A Comparison of Aviation Greenhouse Gas Emission Mitigation Policies for Europe

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Air Transport in Europe

- European RPKM growth of ~3%/year forecast (Airbus, Boeing)
- Several EU emissions targets which affect aviation
  - Emissions trading scheme sets cap on CO$_2$ from included sectors
    - Aviation in EU ETS from 2012
    - Cap for aviation = 97% of average 2004-2006 emissions
    - Airlines can also buy allowances from other sectors
  - UK target – reduce 2050 aviation emissions to below 2005 levels
- Strong political pressure to reduce aviation impacts
  - E.g. Protestors camping at Heathrow
EU Emissions – Change since 1990

Total emissions (sectors 1-7, excluding 5. LULUCF)
- International maritime transport
- International aviation
- 6. Waste
- 4. Agriculture
- 3. Solvent and Other Product Use
- 2. Industrial Processes
- 1.B. Fugitive Emissions from Fuels
- 1.A.5. Other (Not elsewhere specified)
- 1.A.4. Other Sectors
- 1.A.3. Transport
- 1.A.2. Manufacturing Industries and Construction
- 1.A.1. Energy Industries
- 1.A. Fuel Combustion - Sectoral Approach

% change compared to 1990
- EU27 - Tg (million tonnes)
- 2007

[Source: EEA]
Possible Mitigation Measures

• Economic – e.g. EU ETS
  - Increases cost to airlines and/or passengers
  - May reduce demand and/or induce other measures
  - Demand reduction also possible through mode shift – e.g. to high-speed rail

• Technological
  - Retrofits to existing aircraft – e.g. winglets
  - Radical new technology – e.g. Open rotors, BWBs
  - New fuels

• Operational
  - Improved air traffic control
  - CDAs
Possible Mitigation Measures

- Greatest results likely from a combination of measures
- Complicated interactions – not necessarily additive
  - E.g. Applying engine upgrade kit, then re-engining
- Effects dependent on future demand, oil price, carbon price
- Integrated modelling useful in assessing policy results...
Aviation Integrated Modelling

- **Goal:** Develop integrated assessment tool for aviation, environment & economic interactions at local & global levels, now and into the future
  - Assess policies to strike appropriate balances between economic benefits and environmental impact mitigation
  - Independent & transparent tool for mediating between stakeholders

- **Duration:** 3-year “Phase 1” initiated in October 2006

- **Funding from:**

- **Considerable input from UK OMEGA projects for this study**
AIM Policy Assessment

- Aircraft Movement
- Global Climate
  - Global Environment Impacts
- Airport Activity
- Air Quality & Noise
  - Local Environment Impacts
- Aircraft Technology & Cost
  - Local/National Economic Impacts
- Air Transport Demand
- Regional Economics

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Goals

- Simulate emission rates by aircraft type, and the associated direct operating costs

Methodology

- Below 3000 feet: ICAO Exhaust Emission Data, Reference LTO Cycle
- Above 3000 feet: Eurocontrol Base of Aircraft Data (BADA)
- Three size and two technology age categories
- Simple fleet turnover model for introduction of new technology
Air Transport Demand

Goals

- Forecast true origin-ultimate destination passenger and freight demand for air travel
- Global set of 700 cities, 95% of scheduled RPKM

Methodology

- Simple gravity-type model
- Demand is a function of population, income, fare, travel time, road/high-speed rail links etc.
- Estimate separately for short-, medium-, long-haul and different world regions
- Modular – can plug in other projections if required
Airport Activity

Goals
• Generate flight schedules
• Predict delay and LTO emissions

Methodology
• Flight routing and scheduling modelled according to forecast passenger demand
  • Routing network scaled from base year
  • Proportion of flights of each aircraft type estimated using a multinomial logit regression
  • Flight frequencies applying estimated base year load factors
• Flight delay modelled using queuing theory
• LTO emissions estimated according to schedule, delays, and engine emission rates
**Goals**

- Simulate the location of emissions release from aircraft in flight, accounting for ATM inefficiencies

**Methodology**

- Calculate optimal routes between given city pairs, e.g. great circle
- Add “inefficiency factors” to account for air traffic control

*Great circle route 2146 nm
Actual route 2225 nm (3.6% inefficiency)*
Mitigation Measure Scenarios

- Reference case – no measures
- EU ETS only (from 2012)
- ...plus SESAR, airline responses
  - SESAR, open rotors from 2020
  - Retrofits and increased maintenance from present day
- ...plus biofuels (from 2020)
  - Production capacity increase limited
- ...plus High-Speed Rail
  - UK, French, German, Spanish and Italian proposed new lines

Scenarios use OMEGA data
Economic Scenarios

Three main scenarios, using preliminary UK CCC data:

- **CENTRAL**
  - Mid-range GDP growth, oil and carbon prices
  - 2020 Oil price: $74/bbl, Carbon price $63/tonne CO₂

- **LOW**
  - Low GDP growth, oil and carbon prices
  - 2020 Oil price: $56/bbl, Carbon price $27/tonne CO₂

- **HIGH**
  - High GDP growth, oil and carbon prices
  - 2020 Oil price: $139/bbl, Carbon price $86/tonne CO₂

- Biofuel price assumed $0.70/l (or oil price if higher)
Geographic Scope

- Europe model: 173 Cities (337 airports)
- UK Subset: 17 Cities (37 airports)
- Other destinations modeled at region level only
Results - RPKM

- Most measures have small effect on RPKM only (<10%)
- Greatest effects:
  - Carbon trading with high prices and low technology availability
  - High-speed rail

![Graphs showing RPKM trends over time for different scenarios](image-url)
Results - RPKM

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Results - RPKM

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Results – CO₂

• Results differ strongly by scenario...

(a) Europe 'Domestic' Central

(b) UK Domestic Central
Results – CO$_2$

- Results differ strongly by scenario...
Results – CO₂

• Results differ strongly by scenario...

(e) Europe 'Domestic' High

(f) UK Domestic High
Measure Uptake by Scenario

(a) Central, all policies
(b) Low, all policies
(c) High, all policies

Aircraft
Year

2010 2030 2050

Aircraft
Year

2010 2030 2050

Aircraft
Year

2010 2030 2050

- Total Fleet
- Engine Upgrade
- Winglet Retrofit
- Aero Maintenance
- Engine Maintenance
- Open Rotor
- SESAR
- Biofuel
Results- CO$_2$

• Reducing year-2050 fuel lifecycle CO$_2$ emissions to below year-2005 levels may be possible if:
  - Aviation-suitable biofuels are developed, and
  - Aviation is added to the EU ETS, and
  - Future carbon+oil prices follow Central or High trajectories

• SESAR, high-speed rail (all scenarios) and open rotors (High scenario only) can also make significant contributions to emissions reductions
Biofuels – potential problems

• Biofuel scenarios → reduction in lifecycle CO₂
  - Airborne CO₂ little-changed
  - Noise, local emissions also little-changed

• Biofuel land use – by 2050 ~size of England
Conclusions of Study

• Complex interactions - uptake of one mitigation measure can lower future uptake of other measures

• Depending on the scenario and assumptions, reductions in airborne CO₂ over reference case seem possible by 2050
  - Up to 10% (ETS only)
  - 20-30% (ETS+non-biofuel abatement measures)

• Strongest reduction in lifecycle aviation emissions (under assumptions used here) is ETS+biofuels
  - Lifecycle CO₂ emissions below 2005 levels in 2050
  - Requires central-high oil and carbon prices
  - However, noise, local and airborne emissions will be little-changed from reference case
  - Cellulosic biomass fuel → land area problems?
AIM Team

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