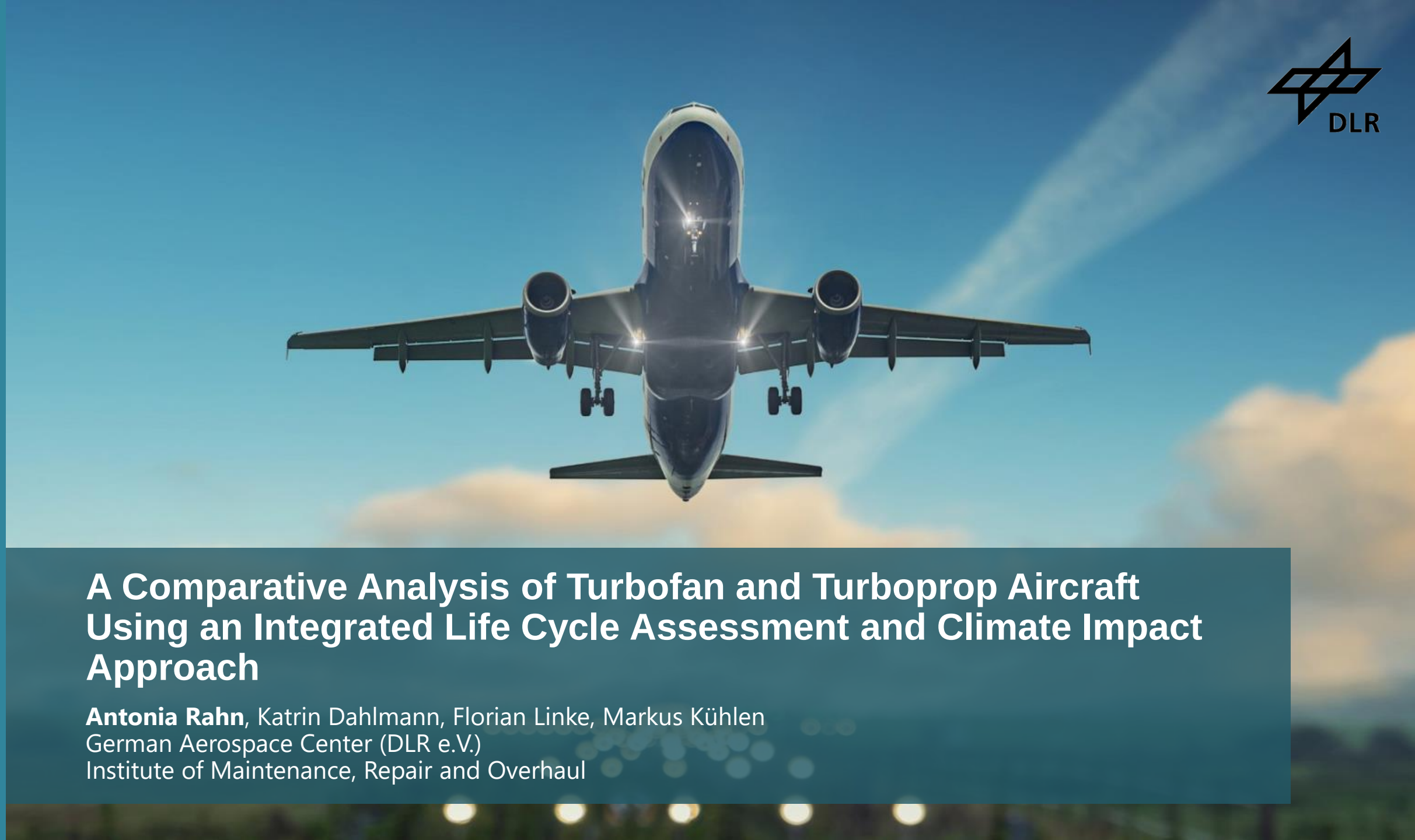

A Comparative Analysis of Turbofan and Turboprop Aircraft Using an Integrated Life Cycle Assessment and Climate Impact Approach

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Institute of Maintenance, Repair and Overhaul

Motivation
Environmental Impacts in Aviation

General Aspects

- aviation is responsible for **3.6 %** of the human-induced greenhouse gas emissions
- air transport is **expected to grow** at a faster pace than technology improvement

Problem

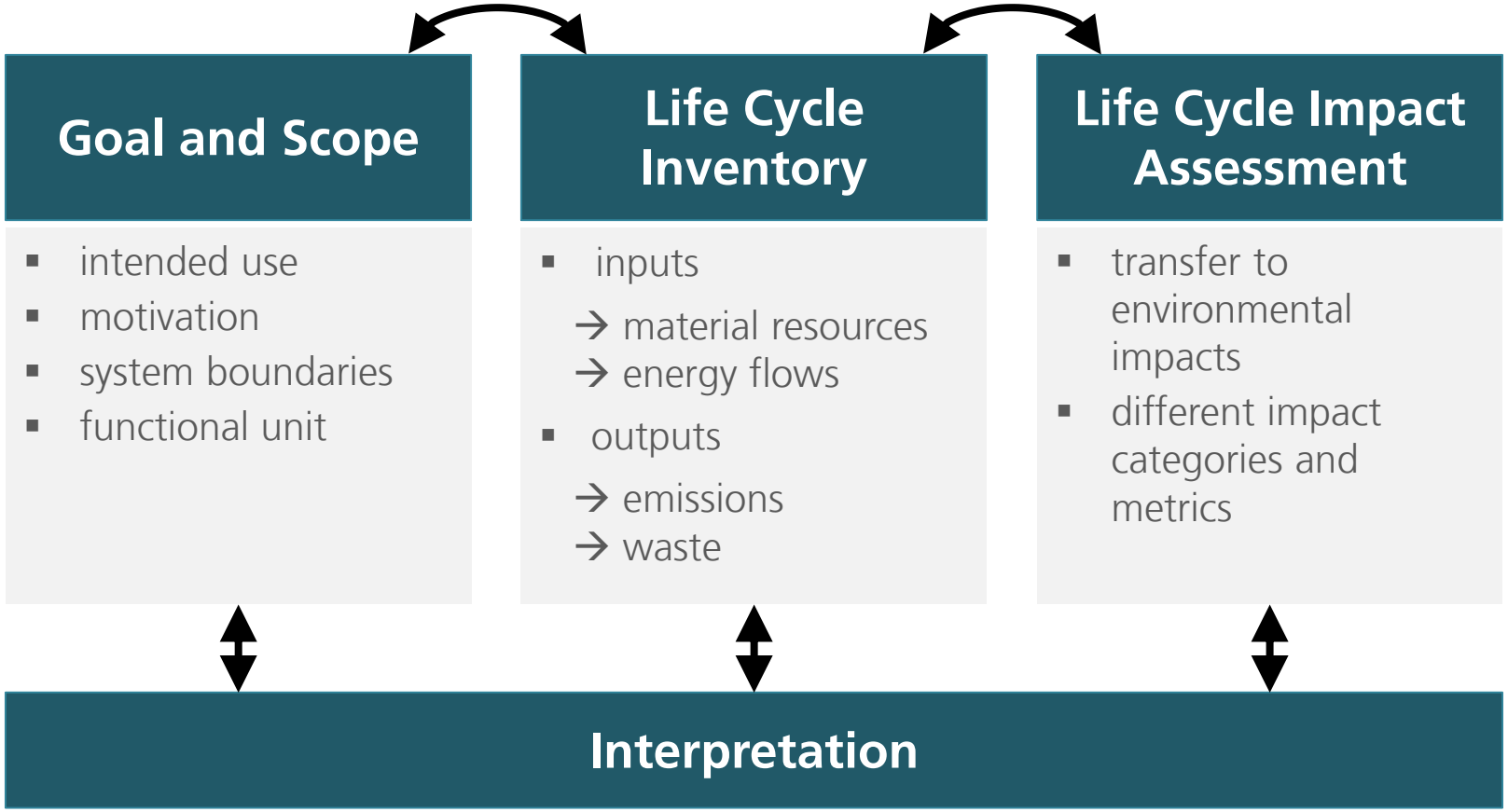
- environmental impacts in aviation are often analyzed in a very **simplified** way
- some life cycle phases (e.g., maintenance) are often **neglected**
- in-flight **non-CO_2 effects** are often overlooked

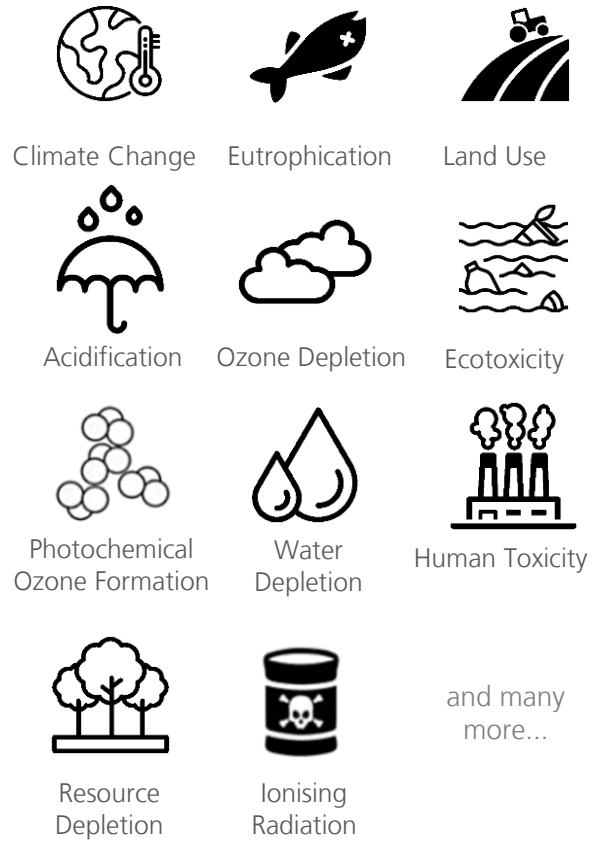
Motivation

- **life cycle assessment** for ground-based impacts
- **climate impact** response model for impacts during flight
- **discrete-event simulation** for an improved comparison of different aircraft designs

Fundamentals
Life Cycle Assessment

LCA is a tool for examining the total **environmental impact** of a product through **every step** of its **life**.

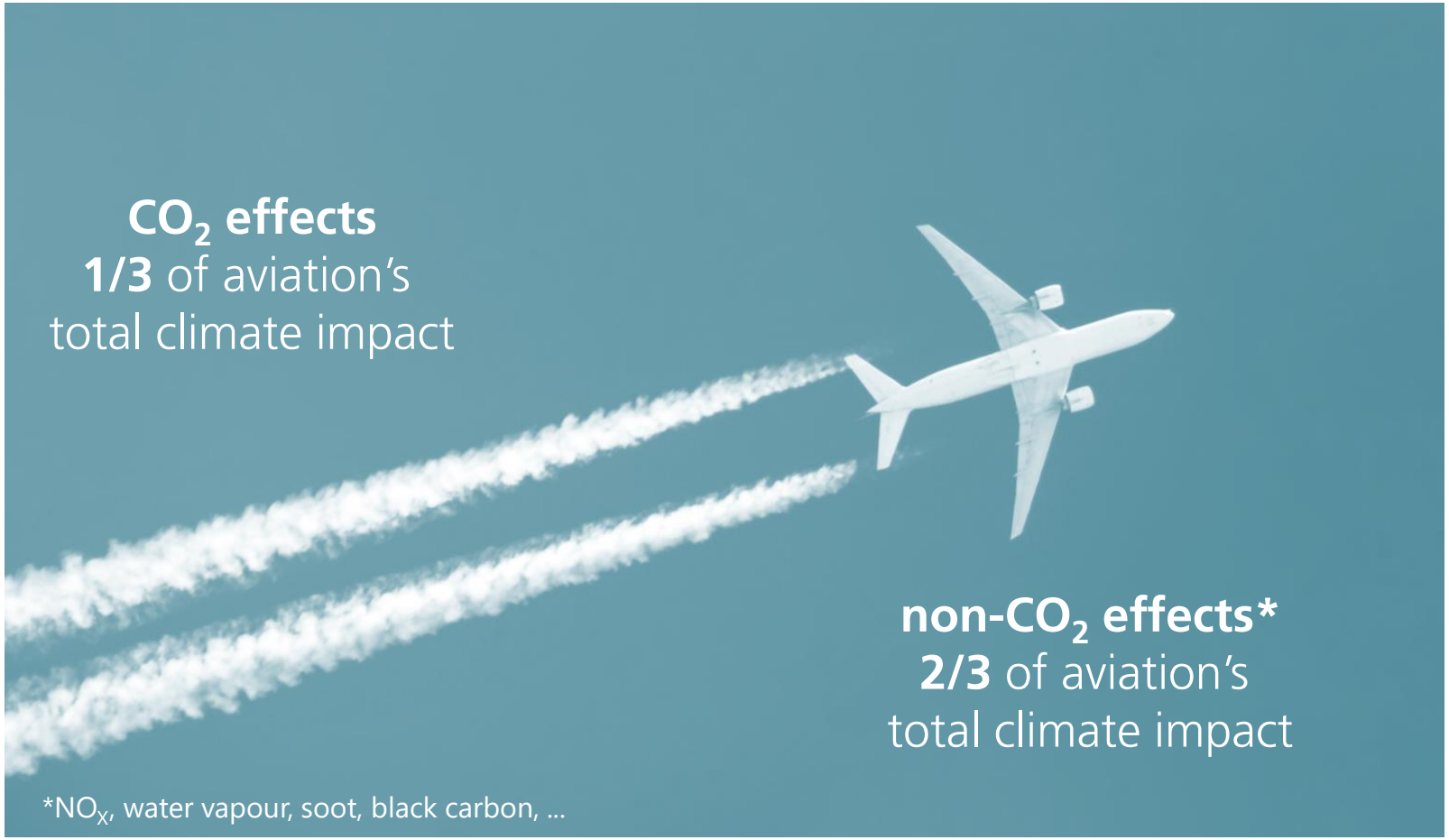




from DIN EN ISO 14040/14044

Fundamentals
Climate Impact

Non-CO_2 effects have a greater impact on aviation's climate impacts.



Method
Combined Approach

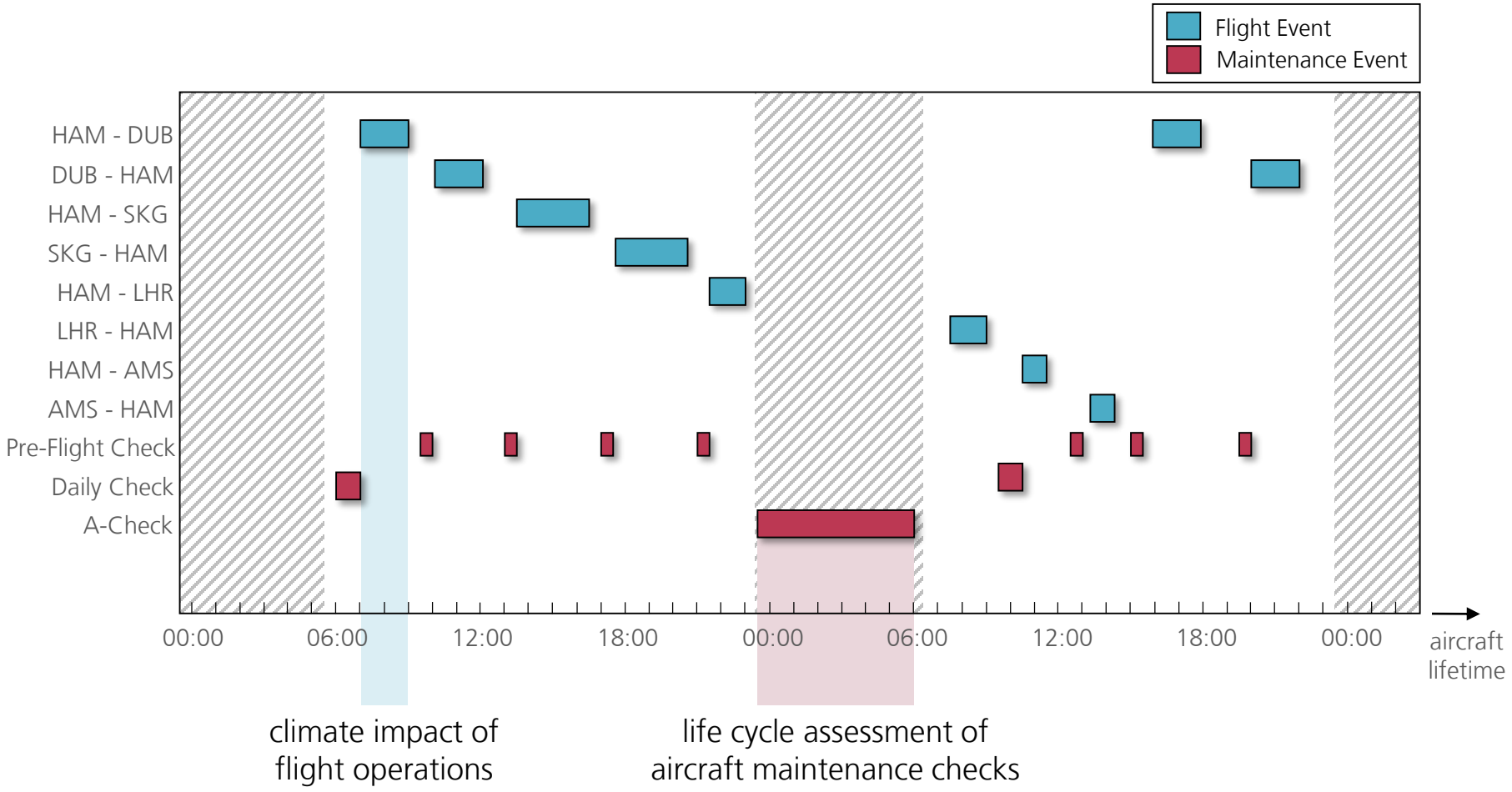
Discrete-Event Simulation

+

Life Cycle Assessment

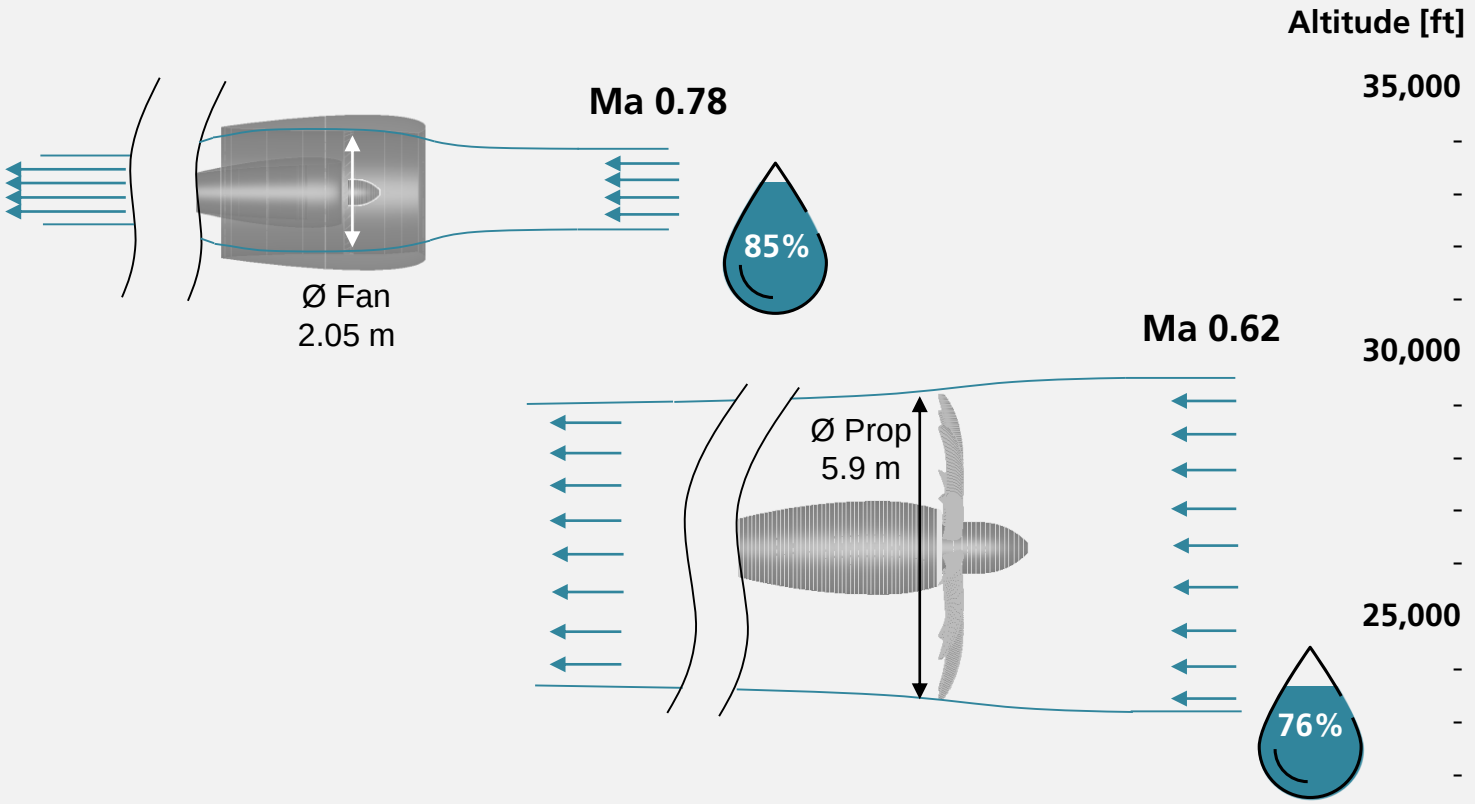
+

Climate Impact Evaluation*



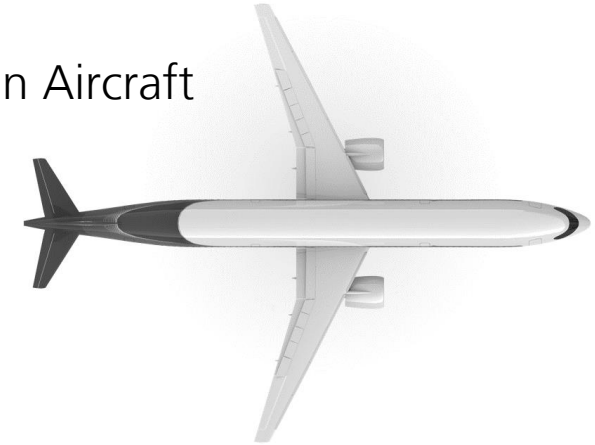
*climate impact is calculated on flight-level based on Dahlmann et al. (2023)
DOI: 10.1080/15568318.2021.1979136

Use Case
Comparison of Turbofan and Turboprop Aircraft

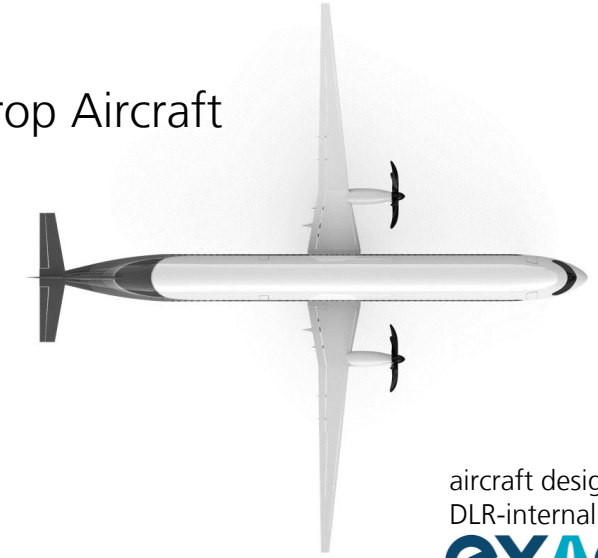


- turboprop aircraft has **lower flight altitude** and **lower Mach number**
- turboprop aircraft has a **higher fuel efficiency**

Turbofan Aircraft

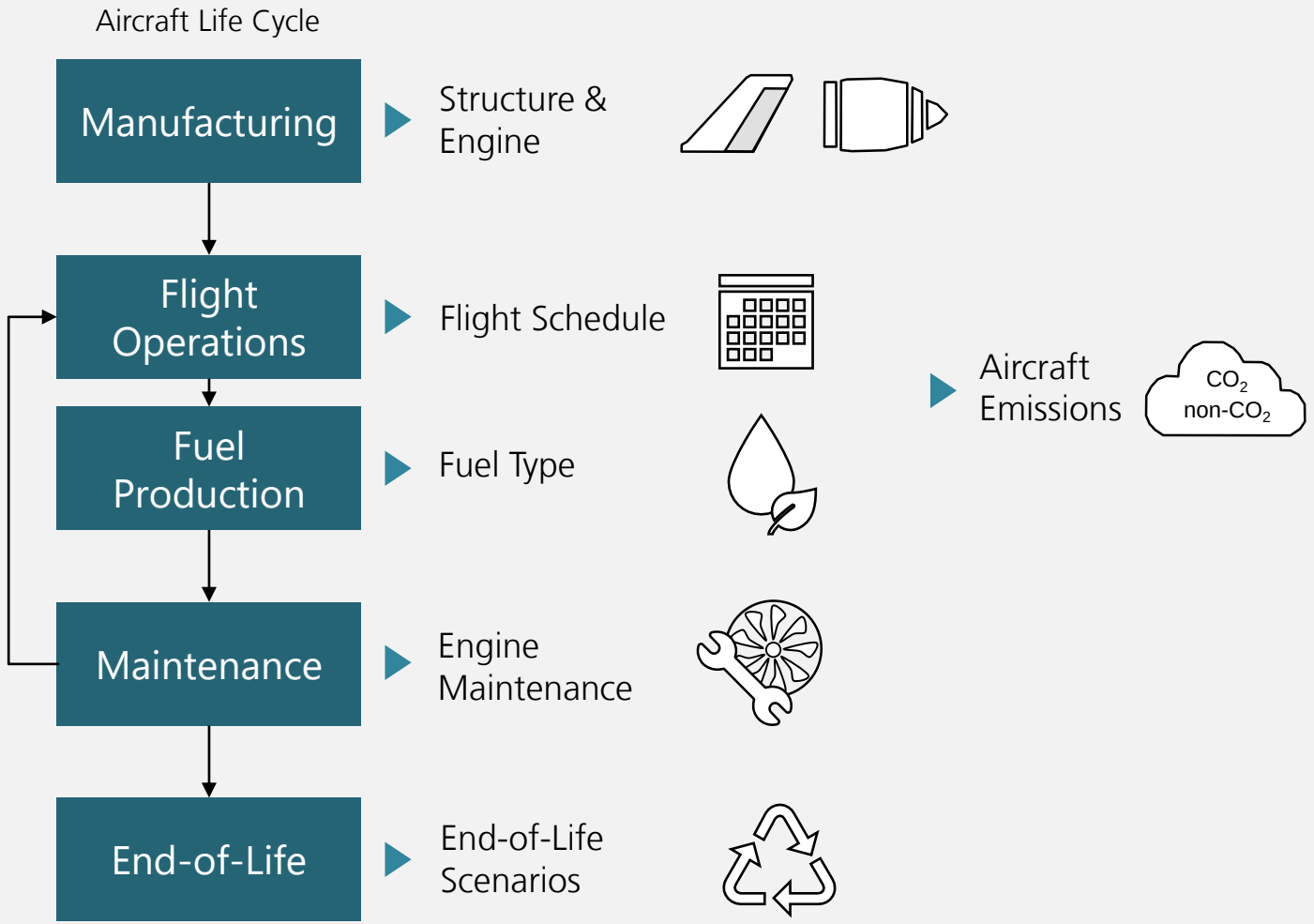


Turboprop Aircraft

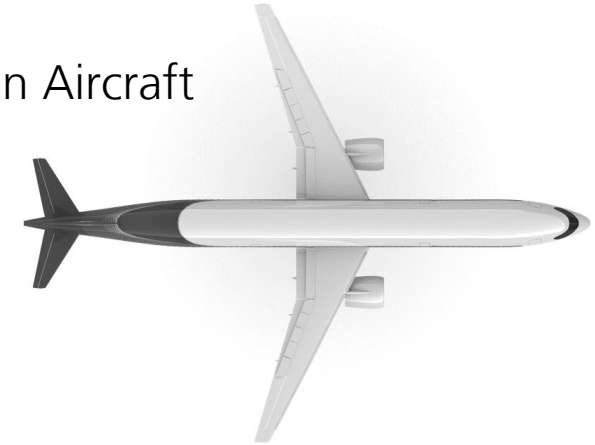


aircraft design from DLR-internal project eXACT

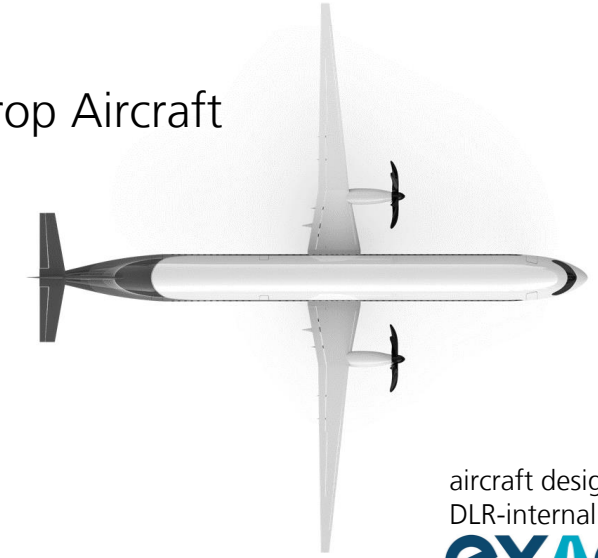
Use Case
Comparison of Turbofan and Turboprop Aircraft



Turbofan Aircraft



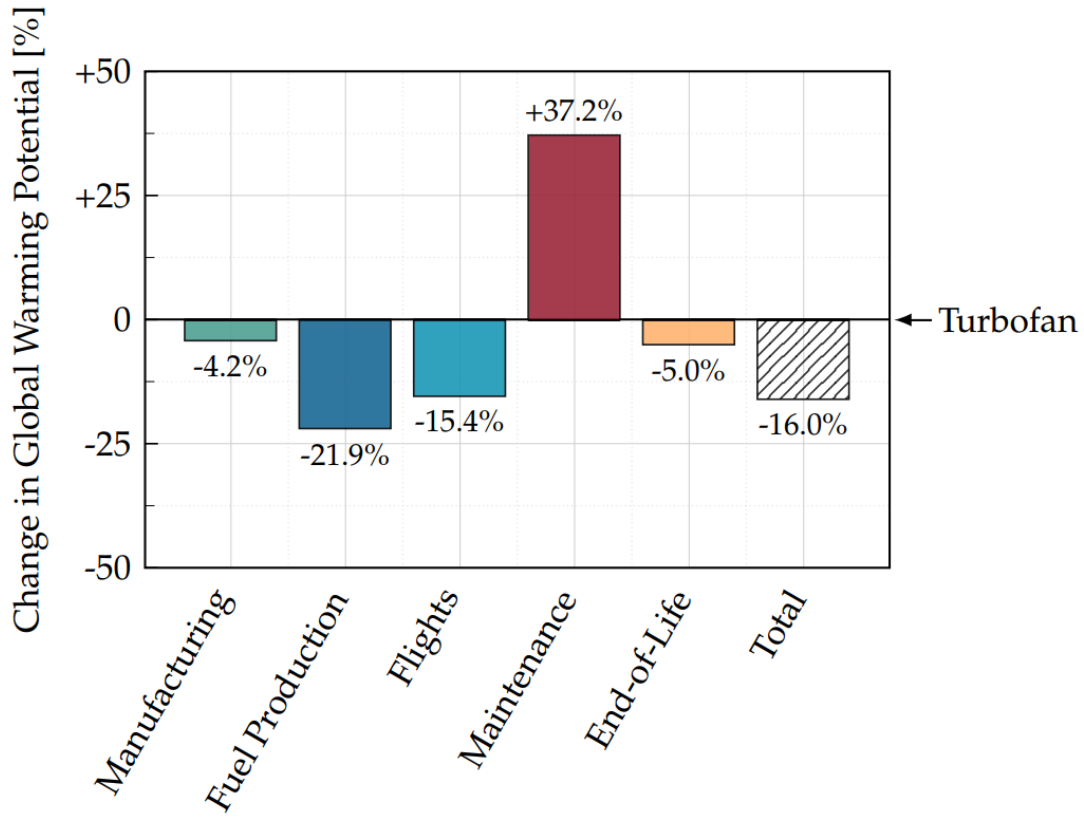
Turboprop Aircraft



aircraft design from DLR-internal project eXACT

Results
Turbofan vs. Turboprop

Impact of Aircraft Life Cycle

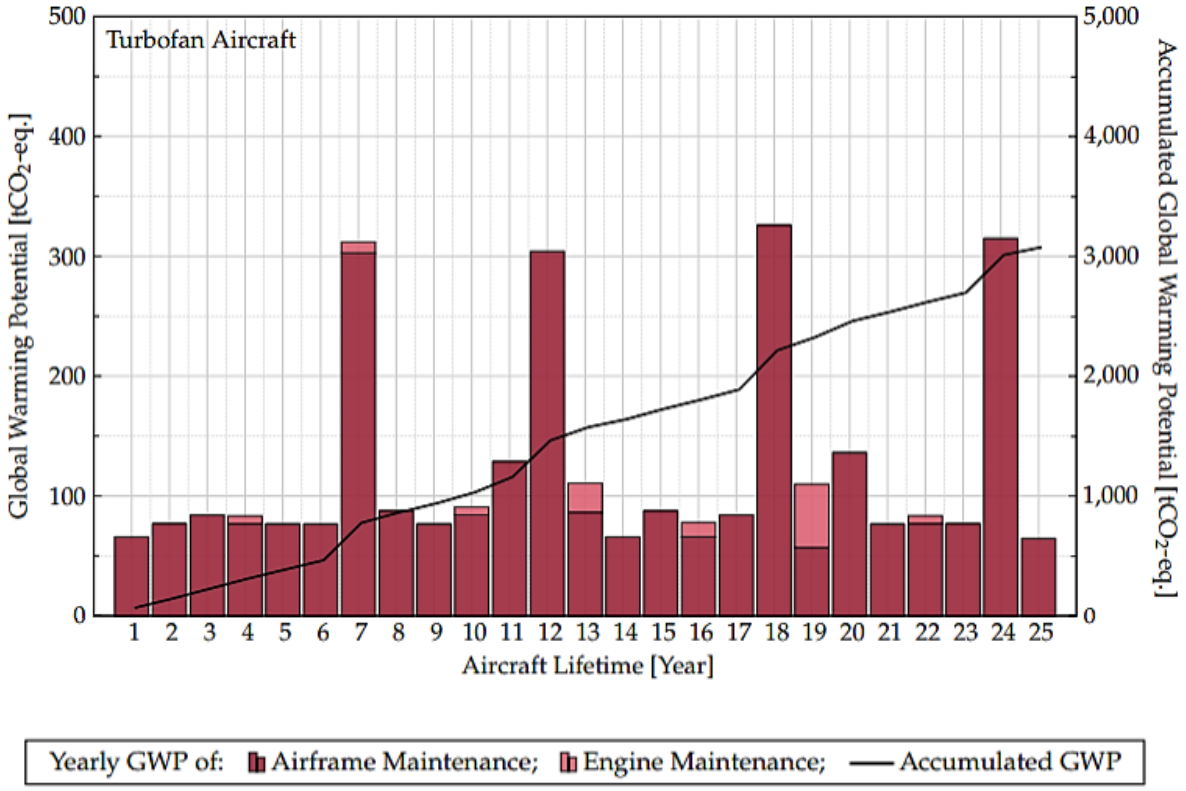


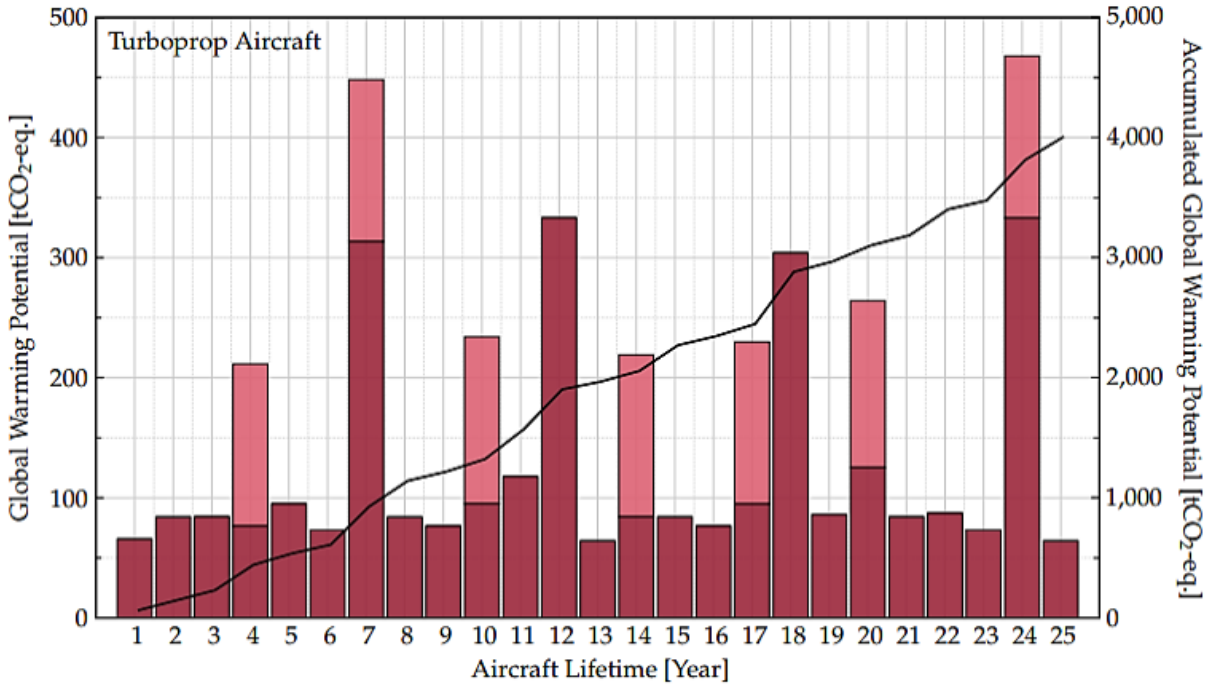
➥ the turboprop aircraft has a lower environmental impact in almost all life cycle phases

more details:
Rahn et al. (2024): Quantifying Climate Impacts of Flight Operations: A Discrete-Event Life Cycle Assessment Approach. Transportation Research Part D: Transport and Environment (currently under review).

Results
Turbofan vs. Turboprop

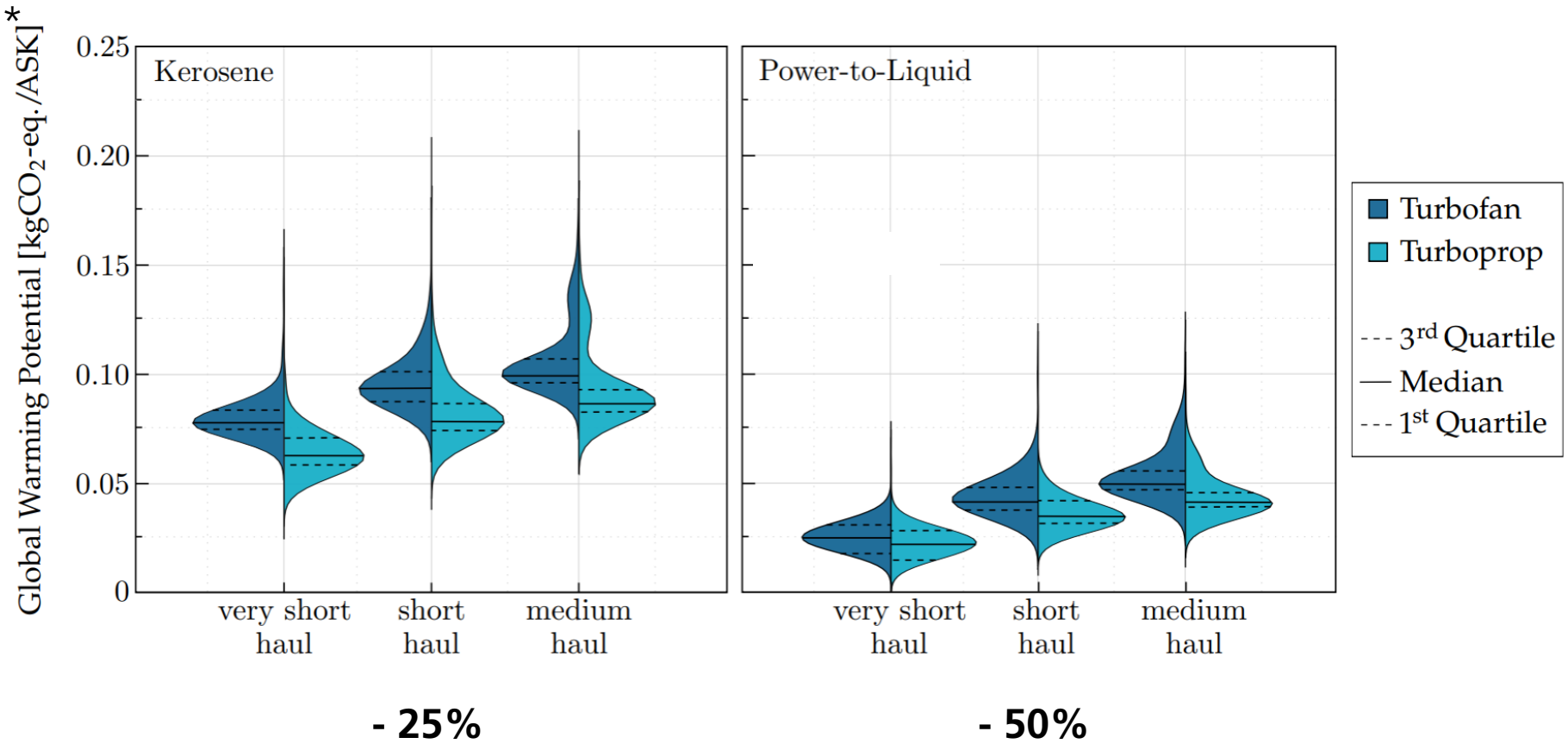
Impact of Maintenance





Results
Turbofan vs. Turboprop

Impact of Flight Operations



- 25% **- 50%**

- the turboprop aircraft have a lower climate impact by up to 25.7%
- Power-to-Liquid can reduce climate impact by up to 50% compared to kerosene

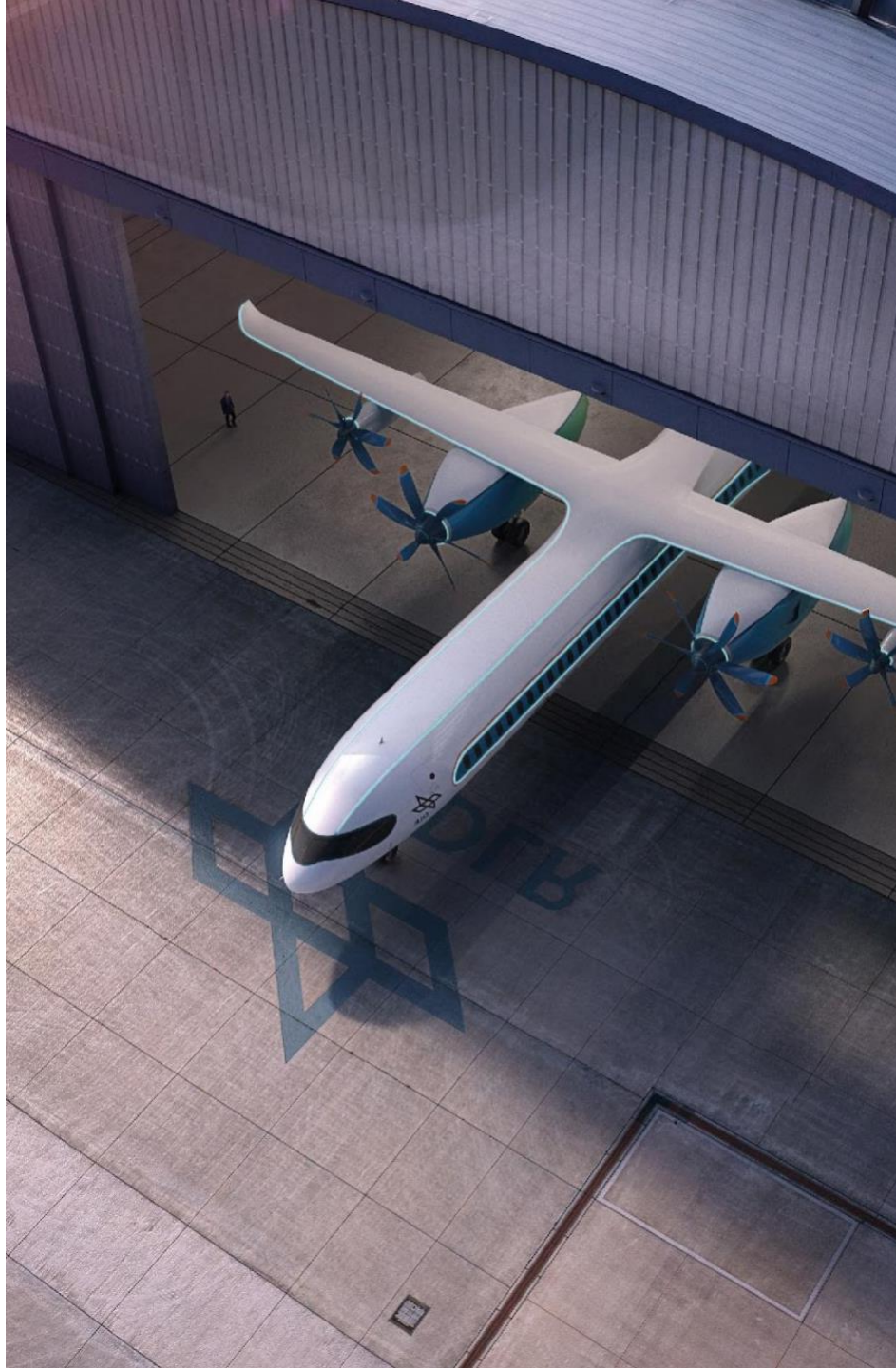
*ASK - Available Seat Kilometre

more details:
Rahn et al. (2024): Quantifying Climate Impacts of Flight Operations: A Discrete-Event Life Cycle Assessment Approach. Transportation Research Part D: Transport and Environment (currently under review).

Conclusion and Outlook

Take Aways

- **Integrated Approach:** combining discrete-event life cycle assessment with a climate response model provides detailed insights into the entire aircraft life cycle
- **Non-CO_2 Climate Impact:** are often overlooked, but significantly influence aviation's overall climate impact
- **Maintenance Focus:** detailed evaluation of regular maintenance tasks, especially for life limited parts, helps to identify hot spots
- **Data Sensitivity:** results are highly influenced by the specific aircraft performance data and operational conditions



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THANK YOU!