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Institute for Aviation and the Environment

The Impact of Economic Emissions Mitigation Measures on Global Aircraft Emissions

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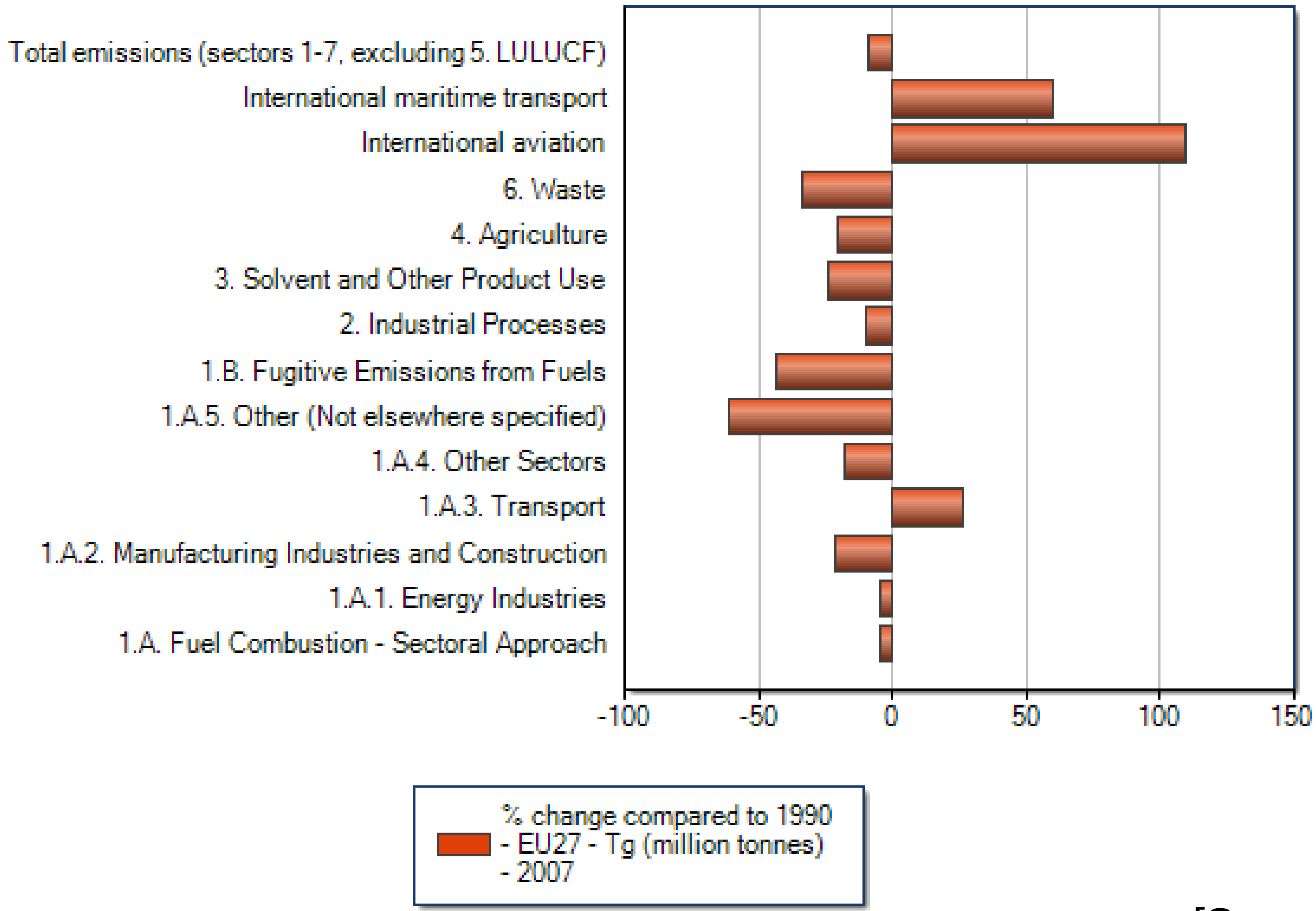
Global Air Transportation

- Contributes about 4.5% of global GDP (IATA 2000)
- About 3% of global energy-use-related emissions (IEA 2008)
- Global RPK growth of ~5%/year forecast (Airbus, Boeing 2009)
  - Even with optimistic reductions in carbon intensity, aviation emissions are likely to grow
- Emissions from other sectors have been decreasing in some regions (e.g. the EU)
  - Aviation potentially a target for emissions reduction policies

EU Emissions – Change since 1990



[Source: EEA]

Emissions Trading

- Basic principle: “Cap and Trade”
  - Set a cap on emissions for a given year (e.g. 10,000 tonnes of CO_2)
  - The number of available allowances adds up to this amount (e.g. 10,000 permits for 1 tonne of CO_2)
  - Allocate these allowances to emitters by some method (often based on past emissions)
  - Allow trading in allowances to account for difference in ease/cost of reducing emissions
    - Emissions > Number of allowances → Buy allowances
    - Emissions < Number of allowances → Sell allowances

- Should theoretically result in lowest-cost pollution reduction solution

Emissions Trading

- Main existing CO_2 emissions trading scheme is the EU ETS
  - Sets cap on CO_2 from included sectors only
  - Cap for aviation = 97% of average 2004-2006 emissions, from 2012
  - Airlines can also buy allowances from other sectors
- Some proposed US GHG emissions trading schemes include aviation indirectly
- Global emissions trading has been proposed (e.g. CCSP 2007)
  - Significant political challenges
  - Allows direct (if uncertain) link between global temperature rise and emissions cap

Stringency Levels

- Stern (2007) – link between chance of temperature rise and atmospheric GHG stabilisation level:

Stabilisation level (CO_2e)	Risk of exceeding 2°C	Risk of Exceeding 3°C	Most likely temperature rise
750ppm	90-100%	60-99%	3-4°C
650ppm	82-100%	44-94%	2-3°C
550ppm	63-99%	21-69%	2-3°C
450ppm	26-78%	4-50%	1-2°C

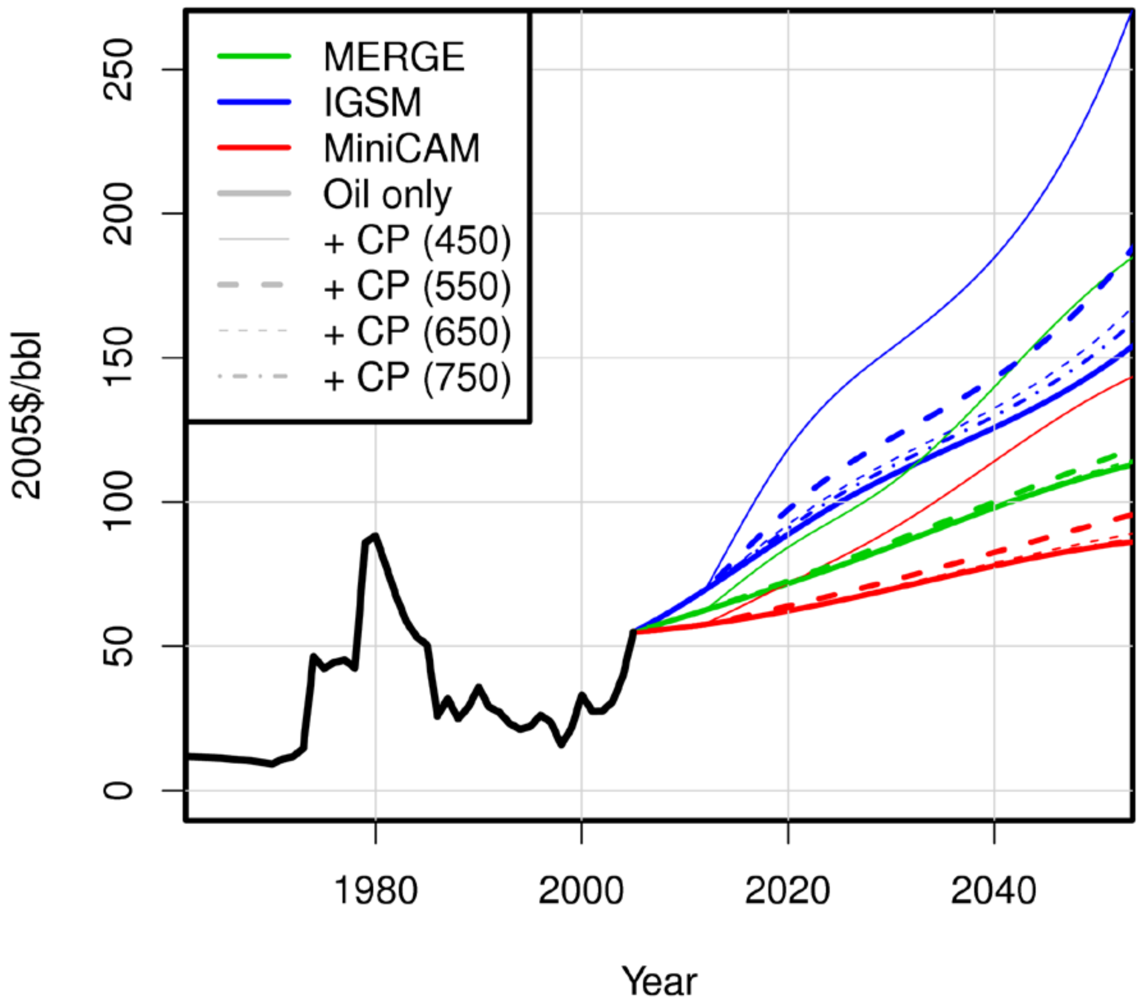
  - 550 ppm CO_2e is equivalent to around 440-500 ppm CO_2

- EU goal is to limit emissions rise to 2°C
- In this study we use CCSP (2007) global emissions trading scenarios for carbon price and other variables by stringency level

CCSP Global Emissions Trading Scenarios

- Main differences between scenarios:
  - Fuel price
  - Carbon price
    - Higher at greater stringency
  - GDP
    - Slightly lower at greater stringency
  - Population
    - Small variation

Forecast Oil + Carbon Prices



[Data: CCSP(2007)]

Responses to Emissions Trading

- Demand
  - ETS increases cost to airlines and/or passengers
  - **May reduce demand and/or induce emissions-saving 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

For this study:

- Identify the effects of global emissions trading on aviation RPK, emissions and technology uptake
  - E.g., How is the fleet affected by emissions trading?
  - How much are emissions reduced by demand increases, and how much by alternative technologies?
  - What is the relationship between stringency level and system changes?
- Assume a range of available technology options for emissions reduction
  - Retrofits (e.g. Winglets, engine upgrade kits)
  - Improved ATM – non-optional
  - Increased maintenance
  - 20% cellulosic biomass fuel blend – from 2020
  - Open rotor short-haul aircraft – from 2020
- Requires integrated assessment modelling...

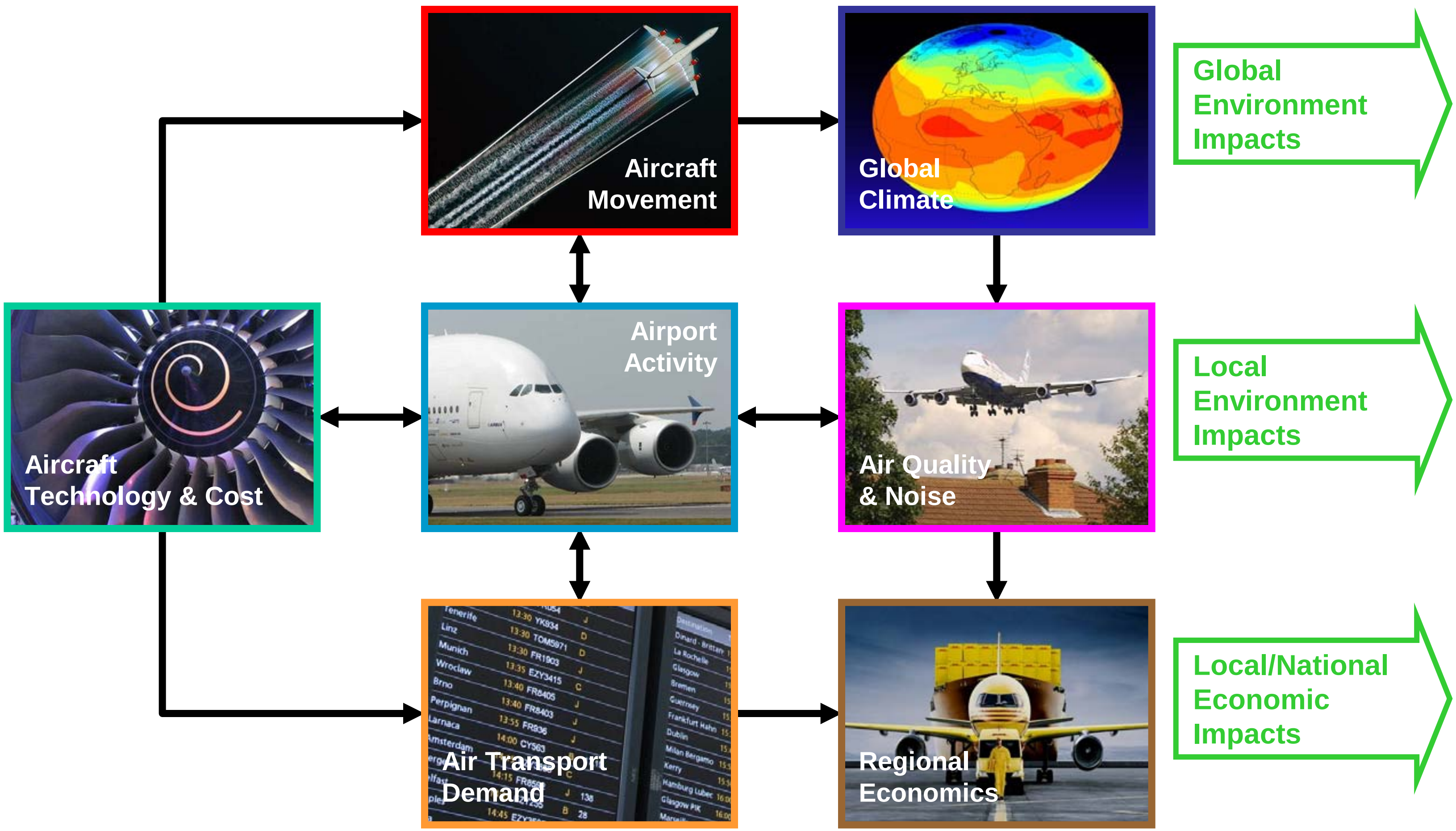
Aviation Integrated Modelling

- 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

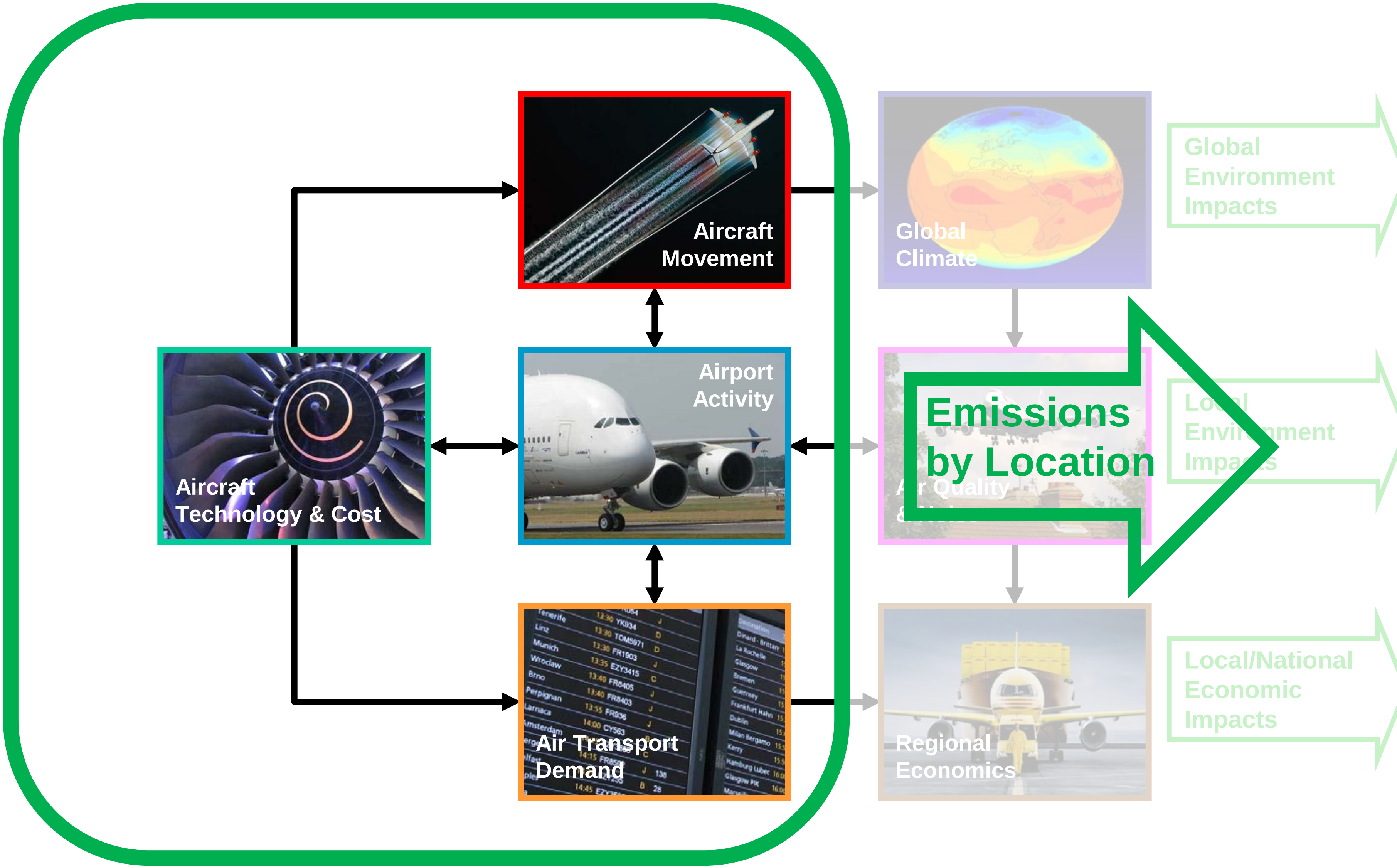
- Funding from: EPSRC Engineering and Physical Sciences Research Council; Natural Environment Research Council

- Considerable input from UK OMEGA projects for this study

AIM Policy Assessment



AIM Policy Assessment



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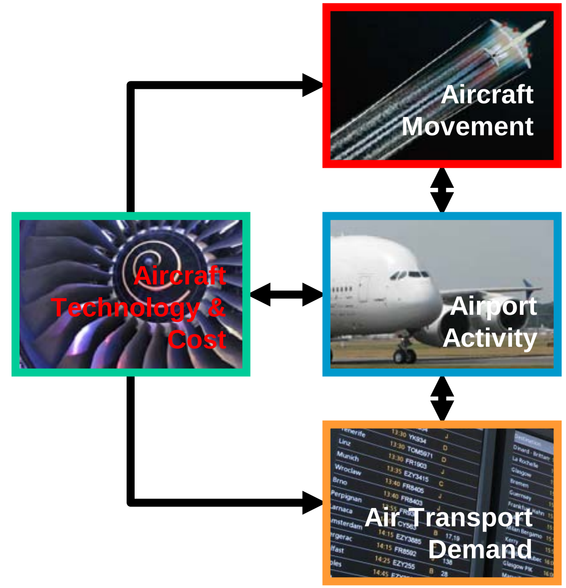
Aircraft Technology & Cost



Goal

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

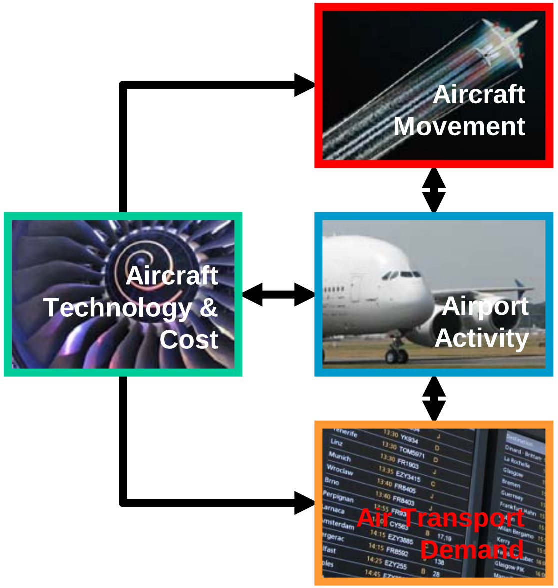
Methodology

- 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

Goal

- Forecast true origin-ultimate destination demand for air travel
- Global set of 700 cities, 95% of scheduled RPK



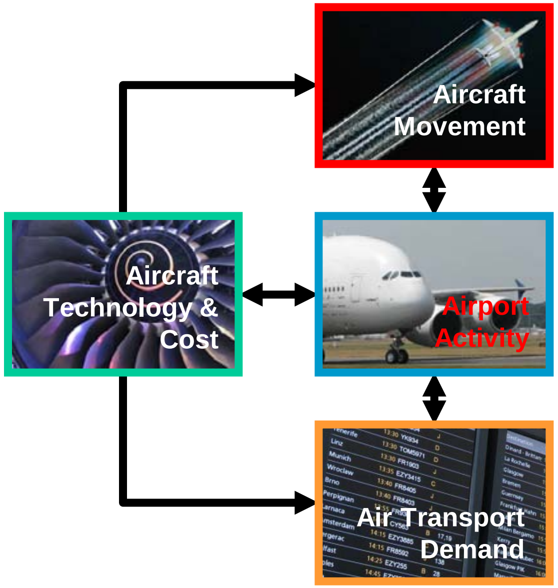
Methodology

- 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

Goal

- Generate flight schedules
- Predict delay and LTO emissions



Methodology

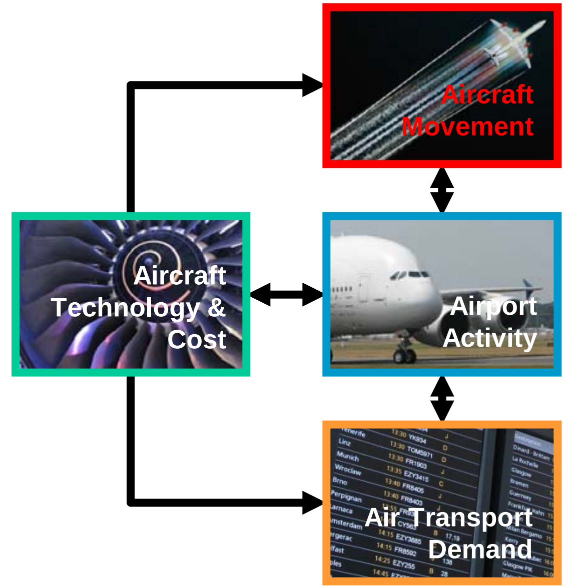
- Flight routing and scheduling modeled according to forecast passenger demand
    - Routing network scaled from base year
    - Proportion of flights of each aircraft size estimated using a multinomial logit regression
    - Flight frequencies applying estimated base year load factors
- Flight delay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

Aircraft Movement

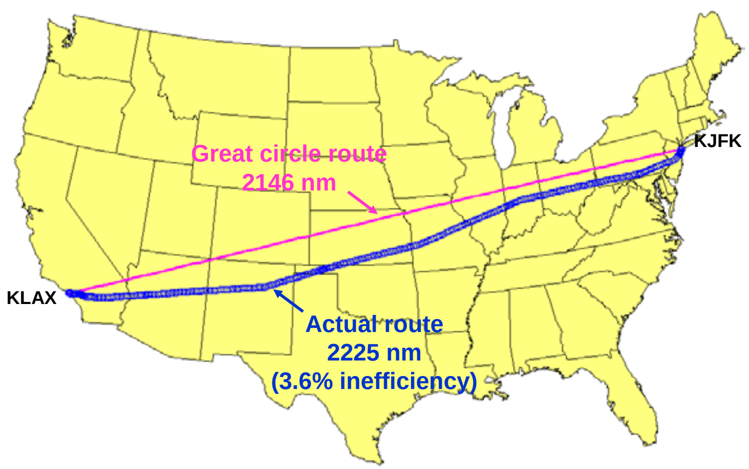
Goal

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

Methodology

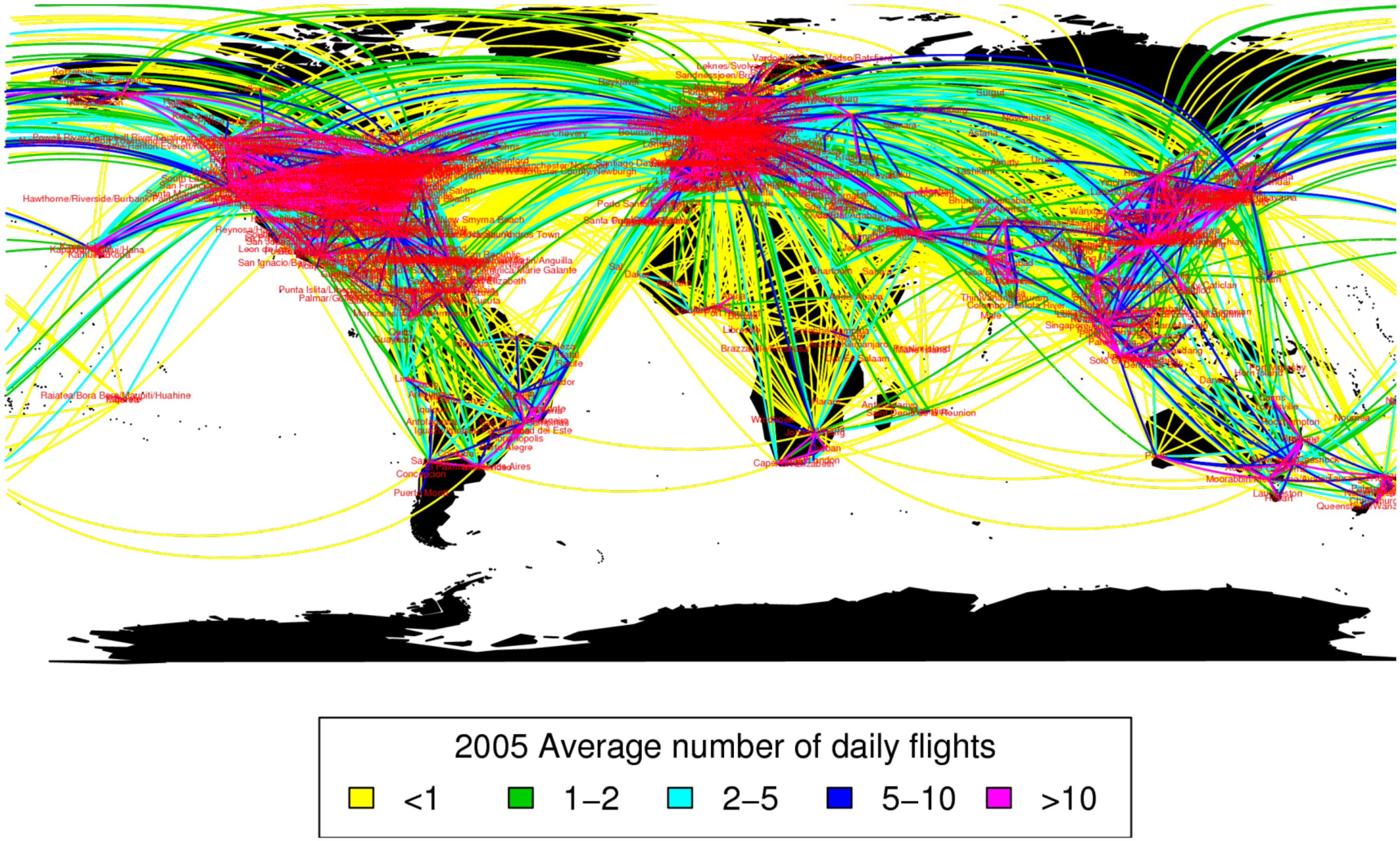


- Calculate optimal routes between given city pairs, e.g. great circle
- Add "inefficiency factors" to account for air traffic control



Geographic Scope

- Global model – 95% of scheduled RPK

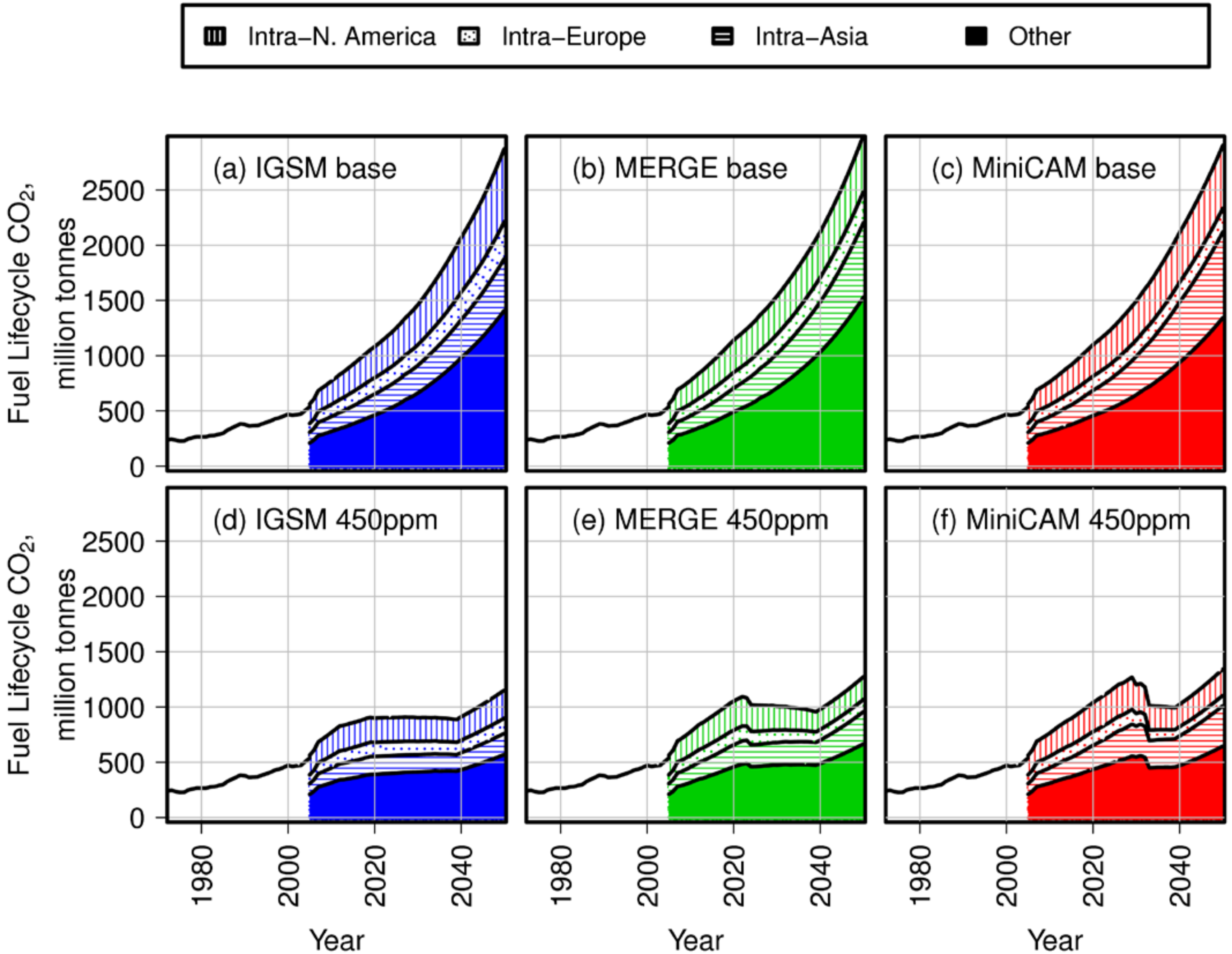


[Data: OAG(2005)]

Results- Fuel Lifecycle CO_2

No Emissions Trading

Global Emissions Trading with 450 ppm Stringency

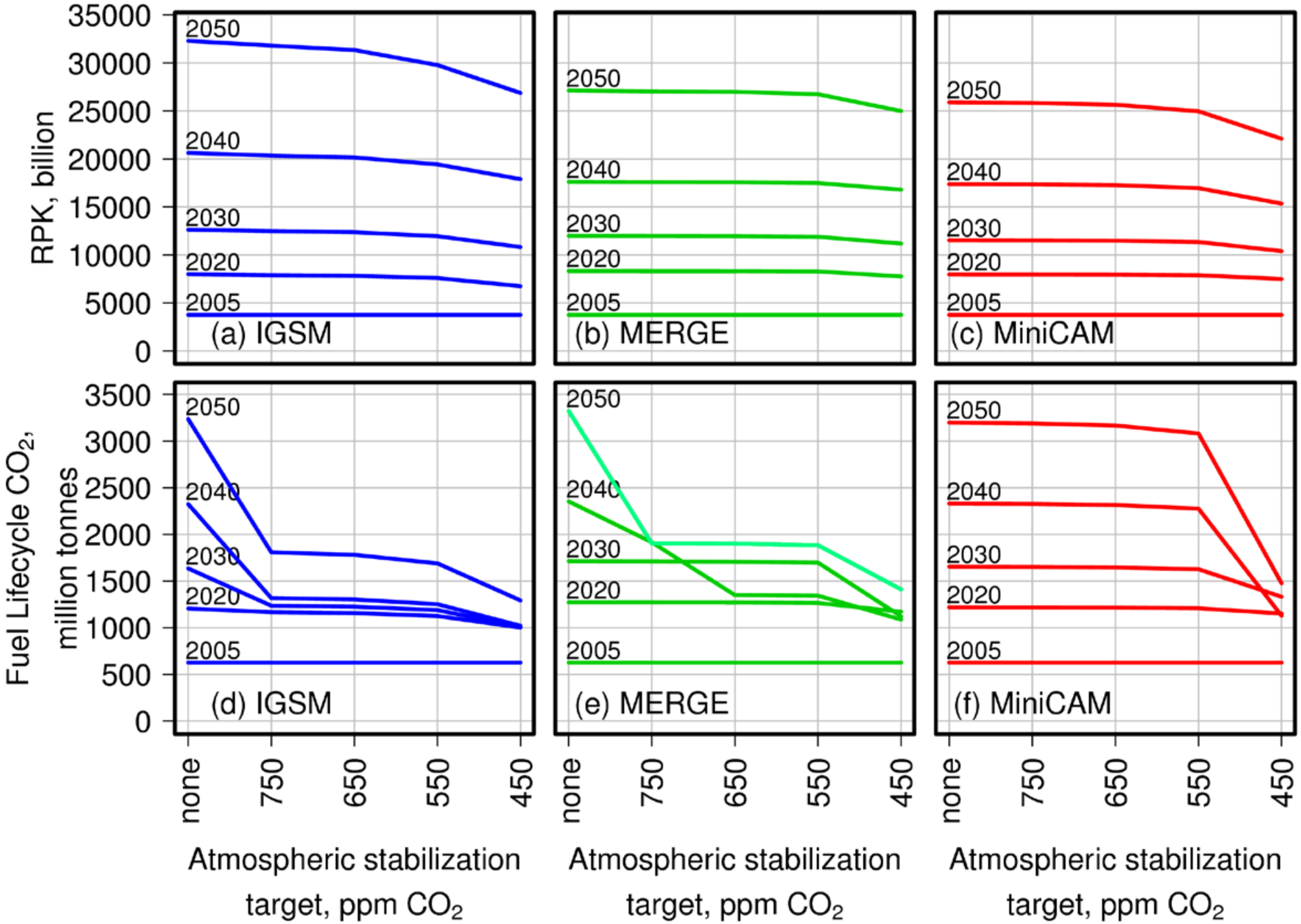


[Past data: IEA]

Results by CO_2 Stringency

RPK

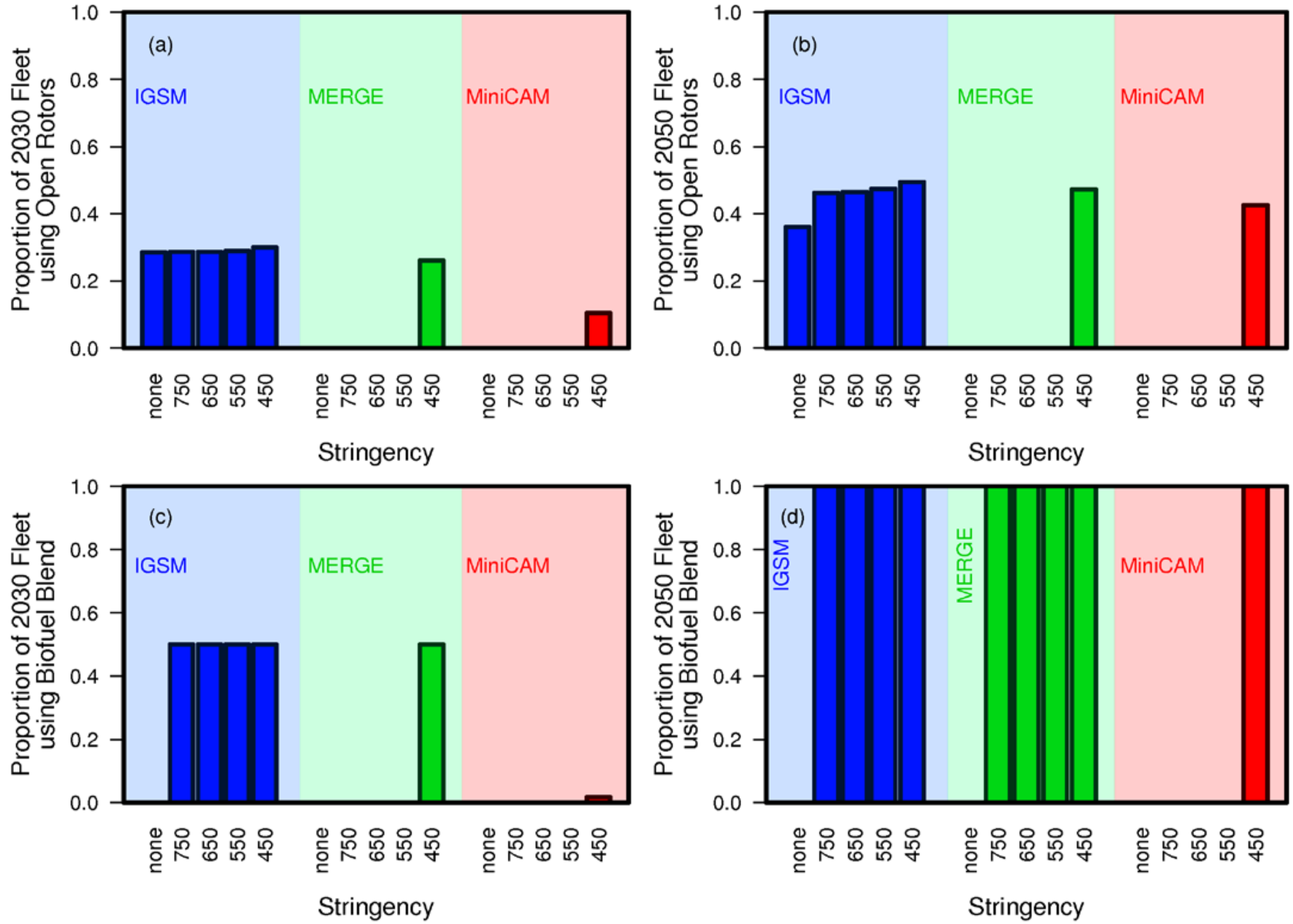
Fuel Lifecycle CO_2



Principal Technology Adoption

Open Rotor Aircraft

Biofuels



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Conclusions of Study

- Aviation emissions grow in all scenarios
  - However, emissions will decrease in other sectors due to emissions trading
  - Geographic location of growth varies
- Largest reduction in 2050 emissions relative to no-trading case: ~60% (450 ppm, IGSM)
  - 1/3 of reduction due to demand reduction, 2/3 due to technology adoption
  - Greatest new-technology adoption for narrowbody open rotor engine aircraft and cellulosic biomass aviation fuel
- Low stringencies (750-550ppm) vary in effect based on how oil price compares to biofuel price

AIM Team

Core team:

- Dr. Andreas Schäfer *(Principal Investigator)*
- Dr. Lynnette Dray *(Air Transport Demand)*
- Dr. Antony Evans *(Airport Activity)*
- Dr. Helen Rogers *(Global Climate)*
- Dr. Maria Vera Morales *(Aircraft Technology and Cost)*

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- Prof. Peter Haynes *(Applied Maths)*
- Prof. Roderic Jones *(Chemistry)*
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