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Speaker

Session 3: Mitigating Non-CO_2 Aviation Emissions – What is possible

Part I – Innovative Technologies

Mitigate the Impact of Non-CO_2 Aviation Emissions Conceptual design perspective

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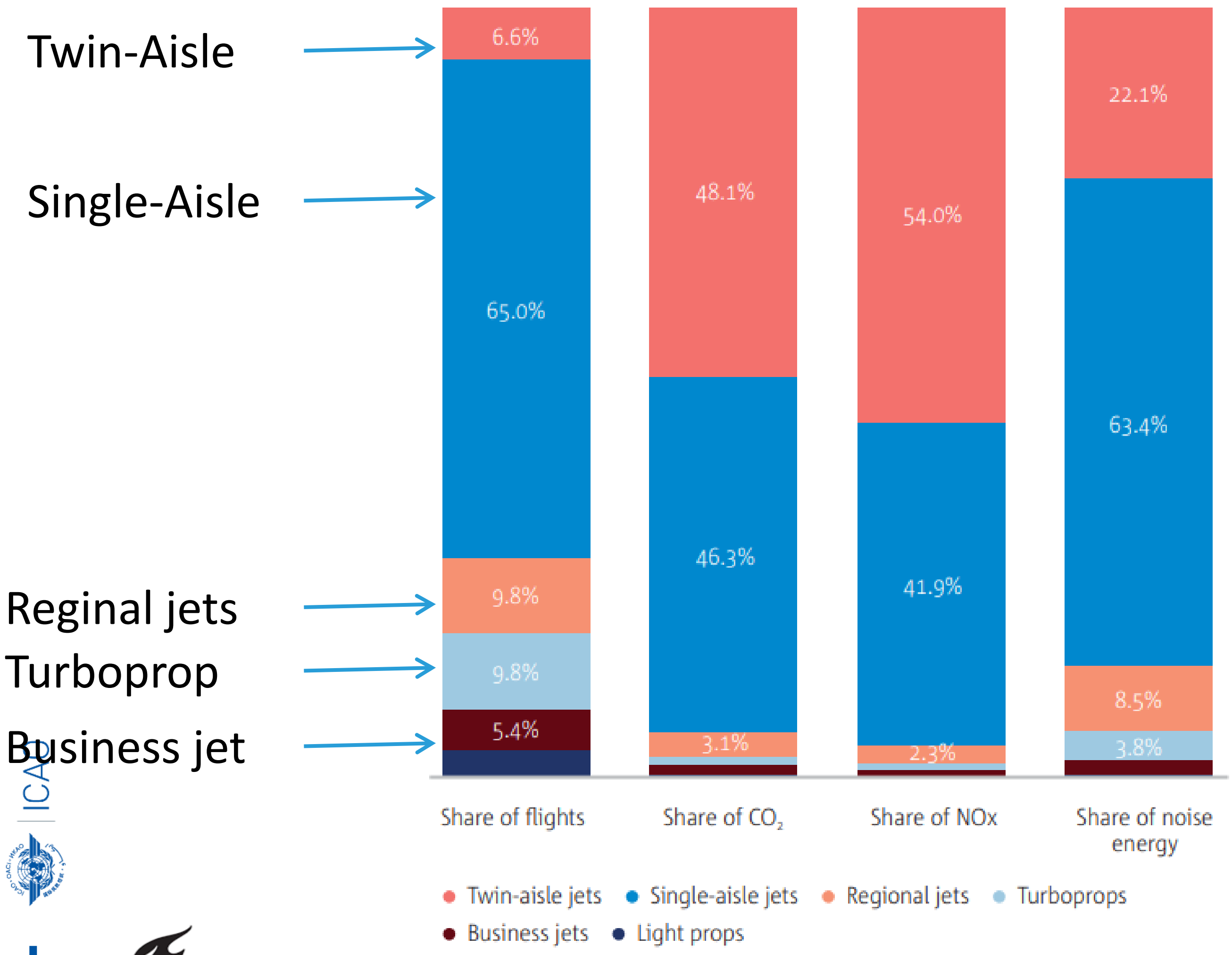
17/09/2024, Montreal, Canada

Flights and emissions per aircraft category



Status:

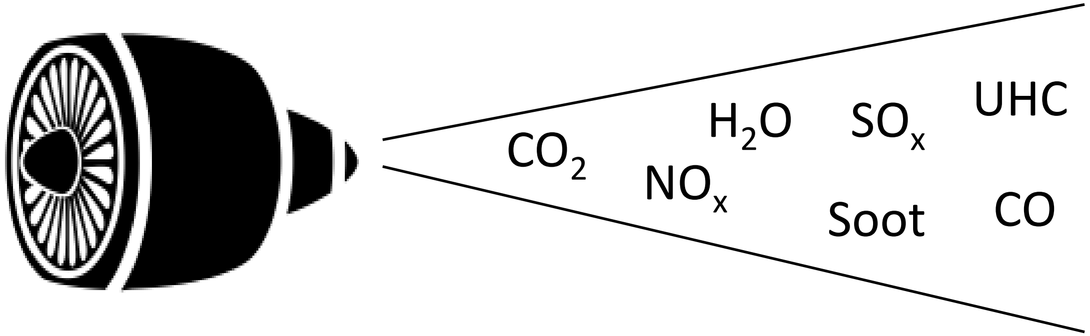
- Single- and twin- aisle contribute > 90% of the total NO_x and CO_2 emissions.
- Long range flights contribute to larger climate impact [1]. (single + twin > ~70%)

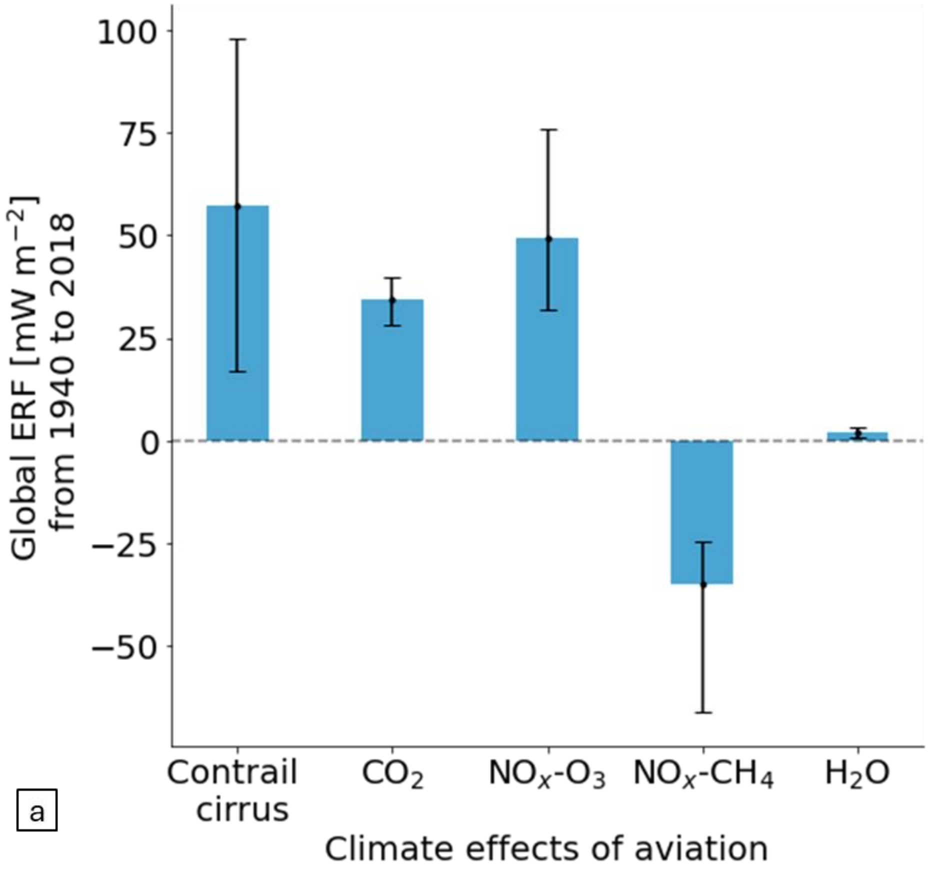
Challenges to mitigate non-CO_2:

- Engine design is driven by fuel efficiency
  - High pressure ratio
  - High bypass ratio
- Strong dependency between
  - CO_2 and non-CO_2 emissions
  - Local and global

Figure source: EASA, Eurocontrol, European Aviation Environmental Report, 2022.
1. Radhakrishnan, Yin, et al., 2022

Aviation’s emissions and their climate impact





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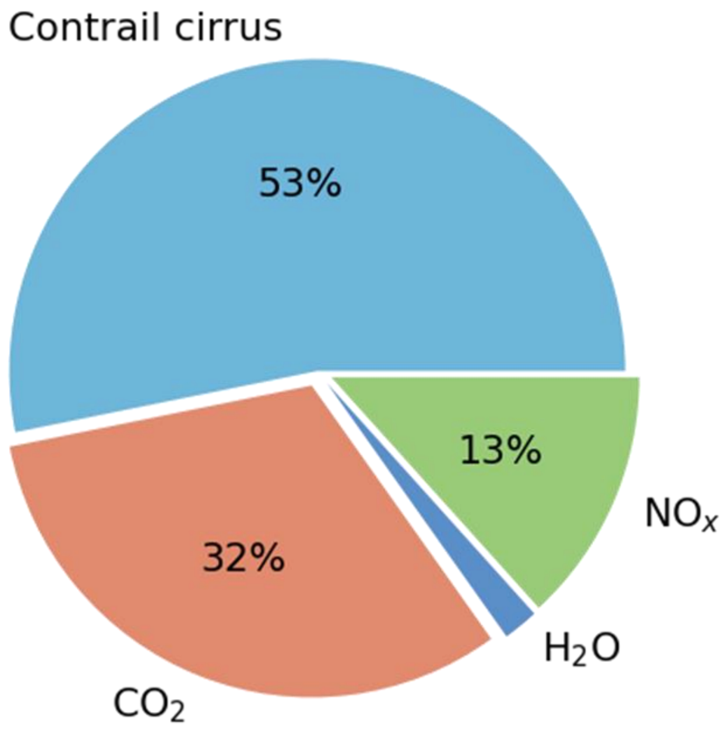
Best estimates



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Castino, 2024, in preparation.
Figure dapted from Table 2 and Figure 3 of Lee et al., 2021.

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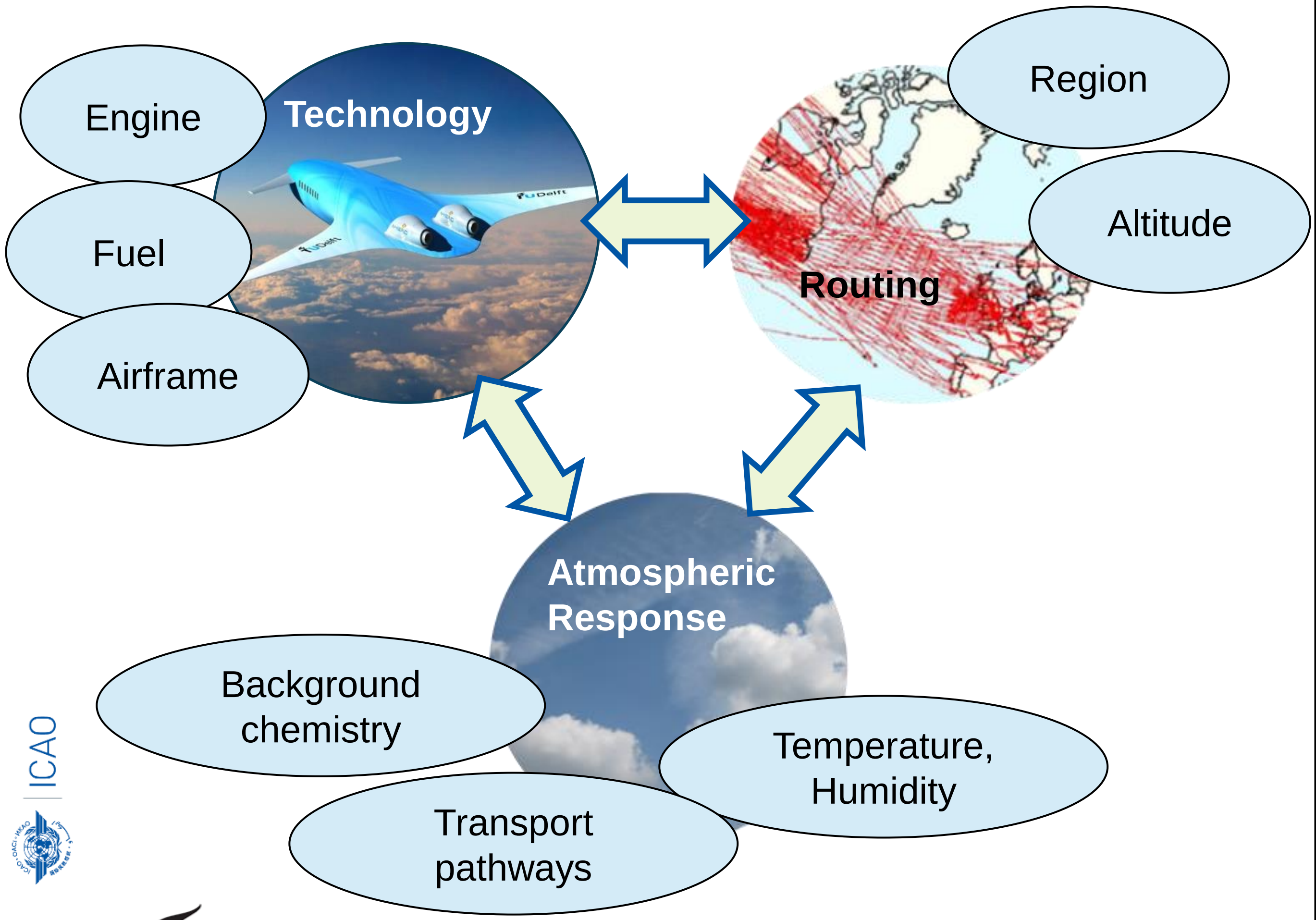
What do we consider for technology impact assessment?



- **Technology:** Aircraft have a long service life (20-30 years), long development phases and slow replacement rates:
  - **Technological improvements** can only be introduced **gradually** into the existing fleet
  - Usage of the **newest** and **older aircraft varies by region**
- Weather vs. Climatology:
  - Non-CO_2 effects are weather sensitive
  - Design is based on **climatology**
- Time horizon:
  - **long term horizon** is more sensible for technology assessment

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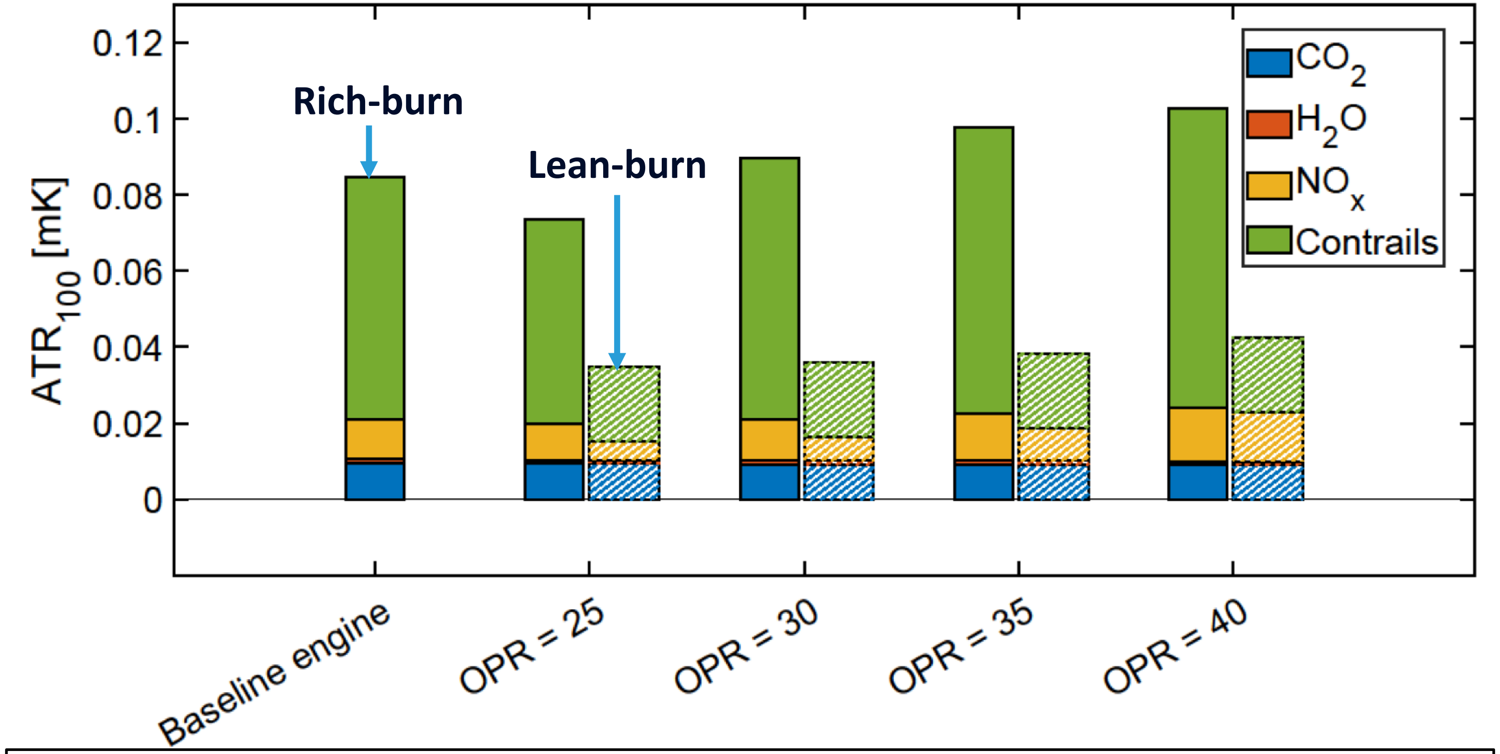
Sensitivity of turbofan parameters to the climate impact

Analysis consideration:

- **Scenario**: Increasing traffic scenario towards future
- **Flight route**: 21900 flights /annual over Europe and North America.
- Operational parameters: **Alt= 33000 feet; Mach=0.78**
- Climate metric: **Average Temperature Response over 100 years (ATR100)**



Engine Parameters (Baseline: A320 + CFM56 engine**):**

- Cycle development: Overall Pressure Ratio (OPR)

→ max ~ 25% increase in ATR100 at OPR of 40

- Combustion: Lean (TAPS combustion) vs. Rich (RQL combustion)

→ Max ~60% reduction in ATR100

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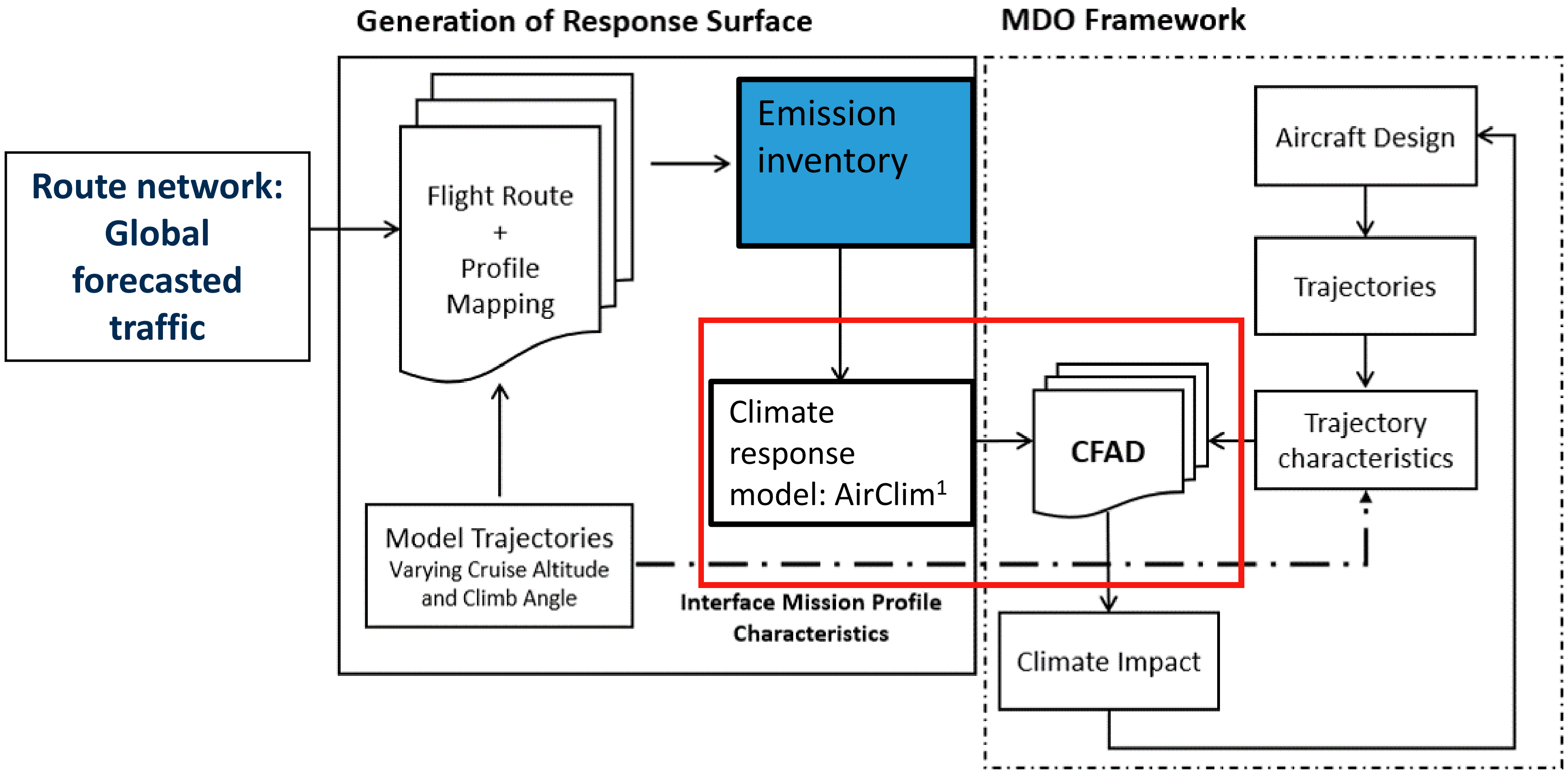
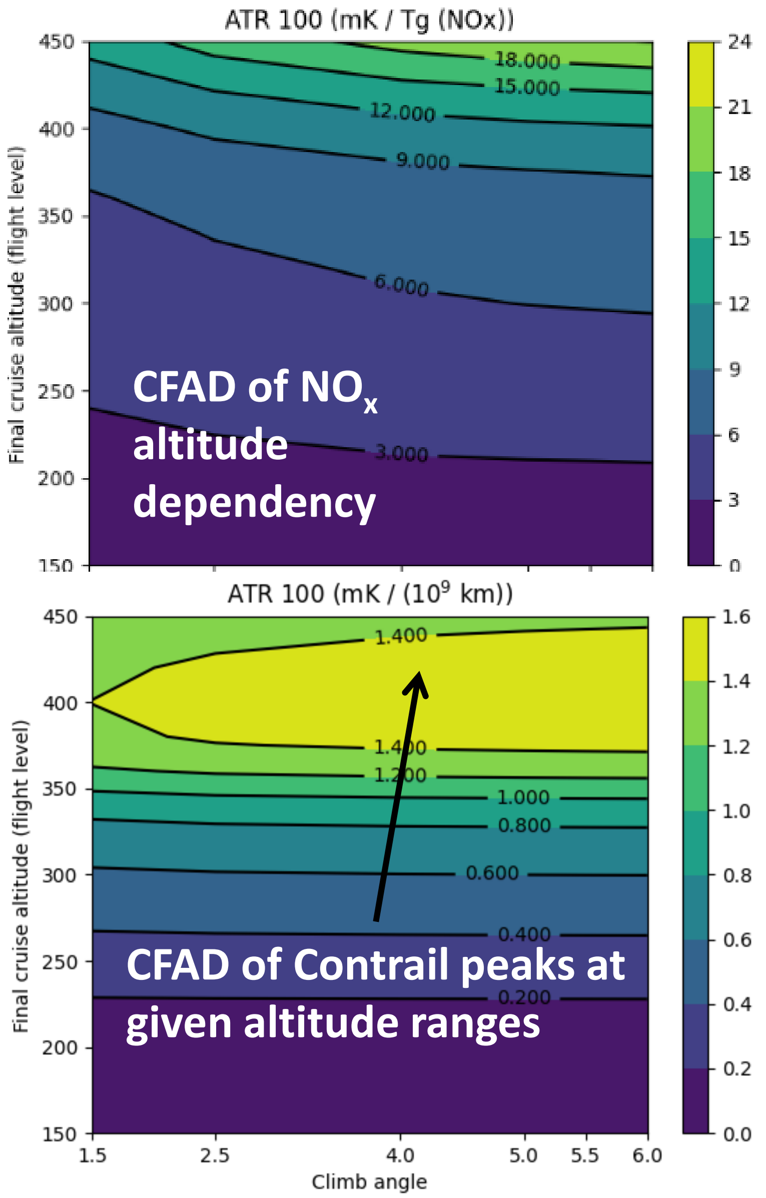
Saluja, Yin, et al. 2023

Develop Climate Functions for Aircraft Design(CFAD)





Radhakrishnan, Yin, et al., 2022.
Deck, Yin, et al. in preparation, 2024.
1. Grewe and Stenke, 2008. Dahlmann et al., 2016.

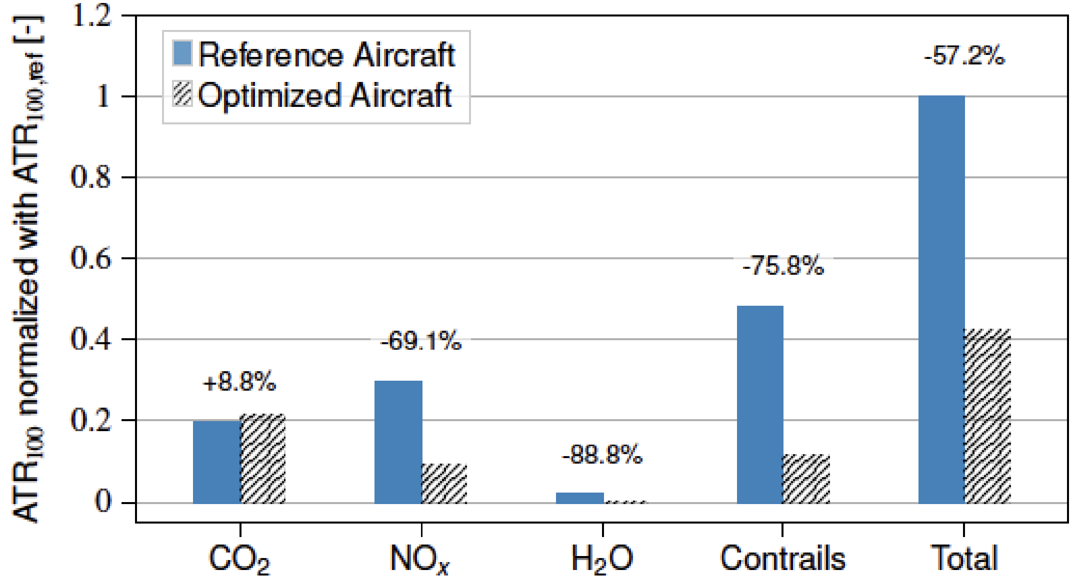
Mitigation option: Integration of climate functions

- Preliminary CFAD model for NO_x, contrail, H_2O and CO_2 is implemented in a MDO framework.

→ Technology: Turbofan + kerosene
→ ATR100 = f(cruise initial altitude, climb angle)
  Other parameters (e.g., engine related) are implicit
→ Verification confirms the model effectiveness but shows increased discrepancy at high altitudes.

- Research ongoing:

→ Improve the fidelity of the model at cruise altitude
→ Evaluate the sensitivity of emission calculation
→ Assess the uncertainty in climate impact mitigation



- Reference aircraft: contemporary aircraft with fuel efficiency
- Optimized aircraft using CFAD

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Radhakrishnan, Yin, et al., 2022.

Summary

- **Technology assessments** requires system-wide approach including
  - Technology & fuels options (influences the emission rate)
  - Routing & fleet forecast (influences emission location over time)
  - Atmospheric response (influences non-CO_2 climate effects)
- Time horizon and emission scenario has influence on CO_2 and non-CO_2 weighting
  - Use of **longer time horizon is needed for technology** with long lifetime and slow replacement
- Climate optimized aircraft conceptual design is facilitated by the climate functions for design:
  - Relative changes matter
  - Risk assessment regarding the uncertainty of non-CO_2 effects
- We need breakthrough (yet “implementable”) technologies to overcome the tradeoffs:
  - **CO_2 vs. non-CO_2 ; Local vs. Global**

H2OPE

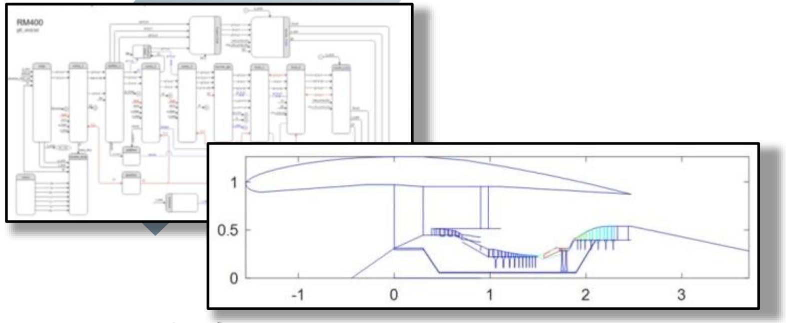
Multi-fuel aircraft propulsion system

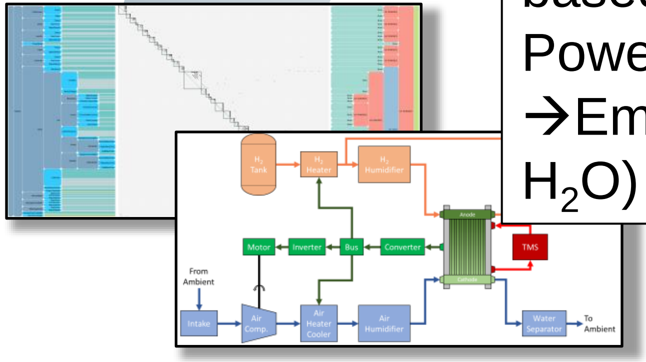
Co-funded by the European Union

UK Research and Innovation

Design an efficient and fuel-flexible aircraft propulsion system to minimize emissions through all segments of aircraft movement. → **reduce CO_2 and non-CO_2 dependency**

Conceptual design of ultra-high bypass ratio **multi-fuel** turbofan (**kerosene/SAF + H_2**):
→Reduce cruise CO_2, NO_x, and nvPM





Conceptual design of **fuel cell-based** Auxiliary Propulsion and Power Unit **(APPU)**
→Emission free taxiing (except for H_2O)

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Multi-fuel combustion chamber design

Co-funded by the European Union

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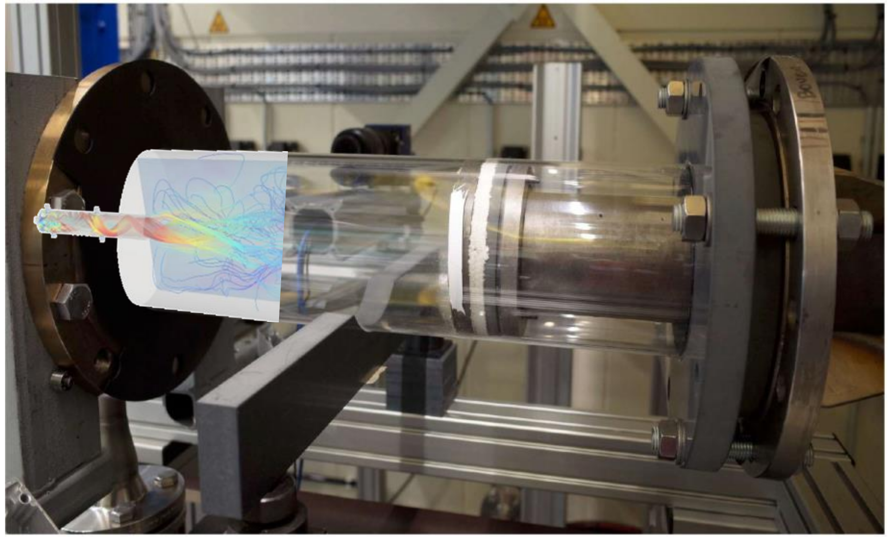
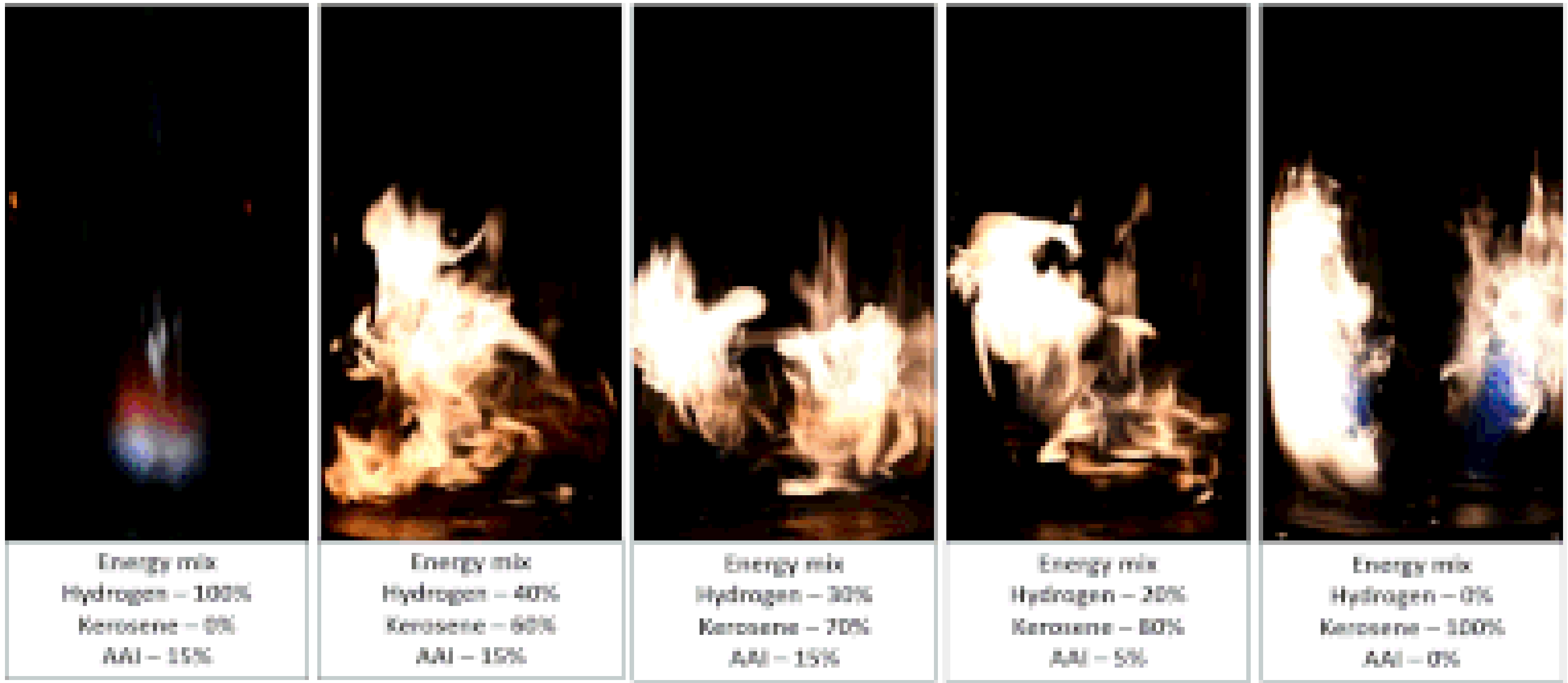


- Numerical simulations (design the multi-fuel combustor, emission characteristics, high pressure condition)
- Lab experiments (given operating conditions & combustor design)

Status: Lab demonstration of the multi-fuel combustion:

Ongoing:
Refining the combustor design
Characteristic of emissions



100% H_2 | 40% H_2 | 30% H_2 | 20% H_2 | 100% kerosene

Thank you for your attentions!

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Thank You

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