC · INGENIEURE RETTEN DIE ERDE · velocity AACHEN · AE ALTERNATIVE ENERGY DRIVEN SOLUTIONS

TRL 1 2 3 4 5 6 7 8 9

### Commercialization in the industry

UK BATTERY INDUSTRIALISATION CENTRE · Ford · covestro · Digatron power electronics · MARELLI · VOLVO · LILIUM · beryls · WAFIOS · BMW · KIEPE ELECTRIC · BENTELER makes it happen · wieland · UNU

TRL 1 2 3 4 5 6 7 8 9

In the PEM network, the mobility system of the future is already being developed and tested today.

*Legend: Typical activity level*

high | medium | low



PEM | RWTH AACHEN UNIVERSITY

# Our history
## RWTH Aachen University is a place of innovation with rapid growth and various spin-offs

RWTH Aachen University

Start of Achim Kampker at WZL of RWTH Aachen University

Total volume > €50 million in electric mobility

Foundation of the chair PEM RWTH Aachen University

Electric mobility laboratory (eLab)

Production Engineering Cluster

Presentation of the e-truck prototype "LiVe"

Research Institution for Battery Cell Production (FFB) Münster

New PEM main site at Avantis European Science and Business Park

E-truck hall Rotter Bruch

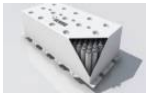
100+ employees *

Opening of 4th location in Cologne (HaPiPro²)

2009 | 2013 | 2014 | 2015 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023+

Spin-offs

StreetScooter GmbH



Futavis GmbH

PEM Aachen GmbH & PEM Mexico

Innovations-park Deutsche Post

5P Capital GmbH

PEM Motion GmbH

battery-news.de

Velocity Mobility GmbH

TÜV Rheinland ACT

Gigabatt

Velocity Aachen GmbH

DroidDrive GmbH

AE Driven Solutions GmbH

Trailer Dynamics GmbH