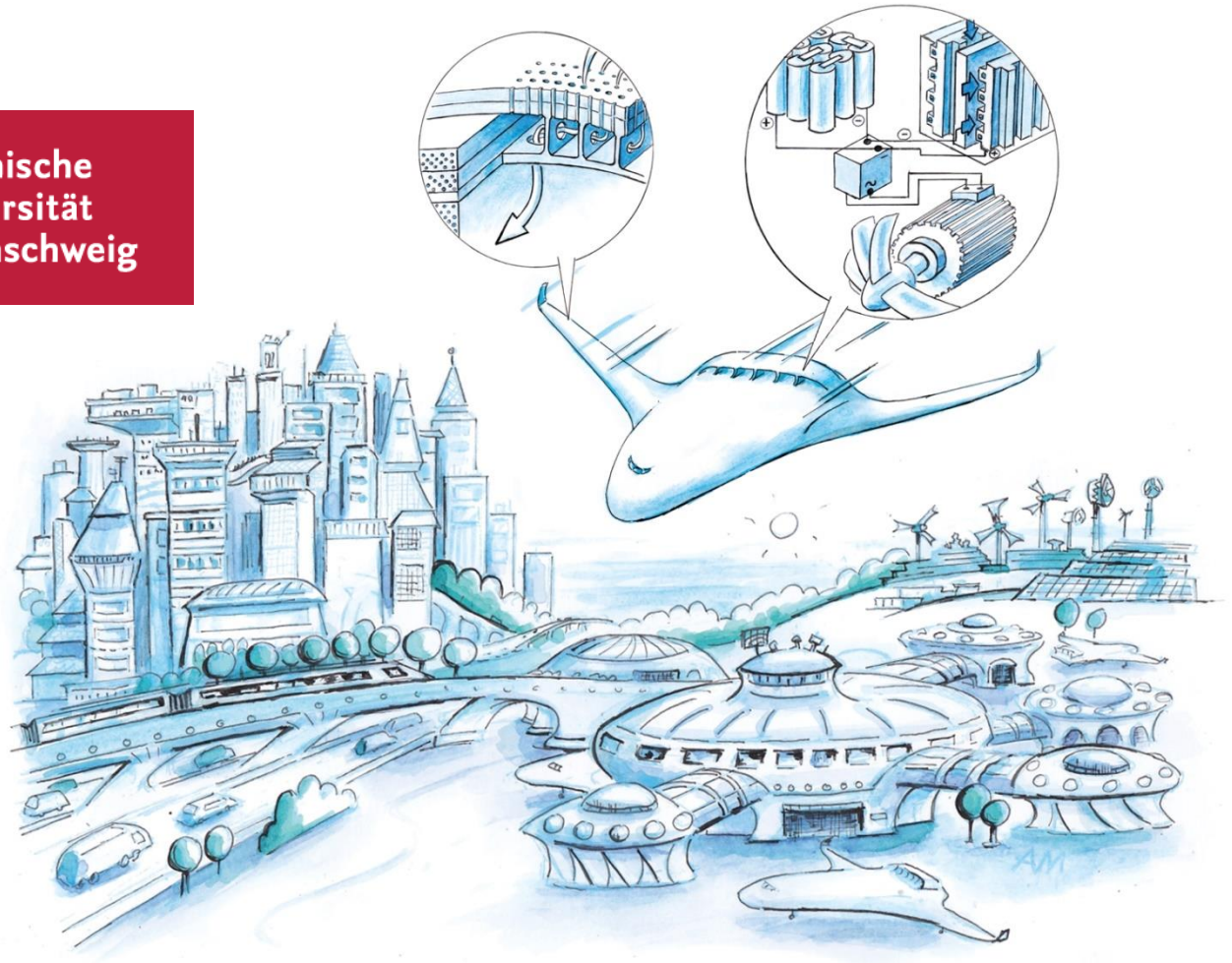
Technische Universität Braunschweig



Bausteine für die Energiewende in der Luftfahrt

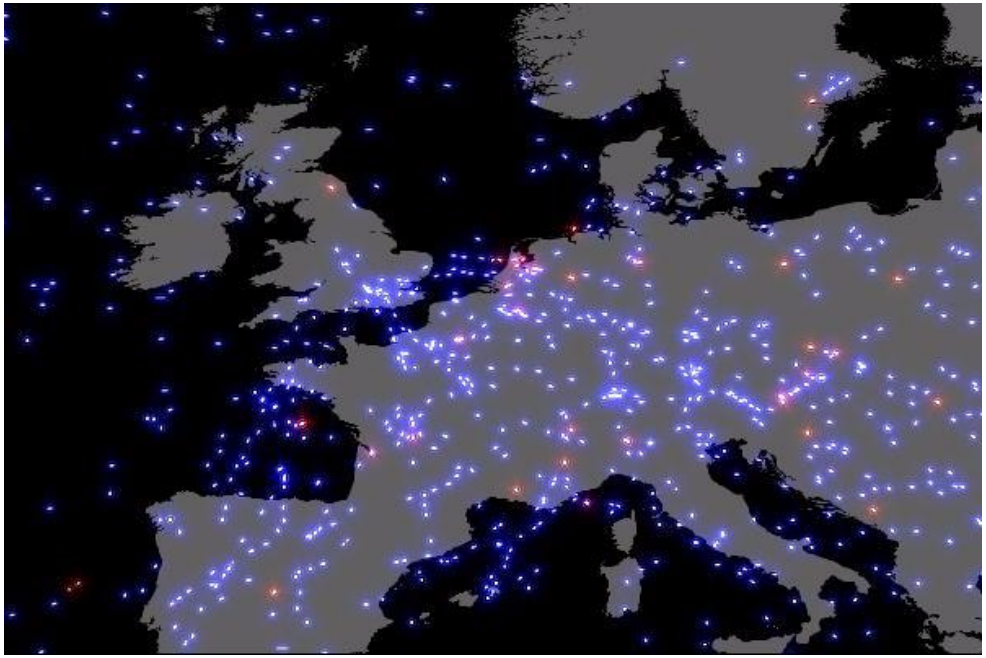
Prof. Dr.-Ing. Ulrike Krewer

11. Niedersächsische Energietage | 20. November 2018

Challenges
Sustainable Air Transport in a Disruptive Environment

Global mobility – mega trend and mega challenge

- 4.1 billion passengers in 2017
- Volume **doubles every 15 years**
- **Sustainable** capacity **growth**
- **Competing requirements**:
  → Travel time and inter-connectivity
  → Individuality
  → Safety
  → Regulatory constraints



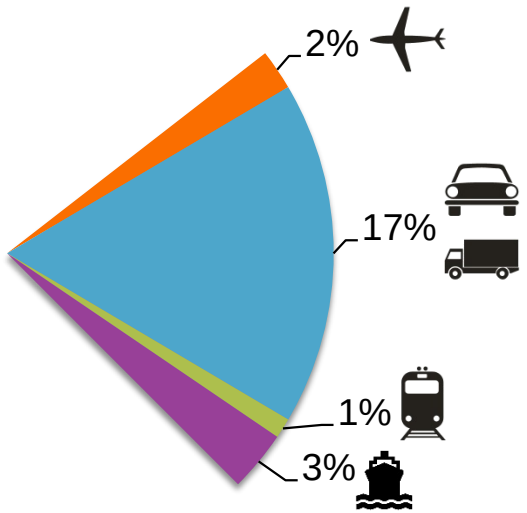
Commercial air traffic over Europe during a day

New approaches required to build sustainable system

Challenges
Sustainable Air Transport in a Disruptive Environment

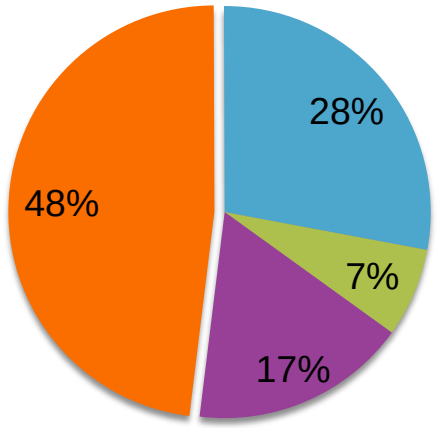
Carbon footprint and climate impact - today

- Global transport produces approx. 23% CO_2
- Small percentage from aviation
- But considerable impact on climate change



Scenario 2050

- Assuming a zero emission stationary sector
- 75% of road transport zero emission
- Parallel growth of other sectors

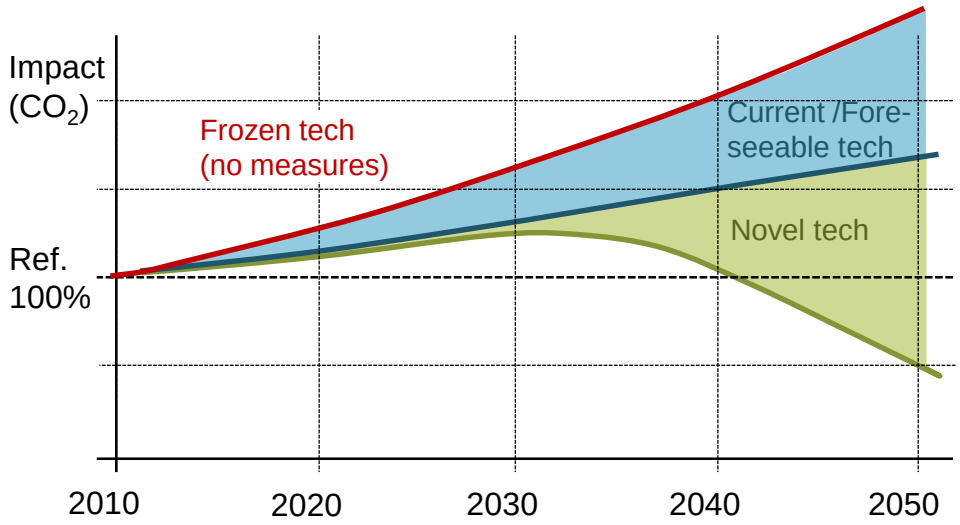


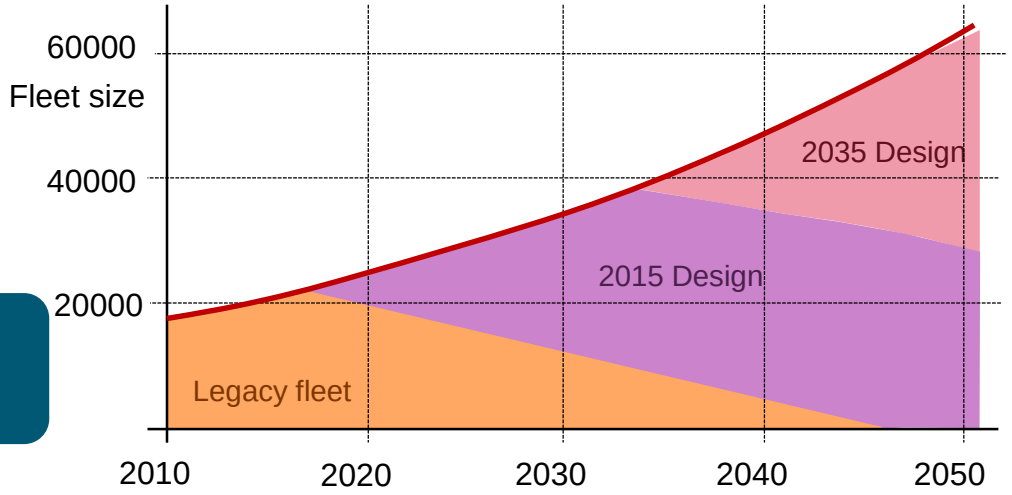
Aviation becomes **major CO_2 source**

Challenges
Sustainable Air Transport in a Disruptive Environment

Sustainable aviation life-cycle design

- Current and foreseeable technology will not reduce the total impact
- Novel technology required
- Average aircraft technology life-cycle increased to > 40 years
- Current (2015) design dominates fleet until 2050

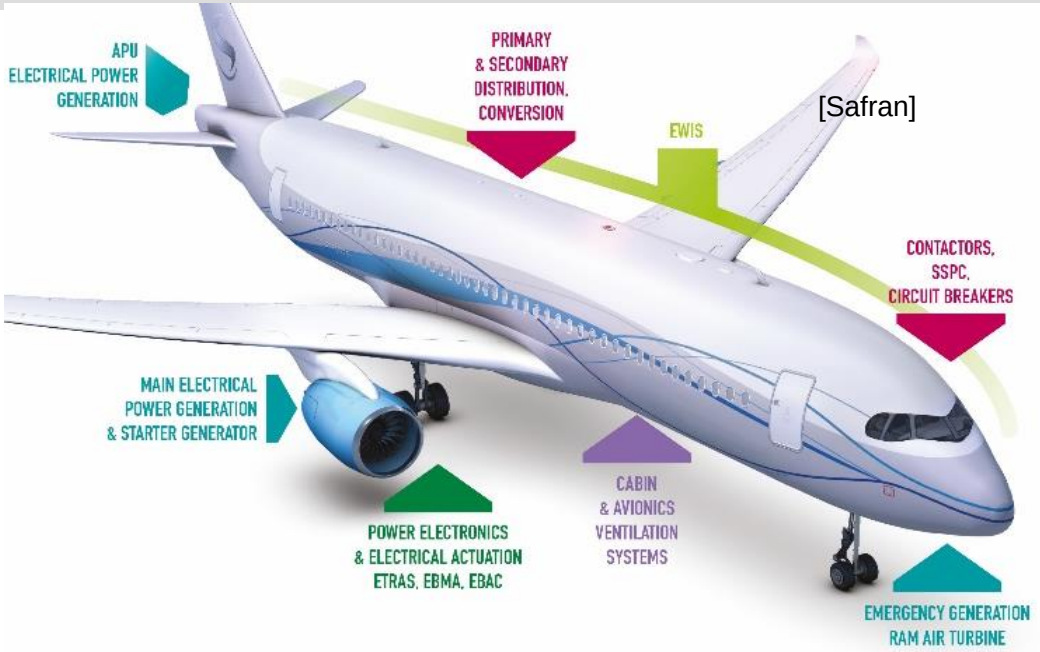




Both, foreseeable AND novel technology required urgently!

From current to novel approaches!

- International initiatives target current and foreseeable technologies
- “More electric aircraft” focuses on non-propulsive systems; few all electric concepts
- Novel approaches **require complete and integrative rethinking of**
  - Air transport system
  - Aircraft
  - Energy supply/management



[Safran]

2050

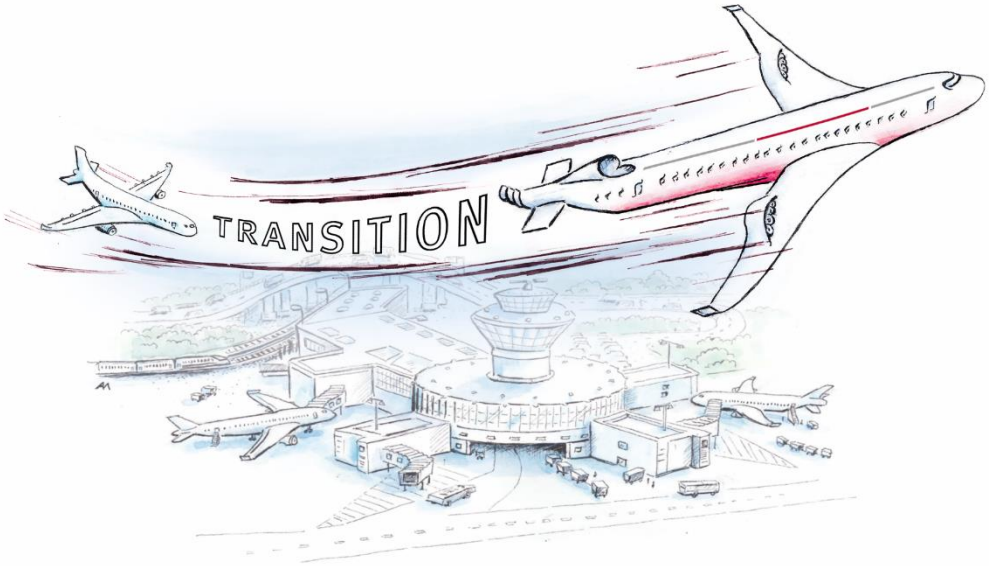
Interdisciplinary effort required with researchers of all 3 areas! Huge!

?

Lower Saxony Initiatives at the Forefront of Novel Technologies

Program
„Spitzenforschung in Niedersachsen“

Energy Transformation in Aviation
9/2016-1/2019



Program
„DFG Cluster of Excellence“

Sustainable and energy efficient aviation
1/2019, 7 years

All Required Competences Present in Lower Saxony

TU Braunschweig, LU Hanover and Braunschweig Univ. of Art

Economics & Social Sciences

TU BS / LUH / HBK

Multi-criteria evaluation
Scenario analysis
Operations research
Life-Cycle assessment
System dynamics
Mathematical optimisation
Total cost of ownership

Aeronautical Sciences

TU BS / DLR / LUH

Aerodynamics
Aeroacoustics
Aero engines
Aircraft structures
Aircraft systems
Air traffic management
Flight experiments

Energy Sciences

LUH / TU BS / PTB

Battery design and prod.
Electrosynthesis
Fuel cell
Combustion
Turbomachinery
Electrical energy conversion
Hybrid structures

Joining the Competencies of Three Partners

Successful long cooperation practised in joint research facilities

Economics & Social Sciences	Aeronautical Sciences	Energy Sciences
TU BS / LUH / HBK	TU BS / DLR / LUH	LUH / TU BS / PTB

NFL - Aeronautics Research Centre of Niedersachsen
(since 2009)

NFF - Automotive Research Centre of Niedersachsen
(since 2007)

BLB - Battery LabFactory Braunschweig
(since 2008)

OHLF - Research Factory for Lightweight Construction
(since 2013)

How it all startet:
Project Energy Transformation in Aviation

- **Goal: Preliminary technology assessment**

- Funded by MWK Niedersachsen
  September 2016 – January 2019

- **Core Team:**

  - 10 institutes of TU Braunschweig, LU Hannover, HBK

  - 5 Postdocs and 6 doctoral researchers

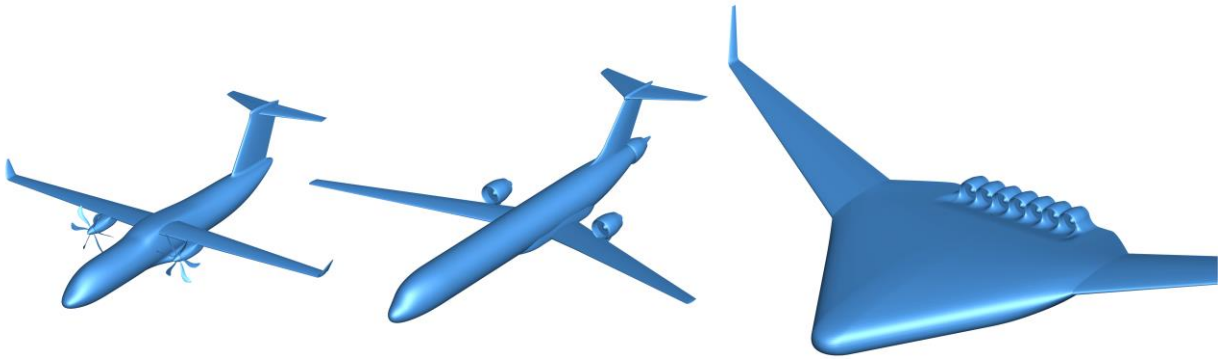
- Huge success in joint research:

  - 16 collaborative publications

  - Energies Special Issue
    "Towards a Transformation to Sustainable Aviation Systems“[1]

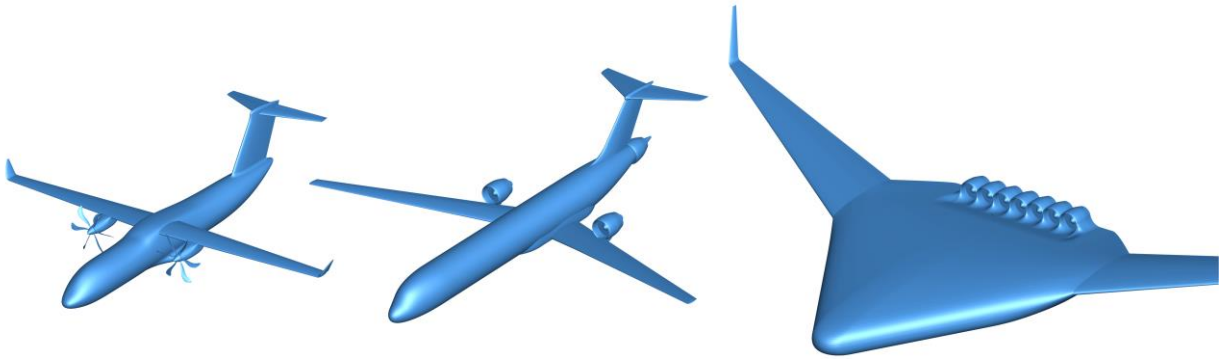
[1] https://www.mdpi.com/si/12555

Results in a Nut Shell:
One size does NOT fit all



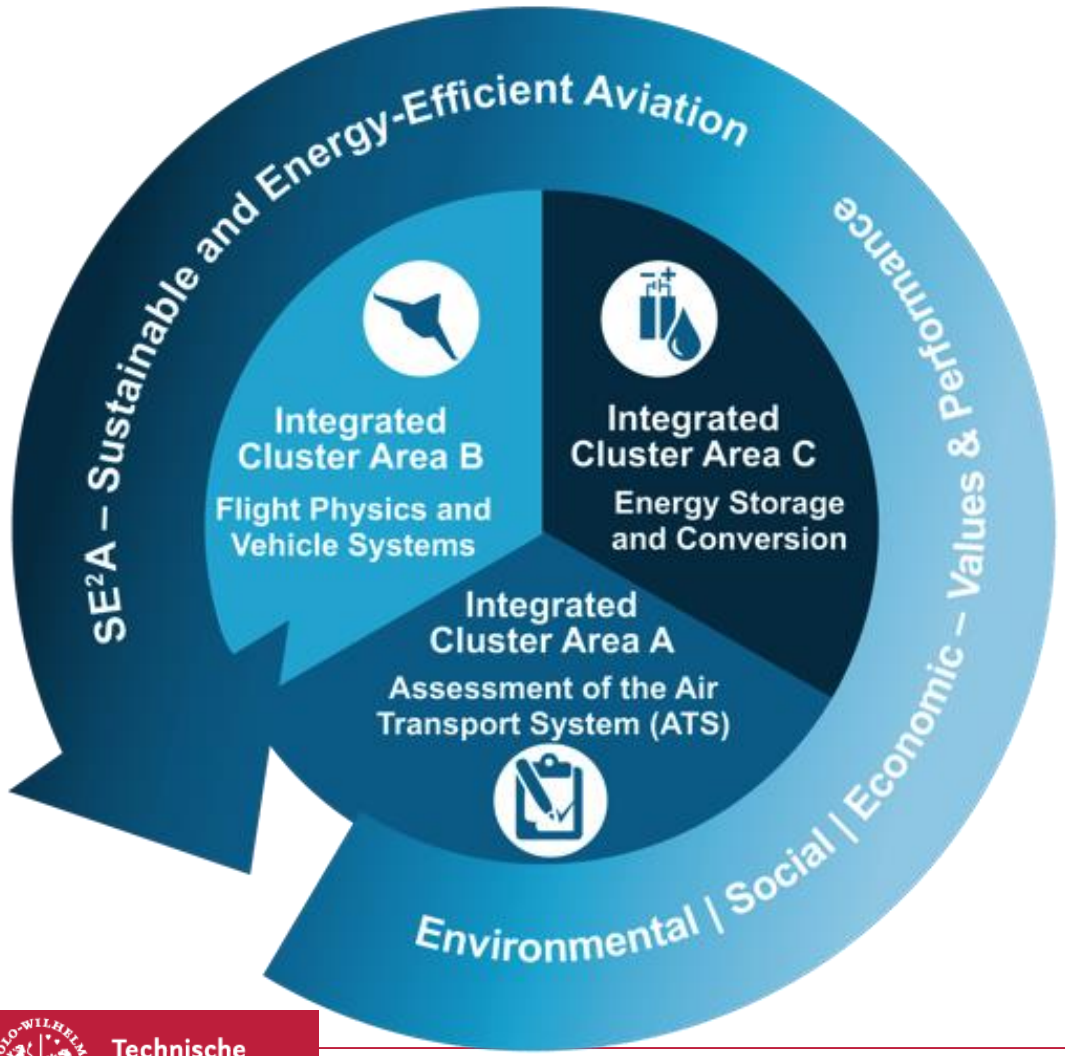
	Regional / Short-Range	Medium-Range	Long-Range
Configuration	Fuselage Tube & Wing	Fuselage Tube & Wing	Blended Wing Body
Passengers	100	150 - 200	300 - 400
Propulsor Integration		Integrated / boundary layer ingestion	
Required max. shaft power	8 MW	16 MW	44 MW

Results in a Nut Shell:
One size does NOT fit all



	Regional / Short-Range	Medium-Range	Long-Range
Configuration	Fuselage Tube & Wing	Fuselage Tube & Wing	Blended Wing Body
Passengers	100	150 - 200	300 - 400
Propulsor Integration		Integrated / boundary layer ingestion	
Energy Conversion	**Electric motor**	**Advanced gas turbine and electric machine**	**Fuel cell and electric machine**
Required max. shaft power	8 MW	16 MW	44 MW
Energy Storage	**Battery**	**Electrofuel: Hydrocarbons and battery**	**Electrofuel: LH_2**

The next 7 years: SE²A
Research within the Excellence Cluster



- **Goal: Detailed technology analysis and development**
- Funded by DFG
  January 2019 – December 2025
- **Team:**
  - >25 institutes of TU Braunschweig, LU Hannover, HBK + DLR
  - >30 new PhD students/postdocs

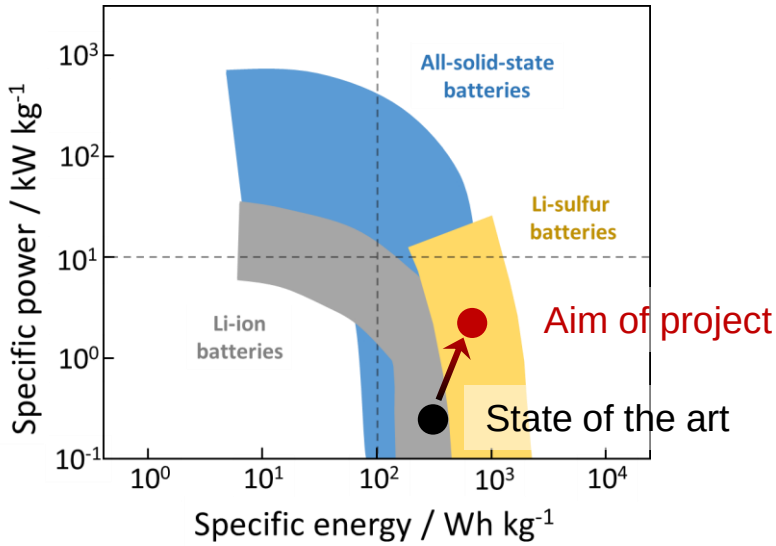
SE²A- Key Research Topics

Advanced Electrical Energy Storage for Short-Range Aircraft

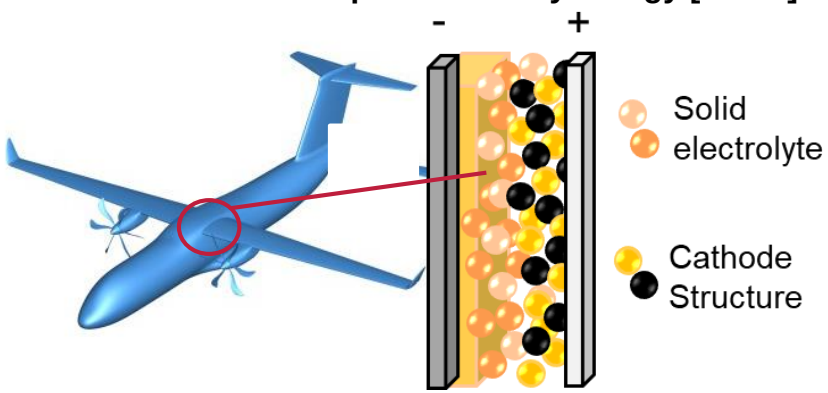
Scientific challenges

- Unleash the **high theoretical specific energy and power** of Next generation Li batteries
- Long **life time**
- Efficient pilot-scale production
- Load-carrying battery design for aircraft structure integration

Best candidate:
Li-S all-solid-state battery



Potential of specific battery energy [Kat16]

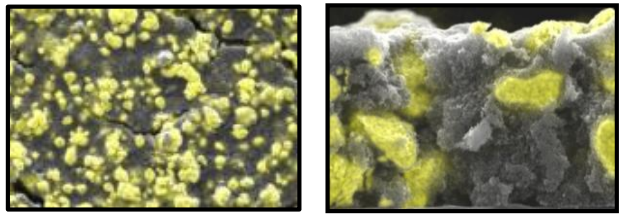


Li-Sulfur all-solid-state battery for aviation

SE²A - Key Research Topics
Advanced Electrical Energy Storage

Specific preliminary work

- First lab-scale Li-Sulfur all-solid-state cells built in joint project with 800 Wh/kg
- **Sufficient energy and power for powering short range aircraft** predicted
- **Predicted 10% weight advantages** by integration of batteries into structures



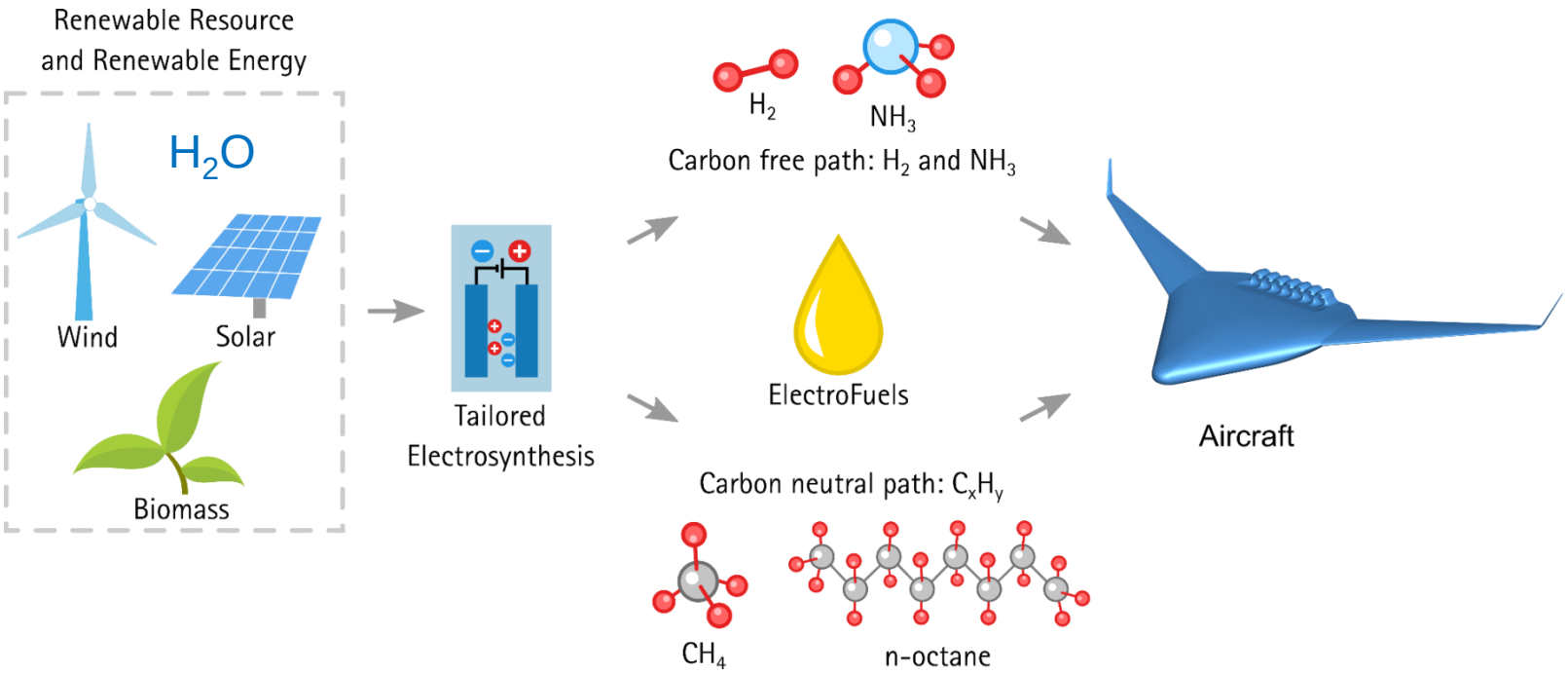
SEM images of sulphur and carbon [Kwa18]

Process chain of the Battery LabFactory Braunschweig (BLB)

SE²A- Key Research Topics
Sustainable Electrofuel for Medium/Long Range

Scientific Challenges

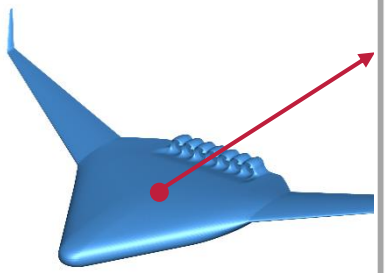
- Large scale production of CO_2 neutral, high specific energy fuel from renewables
- New pathways that allow to use abundant electricity: Electrofuels

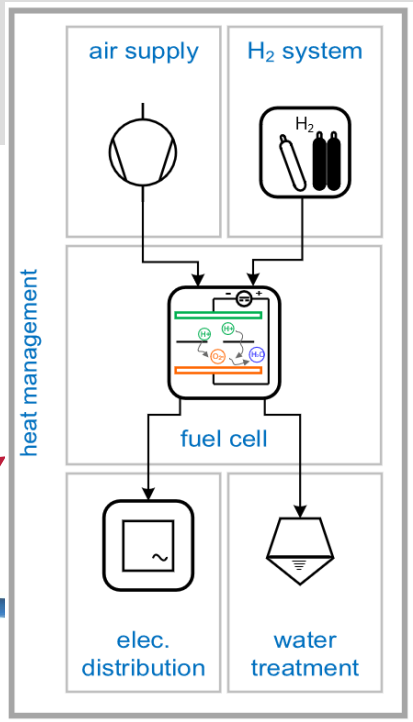


SE²A - Key Research Topics
Advanced Energy Conversion for Long Range

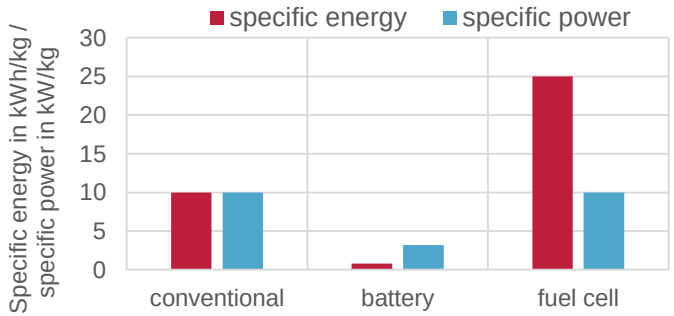
Scientific challenges

- Fuel cell systems with **high specific energy and specific power**
- Address **aviation-specific requirements**
- **Integration** into and synergy with aircraft





Fuel cell systems for aviation



Comparison of energy sources

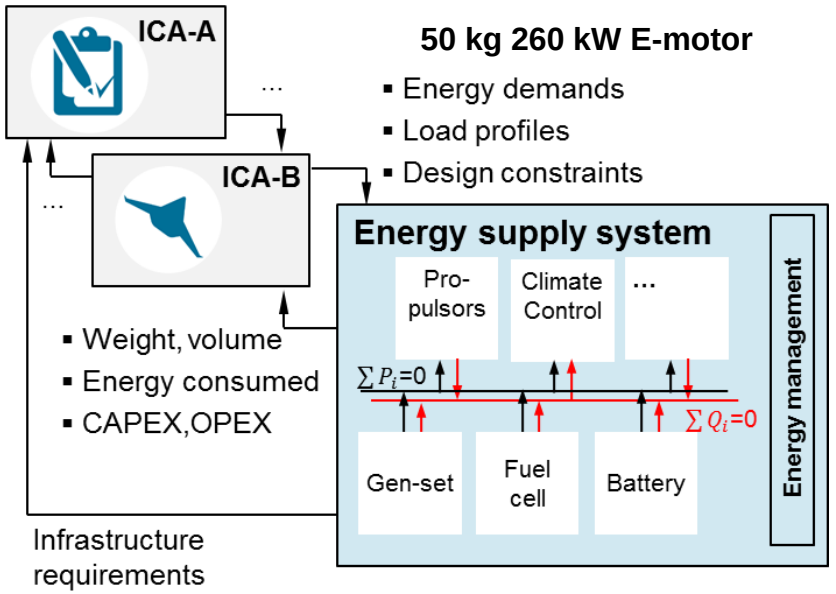
SE²A- Key Research Topics
How to Design and Electrify the Energy System?

Scientific Challenges

- **Ultra-high specific power** at system and subsystem level
- Reliable heat removal
- **Lightweight** (superconductive) DC distribution, protection and power conversion systems
- Identify **best options for on-board energy supply** system

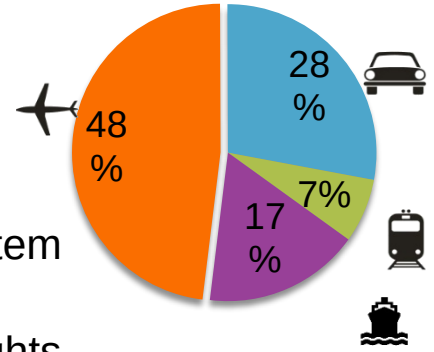
Multidisciplinary integrated design needed at **all system levels**

50 kg 260 kW E-motor



How to Realize The Energiewende for Aviation!

- **Increasing air traffic and climate change** requires huge transformation of aviation sector
- Energy efficiency **and CO_2 neutral** propulsion are key challenges
- New tailored concepts for air transport system, aircraft and its energy system
- There is **no one-fits-all technology** for short, medium and long range flights
- Propulsion technologies:
  - Short range: high energy density batteries required
  - Medium range: electrofuels tailored for low NOx combustion
  - Long range: fuel cells with liquid hydrogen



SE²A:
Delivering Research for Sustainable, Energy Efficient Aviation