MSc Aerospace Engineering

2MAE006 - AVIATION and ENVIRONMENT

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# Using AeroMAPS to Simulate Sustainable Aviation Scenarios

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Authors:
PRABHU Nagaraj Ganesh
SHAIK Sajeed Hussain

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# Introduction

The primary goal of this report is to examine prospective sustainable scenarios for the future of air travel using the AeroMAPS tool. This analysis centers on three core components: the volume of air traffic, the composition of the aircraft fleet responsible for this traffic, and the energy sources that fuel these aircraft. To evaluate the consequences of future developments in air transportation, the report conducts assessments that include a climate analysis concentrating on CO2 emissions, an examination of energy resources, and assumptions related to non-CO2 emissions and the composition of the electricity mix.

# 1 Climate analysis focused on $CO_2$ emissions

## 1.1 Assessment of the characteristics of three reference technological scenarios

A comparison is done between scenarios 1,2 and 3 with the estimates of the average $CO_2$ emissions per passenger-kilometer for the aircraft fleet in 2050. A shift towards a balanced energy mix to power the fleet is the only way to reduce these emissions by about 60%. An optimistic development in all technology (scenario-3) and deployment would reduce 80% of these emissions by 2050.

## 1.2 Approach 1: Determining the share of the carbon budget consumed

A yearly trend of 3% growth in air traffic is considered and a comparison between scenarios is done. The advantage of this approach is it gives an understanding of what should be the goals in technological aspects and planning to see a positive change by 2050. Refer to the table for the values of the share of WCB. The disadvantages of this approach are:

- Future carbon budget calculations are based on assumptions, which may not always be accurate. Uncertainty in these predictions can lead to flawed policy decisions.
- Achieving sustainable growth in air travel may require technologies that are not yet fully developed or economically viable.

## 1.3 Approach 2: Determining sustainable air traffic evolution

By setting the share allocated to the aviation sector and controlling air traffic, this approach prioritizes environmental sustainability by setting a clear limit on the carbon emissions from air traffic. It aligns with global efforts to combat climate change and reduce the aviation industry's carbon footprint.

- For an allocation of 3.4%, the only way to meet the growing demand is to shift towards balanced energy mix considering all other developments rate in technological aspects as realistic.
- For an allocation of 2.6%, only the shift is not enough but development of cutting edge technology in all aspects is required and in a faster rate.

The disadvantages of this approach in a practical view are:

- In the initial years, limits on emissions may lead to increased costs for airlines, potentially affecting ticket prices and the overall economic viability of the aviation sector.
- Accurately determining the appropriate carbon budget and fairly allocating it among stakeholders can be challenging and subject to debate.

# 2 Energy resources analysis

## 2.1 Biomass consumption

By shifting towards a balanced energy mix partially relying on bio-fuels and assuming accelerated and realistic growth in technology, the current biomass availability (164EJ) and allocation of 2.3% would not meet the energy need demand in 2050. The availability of biomass should at least be at 302EJ (optimistic) by 2050 to fulfil the demand in the aviation sector. The maximum share of biomass that could be consumed by aviation in a scenario with low biomass availability worldwide and annual air traffic growth of 3% is 15.9%. This is a very pessimistic scenario, and it is unlikely that the actual share of biomass consumed would be this high without any availability, and the sector would have to find alternative ways to meet its energy needs. If only biofuels are used to power the fleet in 2050, even if it results in 3 gCO2/RPK, a total amount of 557EJ (optimistic) of biomass would not be enough. Hence, relying only on biomass and biofuels is not an option.

### 2.2 Electricity consumption

By shifting towards a balanced energy mix partially relying on electro fuels and assuming accelerated and realistic growth in technology, even an optimistic case of electricity availability in 2050 would not meet the required demand. The development and deployment of technology should be ambitious and optimistic only then the electricity available can fulfil the demand. Considering also hydrogen, provided production is not by electrolysis.

Assuming the current total amount of 100EJ electricity availability in 2050, even being optimistic and ambitious in the development and deployment of technology would not fulfill the requirement. If only electro-fuel is used, a total amount of 300EJ (very optimistic) would not be enough.

## 3 Other specific analyses (non-CO2 and electricity mix)

### 3.1 Taking non-CO2 effects into account

Non-CO2 emissions are emissions of other greenhouse gases and contrails. These emissions can also contribute to climate change, but they are not as well-known as CO2 emissions. The results show that the use of avoidance strategies can significantly reduce the temperature rise induced by aviation. For example, in the first scenario, the temperature rise induced by aviation around 5 mK without avoidance strategies, while with avoidance strategies the temperature is actually projected to decrease. This shows that avoidance strategies are a very effective way to reduce the climate impact of aviation. Coupled with the negative traffic growth rate, the equivalent carbon consumption in scenario 1 reduces to 0.1% of the budget which is highly desirable.

The results of the analysis also show that the use of avoidance strategies is becoming more important as the aviation sector grows and has the potential to reduce the climate impact of aviation significantly. As shown in Scenario 3 which is analyzed with a positive growth rate of traffic. For scenarios 2 and 3, the resulting rise in temperature and the equivalent carbon consumption is effectively halved by using these control avoidance strategies.

### 3.2 Electricity mix influence

Electricity is used to produce certain energy carriers, such as hydrogen or electrofuels. Consequently, the sources of electricity used for these processes can determine the environmental characteristics of these energy carriers, as the production of electricity can also emit greenhouse gases. In the representative technology scenario 3, we consider the "Low-carbon" option for electricity production. This option relates to a transition to a relatively low-carbon mix worldwide between 2019 and 2050.

The breakeven year is calculated when the use of the respective fuels will emit less CO2 than the use of kerosene. From the graph, we observe that the breakeven year for hydrogen is 2028 and electrofuels is 2039. This optimistic scenario estimated that hydrogen and electrofuel will be considered ecologically "cheaper" and the transition away from fossil fuels will be encouraged.

## Conclusion

The study found that the environmental transition of the air transport sector is possible but will require a concerted effort from all stakeholders. From the scenarios considered, it is clear that increasing investment in research and development of new technologies, putting a price on carbon emissions and promoting changes in air traffic demand (see scenario 4 proposed), are imperative steps in achieving the proposed emission targets and achieving the environmental transition of the air transport sector.

# Appendix - Table of Results

| Data and questions | Variable in AeroMAPS | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 3B | Scenario 3E | Scenario 4 (S:0.5; M:+0.5; L:+3; F:+3) | Unit | Description |
|---|---|---|---|---|---|---|---|---|---|
| Technological parameters | Aircraft efficiency | Renewal | Accelerated | Ambitious | Ambitious | Ambitious | Accelerated | [-] | Setting of aircraft energy efficiency improvements |
| | Operations | Constant | Realistic | Optimistic | Optimistic | Optimistic | Optimistic | [-] | Setting of flight and ground operations improvements |
| | Load factor | Unambitious | Trend | Ambitious | Ambitious | Ambitious | Trend | [-] | Setting of aircraft load factor improvements |
| | Energy mix | Kerosene | ReFuelEU | ReFuelEU | Biofuel | Electrofuel | ReFuelEU | [-] | Setting of aviation energy mix (excluding hydrogen) |
| | Hydrogen aircraft | Absence | Limited | Ambitious | Ambitious | Ambitious | Limited | [-] | Setting of hydrogen aircraft introduction into the fleet |
| | Biofuel production | / | Current | Low-carbon | Low-carbon | Low-carbon | Current | [-] | Setting of biofuel production characteristics |
| | Hydrogen production | / | Gas without CCS | Electrolysis | Electrolysis | Electrolysis | Gas with CCS | [-] | Setting of hydrogen production characteristics |
| | Electricity production | / | Low-carbon | Dedicated low-carbon | Dedicated low-carbon | Dedicated low-carbon | Low-carbon | [-] | Setting of electricity production characteristics |
| 1.A. | / | 90.5 | 36.2 | 13.7 | | | 31.5 | [gCO2/RPK] | Average global $CO_2$ emissions per passenger-kilometer for the aircraft fleet in 2050 |
| 1.B. | / | 5.4 | 3.6 | 2.8 | | | 2.3 | [%] | Share of the world carbon budget consumed by aviation for an annual air traffic growth of 3% |
| 1.C. | "Air traffic" variables | -0.8 | 2.5 | 5 | | | S:+3 ; M:+3; L:+4; F:+5 | [%] | Annual air traffic evolution for balancing the aviation carbon budget for a 3.4% allocation |
| | | -3.5 | -0.2 | 2.3 | | | S:+1; M:+3; L:+3; F:+4 | [%] | Annual air traffic evolution for balancing the aviation carbon budget for a 2.6% allocation ⚠ **You will keep this value in the following** |
| 2.A. | / | 0 | 1.5 | 3 | 8.6 | 0 | 2.4 | [%] | Share of the world biomass consumed by aviation in 2050 |
| 2.B. | / | 0 | 2.1 | 5.1 | 2.9 | 9.4 | 4.4 | [%] | Share of the world electricity consumed by aviation in 2050 |
| 3.A. | Without "contrails avoidance strategies" | 52 – 5.1 | 65.9 – 19 | 82.1 – 35.2 | | | 78.2 – 31.3 | [mK] | Total temperature rise in 2050 - Temperature rise between 2019 and 2050 |
| | | 1.1 | 3.8 | 7.1 | | | 5.8 | [%] | Share of the world equivalent carbon budget consumed by aviation without contrails avoidance strategies |
| | With "contrails avoidance strategies" | 46.5 - -0.4 | 54.7 - 7.8 | 82.1 - 18.4 | | | 62.5 – 15.6 | [mK] | Total temperature rise in 2050 - Temperature rise between 2019 and 2050 |
| | | 0.1 | 1.6 | 3.4 | | | 2.9 | [%] | Share of the world equivalent carbon budget consumed by aviation with contrails avoidance strategies |
| 3.B. | Low-carbon for Electricity production | | | 2031 – 2039 | | | 2028 – 2039 | [yr] | Break-even years when hydrogen and electrofuels become more interesting than kerosene |