Air Transportation and the Environment

Andreas W. Schäfer
(a.schafer@UCL.AC.UK)

Air Transportation Systems Laboratory, UCL Energy Institute,
University College London

66th LCA Discussion Forum
LCA of Mobility solutions: approaches and findings
Wednesday, 30 August 2017, ETH Zürich, Alumni Pavilion
About Air Transportation Systems Lab

Air transportation is a vital enabler of growth in the economy and quality of life through empowering trade and tourism. At the same time, its large and still growing scale generates undesirable effects, such as air traffic delays and environmental impacts at the local, regional, and global level. Emerging from the Institute for Aviation and the Environment at the University of Cambridge, the Air Transportation Systems Laboratory at University College London (UCL) explores the interaction between air transportation, the economy, and the environment.
What Makes Air Transportation Different?

- Comparatively small share in CO₂ emissions (≈ 2.5%) but high growth in demand (≈ 5.3%/yr) and fuel use (≈ 3.6%/yr, since 1980)
- Warming impact of non-CO₂ emissions ≈ CO₂ emissions
- Aircraft noise and LAQ are additional, important concerns
- (Potentially) higher energy intensity than surface modes
- Significantly reducing emissions more challenging
  - Saving fuel imperative for industry survival
  - Numerous design trade-offs under binding environmental constraints
  - Reliance on high-energy density fuels → limited opportunities for fuel switching
  - Very high capital intensity
Energy Intensity and Systems Scale
Total Passenger Mobility Growth (1950-2005)
Shift Toward Faster Modes (1950-2005)

Public Transport Modes (%PKT)  Light-Duty-Vehicles (%PKT)  Aircraft (%PKT)

Air Transportation Demand Projections

\[
\frac{\text{CO}_2}{\text{RPK}} = \text{CO}_2\text{EF} \cdot \frac{Q \cdot \text{SFC}}{\text{PAX} \cdot V \cdot L/D} \cdot \frac{W_F}{\ln\left(\frac{W_0}{W_0 - W_F}\right)}
\]

In equation (1), \(\text{CO}_2\text{EF}\) is the \(\text{CO}_2\) emissions factor (87.6 g\(\text{CO}_2\) MJ\(^{-1}\) for Jet A-1 fuel on a life cycle basis, that is, after accounting for upstream emissions with respect to crude oil extraction, transportation, refining, jet fuel distribution and storage, which represent around 21% of the fuel carbon-related \(\text{CO}_2\) emissions\(^{14}\)), \(Q\) is the fuel’s lower heating value (42.8 MJ kg\(^{-1}\) for jet fuel), SFC is the engine-specific fuel consumption (fuel burn per unit thrust), \(\text{PAX}\) is the number of passengers, \(V\) is the aircraft speed, \(L/D\) is the lift-to-drag ratio, \(W_F\) is the fuel weight before takeoff, and \(W_0\) is the aircraft weight at takeoff. Hence, aircraft \(\text{CO}_2\) intensity can be reduced through fuels containing less carbon on a life cycle basis, higher engine efficiency, a larger number of passengers, higher aerodynamic efficiency, and a lower structural weight (a smaller \(W_0 - W_F\)). Note that the variables in equation (1) are interrelated. Thus, changing one variable will lead to changes in others, typically offsetting part of the impact on \(\text{CO}_2/\text{RPK}\).
Costs of Mitigating CO₂ Emissions

- US Domestic Air Transportation Market
- Narrowbody A/C (B737, A320, Bombardier CSeries)
  - 55% of departures
  - 60% of commercial A/C fleet
  - 75% of fuels and CO₂
  - 80% of RPK
- 20+1 CO₂ mitigation measures
  - Technology retrofits and new aircraft
  - Synthetic cellulosic biomass-based fuels
  - Operational measures (ground and air)
  - Airline business strategies (incl. early retirement)
CO$_2$ Intensity, Mitigation Costs, and Stabilization Wedges

(US domestic air transportation, narrow body aircraft)

Open Source Aviation Integrated Model
The Rebound Effect in Aviation

Other Model Applications

• Environmental and economic implications various carbon tax schemes (recycling, transfers to less developed countries, etc.)

• ACCLAIM: Simulate the local and global implications (air transportation system, economic, environmental) from expanding airport capacity at any airport, world-wide (in progress)

• Understanding the environmental impact of (hybrid-) electric aircraft on air transportation related GHG emissions (in progress)

• Others, see publications section of website
Electric Aircraft Ecosystem
Projected Electric Aircraft Network (2050)