Life Cycle Assessment of Power-to-Liquid for Aviation: A Case Study of a Passenger Aircraft

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Background and motivation

- Aviation is one of the sectors considered as „hard-to-abate“ with respect to its climate impact
- New solutions need to be found to reach the goals of the Paris Agreement of 2016
- Power-to-Liquid (PtL) as aviation fuel is one possible solution, especially for longer distances

This work:

- ➢ Impacts of the flight emissions of a **fleet** of narrow-body aircraft with expected entry into service in 2040
- ➢ Passenger-demand based simulation of a **global route network**
- ➢ Analysis includes **fuel production phase and fleet operation**
- ➢ Environmental impact analysis considers the **aircraft performance during flight**
- ➢ Consideration of the **geographic position and altitude** of the aircraft for climate change impacts

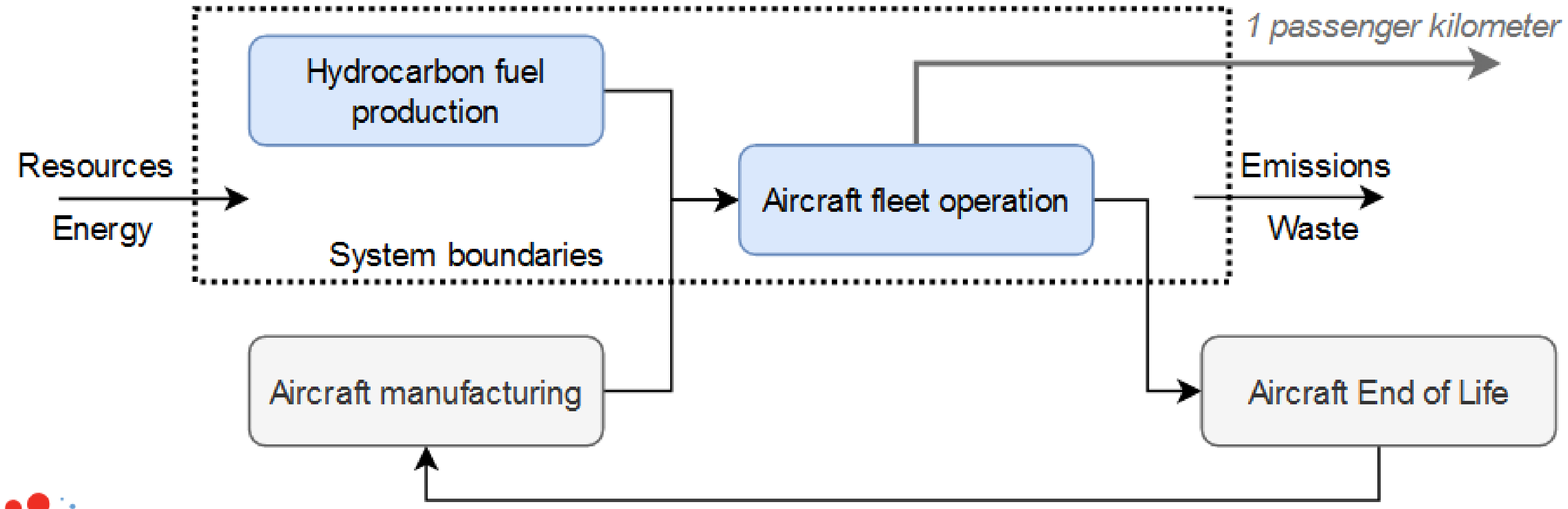
Case study description

Overview of the aircraft

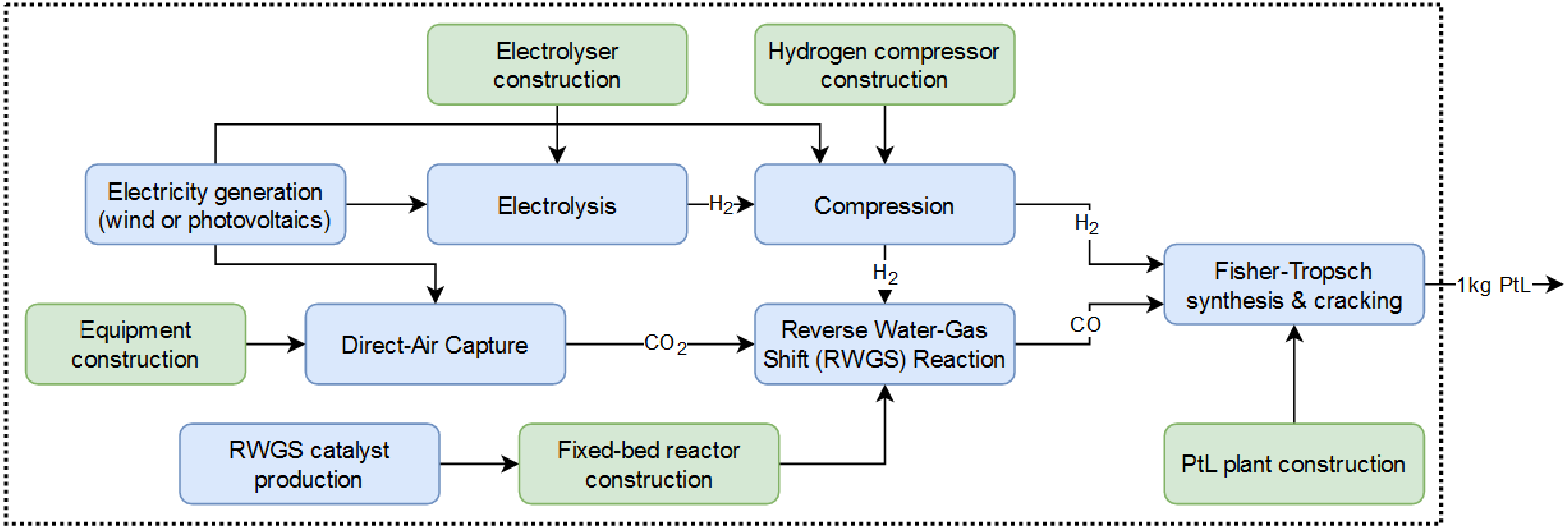
System: Fleet of advanced short-range turbofan aircraft with entry into service in 2040

Parameter	Value
Design range	1500 nm / 2780 km
Design cruise mach number	0.78
Number of passengers	250

System boundaries:



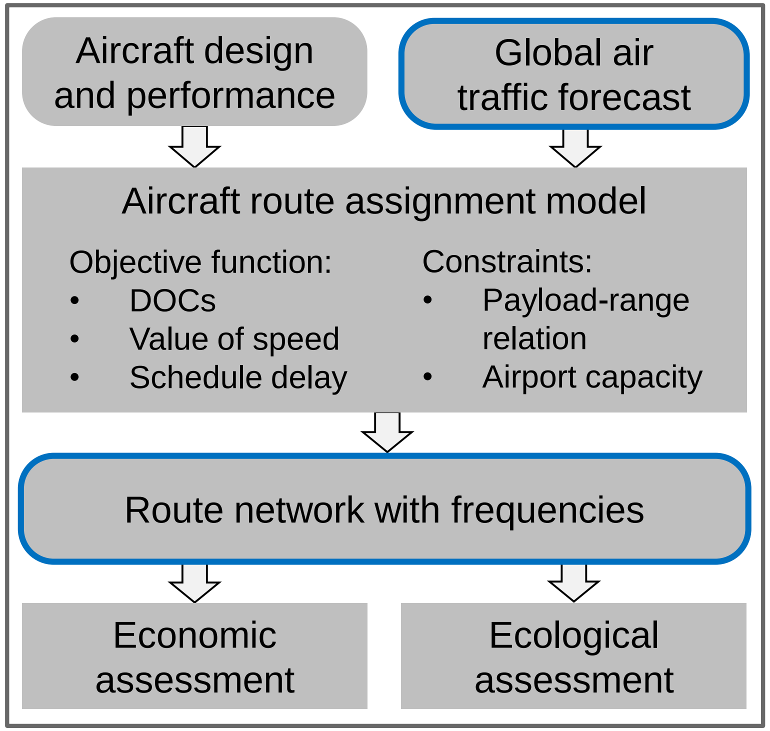
Synthetic fuel production (Power-to-Liquid)



Flow diagram of the PtL production pathway adapted from van der Giesen et al. 2014 [1]

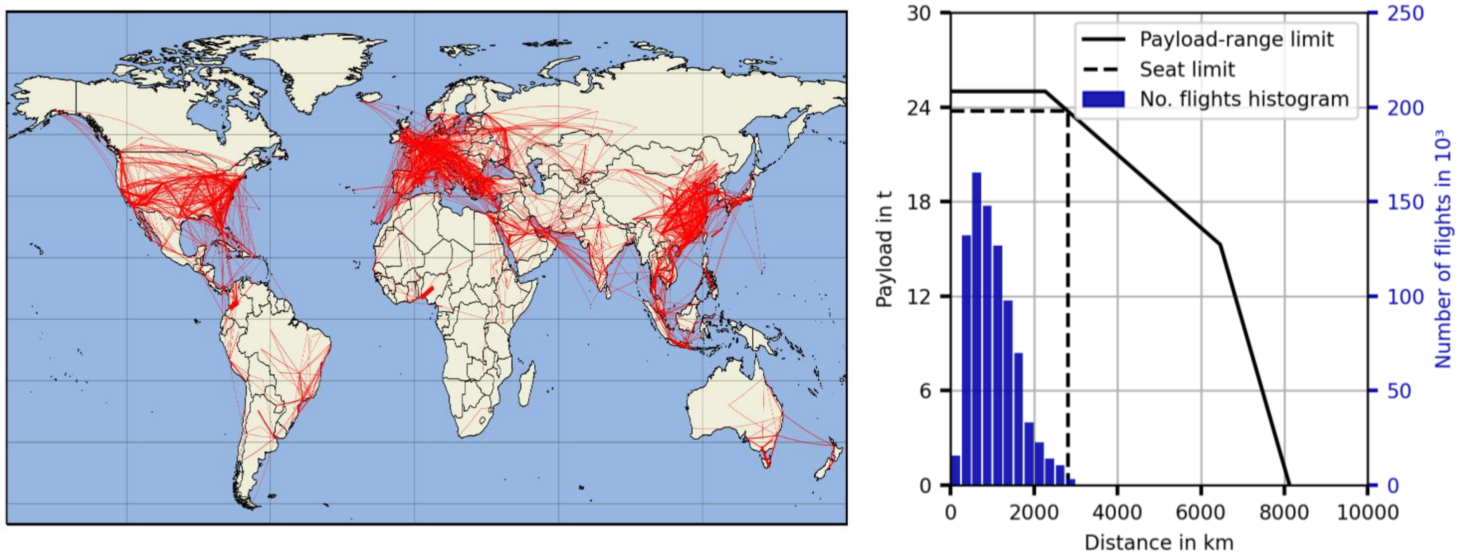
[1] van der Giesen et al., Energy and Climate Impacts of Producing Synthetic Hydrocarbon Fuels from CO2, Environ. Sci. Technol., Vol. 48, No. 12, 2014, pp. 7111–7121.

From traffic forecast to route network



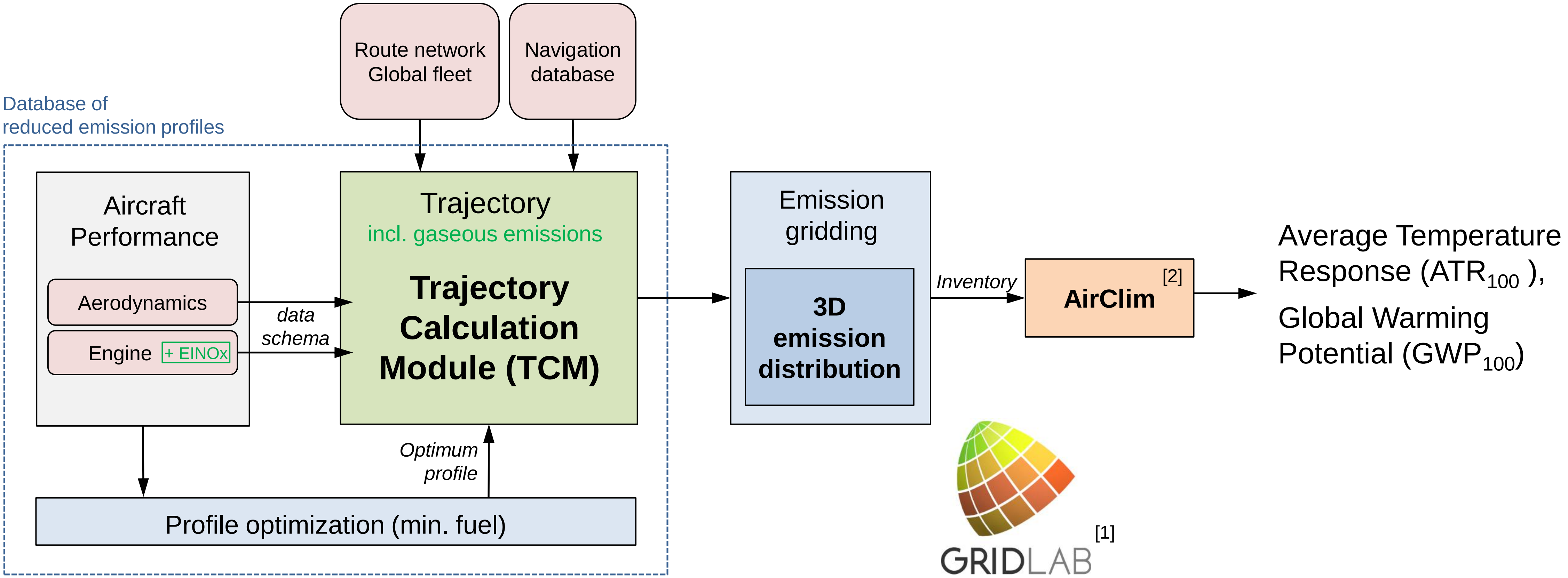
Workflow integration of route network calculation

- Passenger demand forecast on airport pair level based on socioeconomic factors
- Passenger and flight volumes are constrained by airport capacities



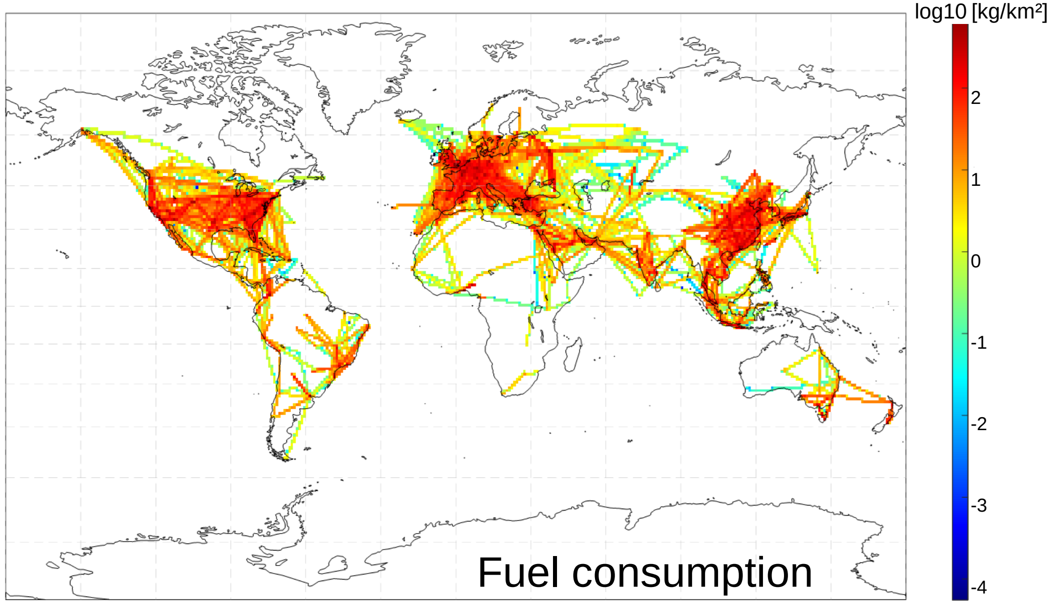
Potential route network for the modelled aircraft in 2040 (own figure)

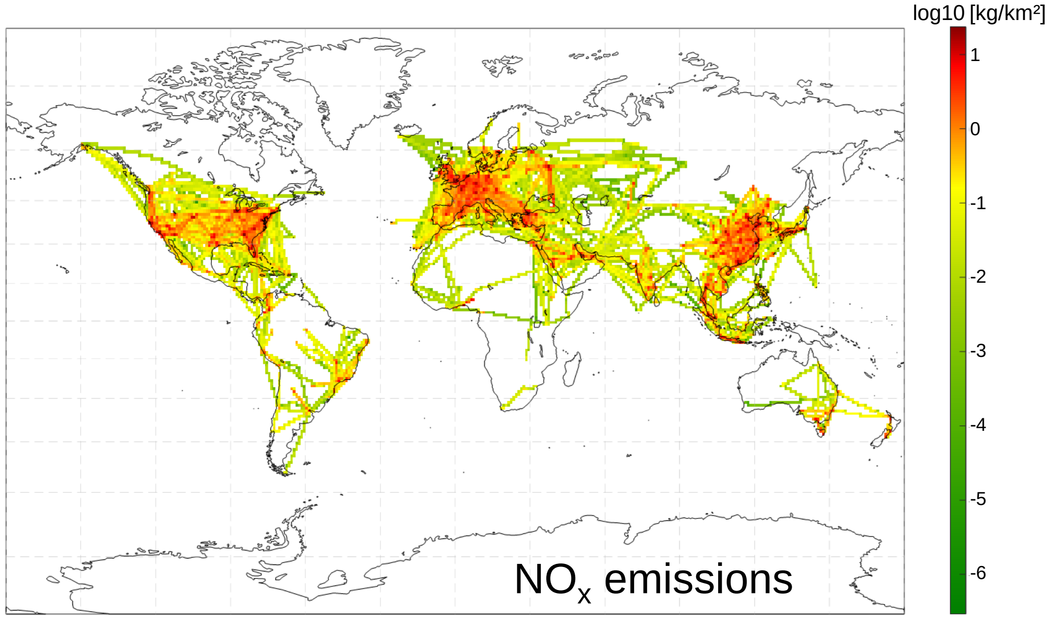
Engine emissions and climate impact assessment
Methodology

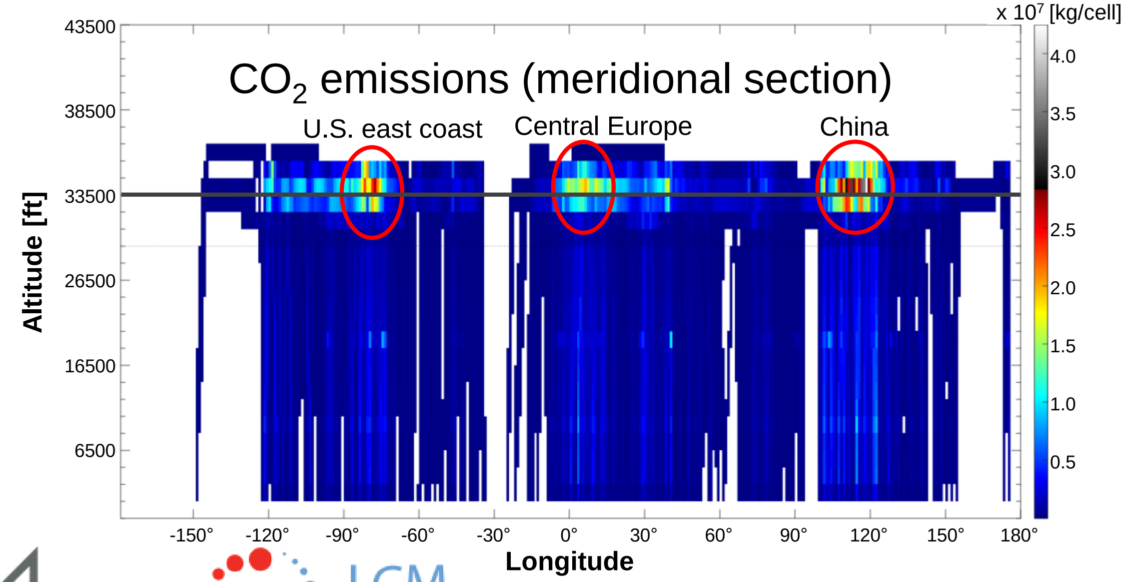


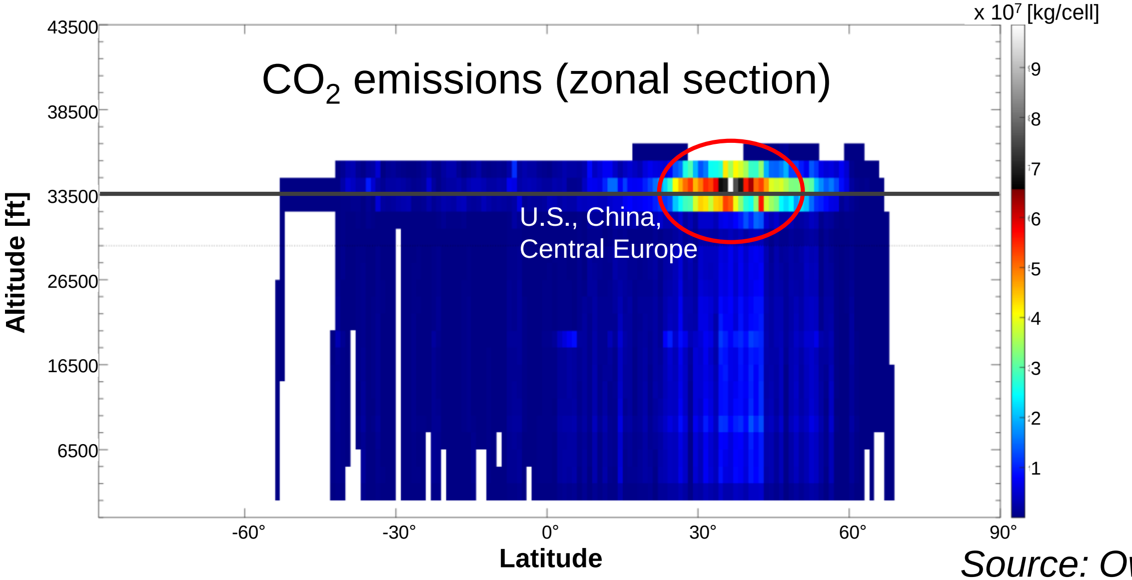
[1] Linke, F., Grewe, V., and Gollnick, V., "The Implications of Intermediate Stop Operations on Aviation Emissions and Climate," *Meteorologische Zeitschrift*, Vol. 26, No. 6, 2017, pp. 697–709.
[2] Dahlmann, K., Grewe, V., Frömming, C. and Burkhardt, U. "Can we reliably assess climate mitigation options for air traffic scenarios despite large uncertainties in atmospheric processes?" Transportation Research Part D 46 (2016) 40–55

Turbofan emissions | Annually aggregated (2040)









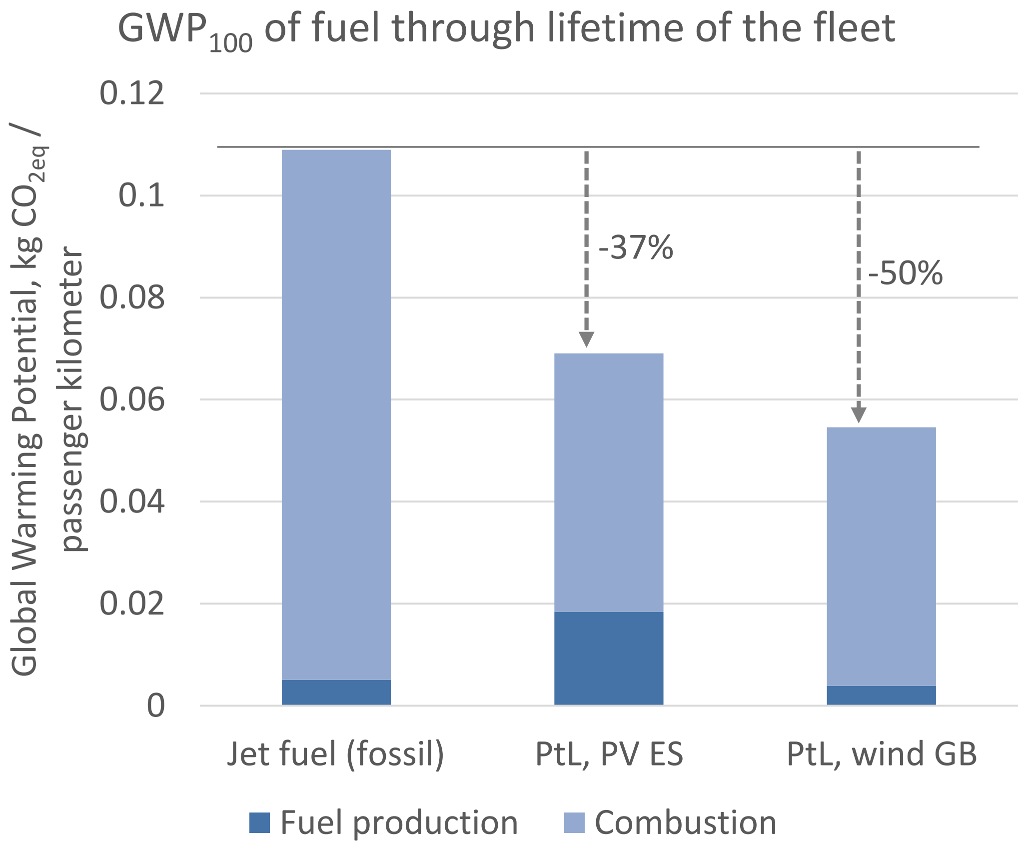
Source: Own figure

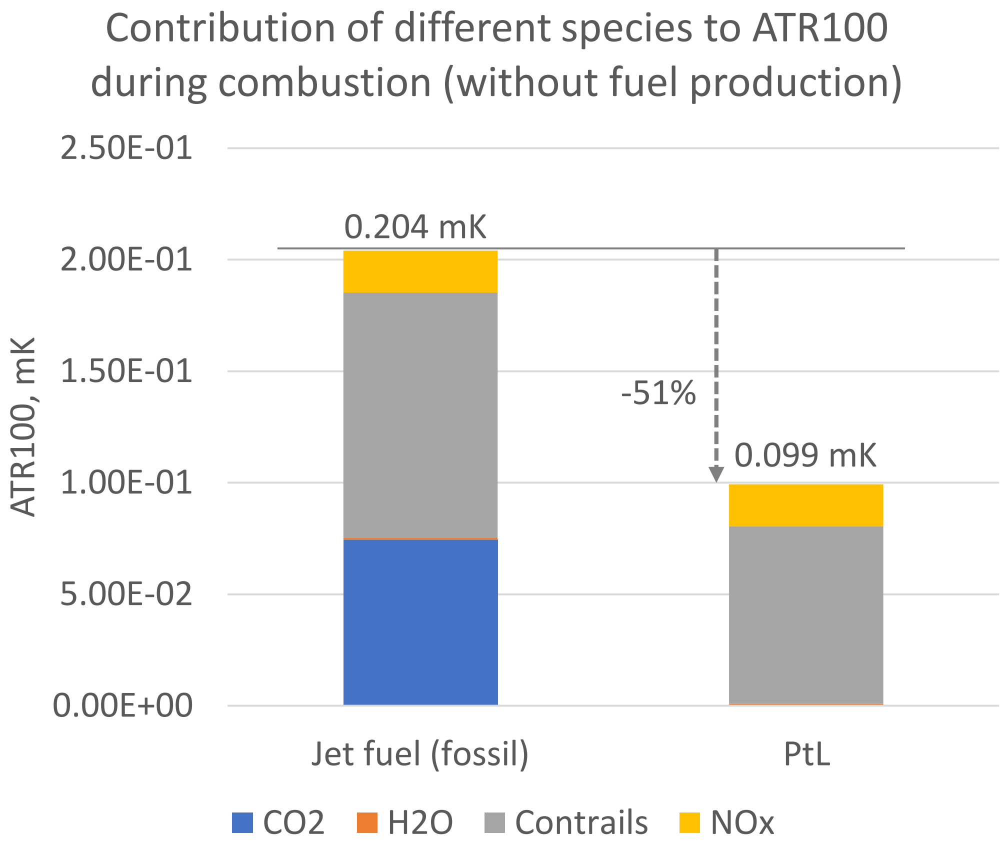
Environmental assessment methodology

Goal: Comparison of the environmental impacts generated by the selected aircraft fleet using different fuels by means of a life cycle assessment (LCA)

Product/System	Narrow-body turbofan aircraft fleet using fossil jet fuel vs. synthetic fuel from renewable energy (PtL)
Geographical boundaries	Global
Temporal boundaries	2040 – 2070
Foreground & background data	Ecoinvent 3.7.1 LCI other studies (secondary data) EXACT project (primary data)
Allocation model	Cut off by classification
Impact assessment method	ILCD 2.0 (2018)
Software	Brightway2 and inhouse software (AirClim)
Functional Unit	1 passenger kilometer

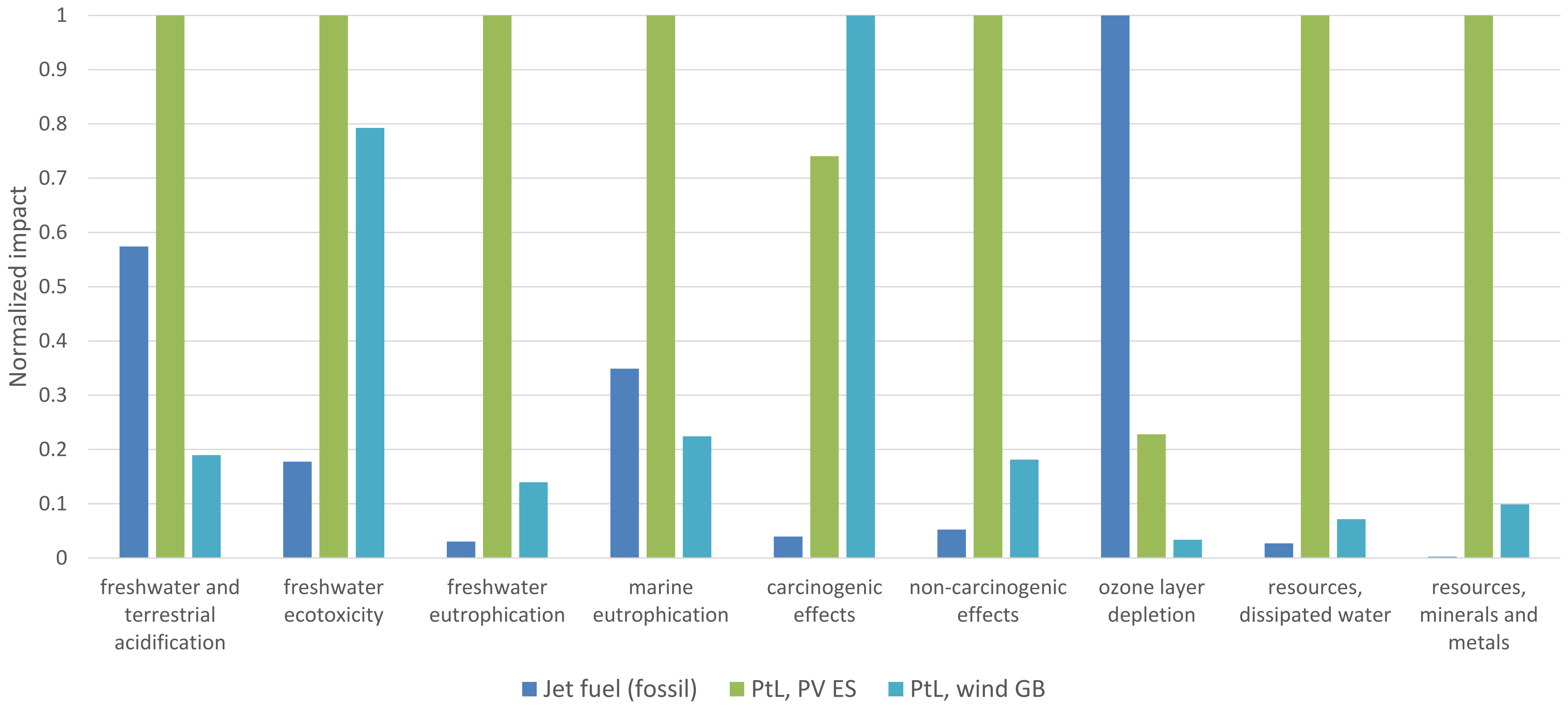
Results of LCA – Climate change





PV ES: multi-Si photovoltaic panels, 3kWp, slanted-roof installation, Spain
Wind GB: wind onshore, 1-3 MW, United Kingdom

Results of LCA – Other impact categories



Summary and Outlook

- The potential of synthetic fuels from renewables to reduce climate impact of aviation has been demonstrated.
- Impact categories with higher burdens of PtL from renewables compared to fossil fuel have been identified.

- Future developments of the energy sector and energy-intensive industry should be taken into account for more consistent assessment of the background activities involved in the lifecycle of the aircraft.
- Reuse and recycling options should be considered for the fuel production technologies to further reduce their environmental impact.

- A combination of different means will be needed to reduce the climate impact of aviation: technological (e.g. new fuels, electrification, etc.) and operational (e.g. climate-optimized flight trajectories).

Thank you for your attention!

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