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

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% CO₂
- 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 CO₂ 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

**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**

<table>
<thead>
<tr>
<th>Economics &amp; Social Sciences</th>
<th>Aeronautical Sciences</th>
<th>Energy Sciences</th>
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<td>Aerodynamics</td>
<td>Battery design and prod.</td>
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<td>Electrosynthesis</td>
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<td>Total cost of ownership</td>
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<td>Hybrid structures</td>
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Joining the Competencies of Three Partners

Successful long cooperation practised in joint research facilities

- **Economics & Social Sciences**
  TU BS / LUH / HBK

- **Aeronautical Sciences**
  TU BS / DLR / LUH

- **Energy Sciences**
  LUH / TU BS / PTB

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**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 started:
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](https://www.mdpi.com/si/12555)
## Results in a Nut Shell:

*One size does NOT fit all*

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

Scientific Challenges

- Large scale production of CO₂ neutral, high specific energy fuel from renewables
- New pathways that allow to use abundant electricity: Electrofuels

![Diagram showing renewable resources, production processes, and electrofuels](image)
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

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
How to Realize The Energiewende for Aviation!

- **Increasing air traffic and climate change** requires huge transformation of aviation sector

- Energy efficiency **and CO₂ 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

Transformation Path: positive extreme scenario
Transformation Path: negative extreme scenario
Trend Scenario

2018

2050