Are Electricity and Hydrogen the solutions to reduce CO₂ emissions?

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Forum 3AF : To Reinvent Air Transport

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1. Motivation

Is it possible to reduce the CO2 emissions caused by the aviation industry without compromising on other aspects? (travel time, comfort, logistics...)

What are the possible alternatives?

2. Today's Air Travel: two case studies

- To analyse the emissions caused by different means of transportation in different situations, two particular cases were studied:
 - Porto Barcelona (Portugal + Spain)
 - Córdoba Tucumán (Argentina)

- Main characteristic:
 - Cities with no direct connections by train

Case Study: Porto - Barcelona

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Case Study: Porto - Barcelona

• Transports chosen:

- Conventional aircraft ATR 72-600 (load factor: 80% max capacity)
- Car Volkswagen Golf using diesel (occupancy rate: 2 pax)
- Electric car Tesla Model 3 (occupancy rate: 2 pax)
- Public transportation available (train + bus)

• In all cases, only direct emissions are considered

Case Study: Porto - Barcelona



Case Study: Córdoba - Tucumán



• Travel options:



Source: Ministerio de Transporte, Argentina

Case Study: Córdoba - Tucumán

- Transports chosen:
 - Conventional aircraft Embraer RJ-190 (load factor: 83%)
 - Car Volkswagen Golf using gas (occupancy rate: 1.6)
 - Bus using diesel (35 pax per service)
 - Train diesel-electric (T-R: 422, R-C: 237 average pax/train)

• In all cases, only direct emissions are considered

Case Study: Córdoba - Tucumán



3. Reinvent Air Travel

- Kerosene produces an unacceptable quantity of CO2 emissions.
- Is there a better alternative to conventional aviation?
- Two innovative alternatives are proposed:
 - Electric aircraft
 - Aircraft using hydrogen propulsion

• The electric aircraft is a good solution to provide a fast travel time while having lower CO2 emissions than when using a conventional aircraft.



Alice aircraft by Eviation



Tool composed of models that compute CO2 emissions associated to each phase

• CO2 emissions for the electric aircraft are highly dependable on the production of electricity.







Electric aircraft is not useful when emissions for production of electricity > 650 gCO2/kWh

• Results for the <u>electric aircraft</u> applied to the study cases:



• What percentage of the population can benefit of the advantages of an electric aircraft nowadays?



Electric aircraft can greatly decrease CO2 emissions for air travel

But...

Emissions depend on countries manner of producing electricity

Solution is only feasible for short haul flights (technological limitations)

Aircrafts under development have a small number of seats





Source: A320 AIRCRAFT CHARACTERISTICS - AIRPORT AND MAINTENANCE PLANNING. AIRBUS S.A.S. Customer Services. Issue: Sep 30/85 - Rev: Dec 01/20



"Well to wake" CO2 emissions Kerosene 0.6 LH - Fossil electrolysis CO2 emissions [kgCO2/pax/km] LH - Low-carbon electrolysis 0.5 0.4 0.3 0.2 0.1 4000 4500 5000 5500 6000 Range [km]

Hydrogen aircraft produce less CO2 emissions <u>only if</u> hydrogen production is lowcarbon

Hydrogen vs. Conventional

• Results for the <u>hydrogen aircraft</u> (low-carbon hydrogen production) applied to the study cases (only fuel "well to wake" emissions are considered):





Conclusions

Are Electricity and Hydrogen the solutions to reduce CO₂ emissions?

Electric aircraft

Emissions depend on production of electricity

Non-homogeneous value of kgCO2/pax/km

Technical limitations that lead to short range

Hydrogen aircraft

Emissions depend on production of hydrogen

Key development: lighter hydrogen tanks

New designs to store high volumes of fuel