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Institute for Aviation and the Environment

Understanding Aviation Emissions on the Global Level

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Advanced Aerospace Structures Seminar

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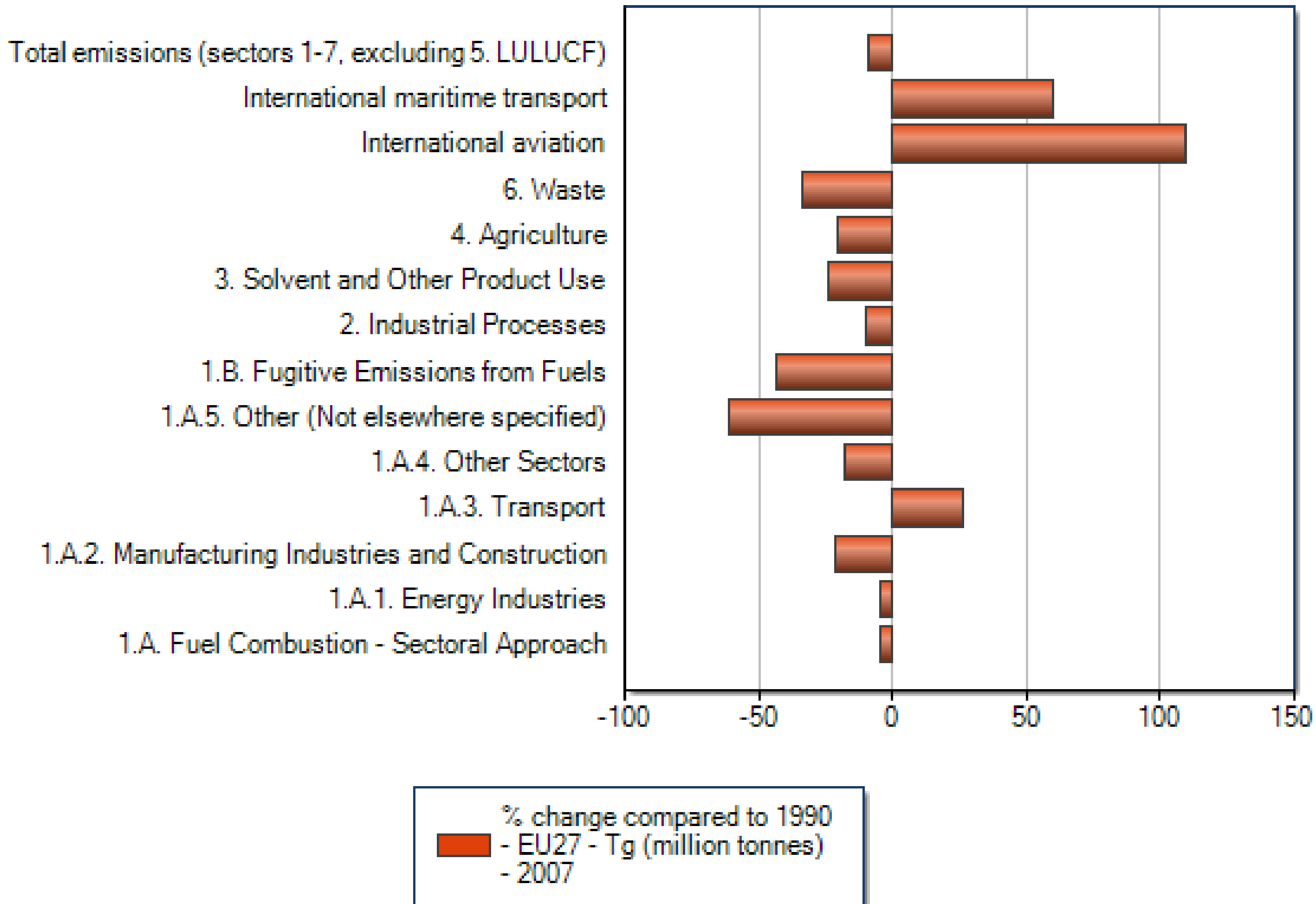
Global Air Transportation

- 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 a target for emissions mitigation policies

EU Emissions – Change since 1990



[Source: EEA]

Some Possible Mitigation Measures

- Economic – e.g. EU ETS
  - Increase cost to airlines and/or passengers to reduce demand or stimulate other measures
  - Or provide alternatives – e.g. high-speed rail
- Technological
  - Retrofits to existing aircraft – e.g. winglets
  - New aircraft materials and designs (composite materials, open rotor engines, BWBs, ...)
  - Alternative fuels
- Operational
  - Improved air traffic control, CDAs, etc.

Some 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
  - Interventions which improve fuel economy may lead to lower ticket prices and higher demand
- Effects dependent on future population, GDP/capita, oil price, carbon price, ...

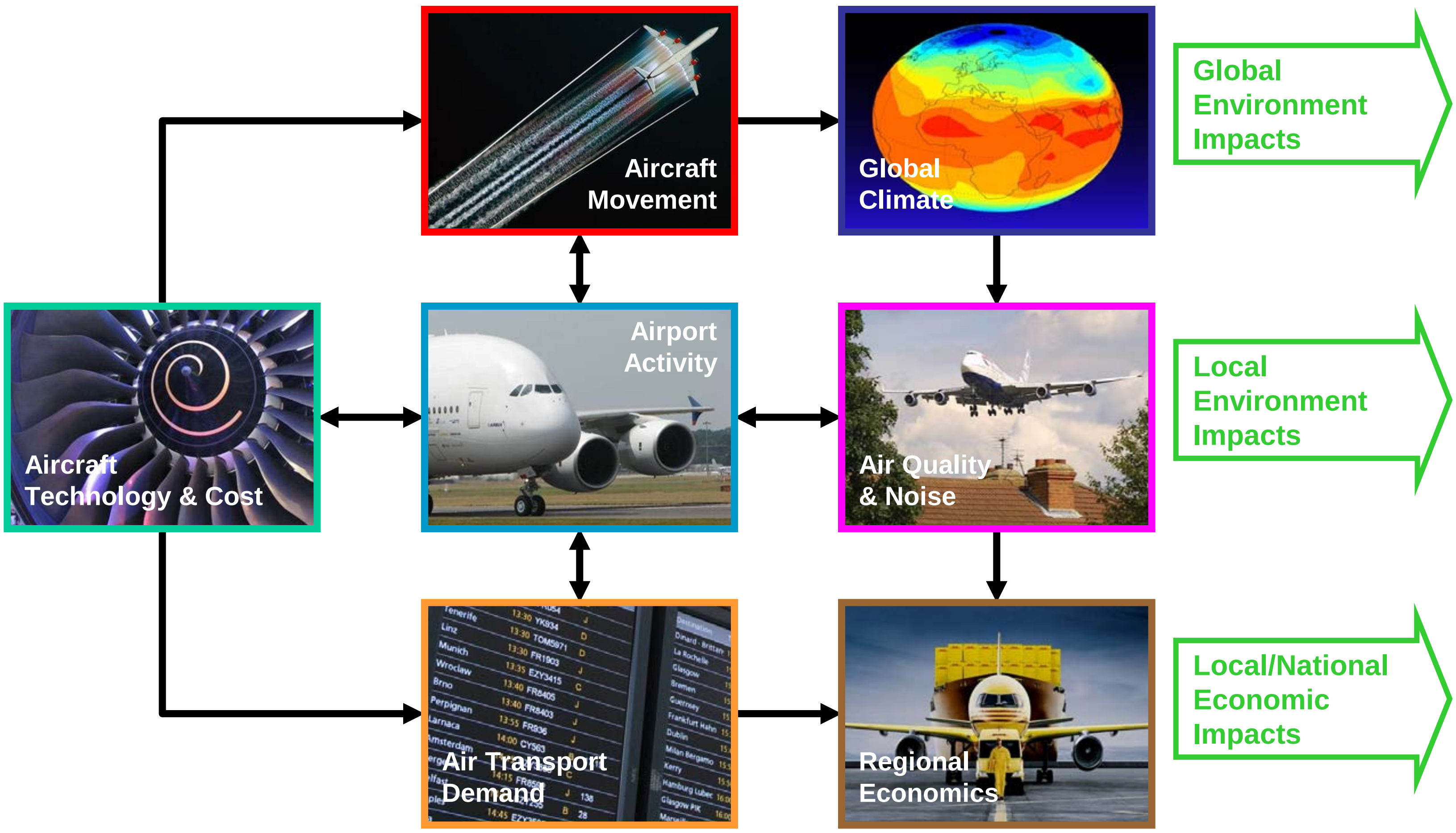
Integrated modelling useful in assessing policy results

Aviation Integrated Modelling

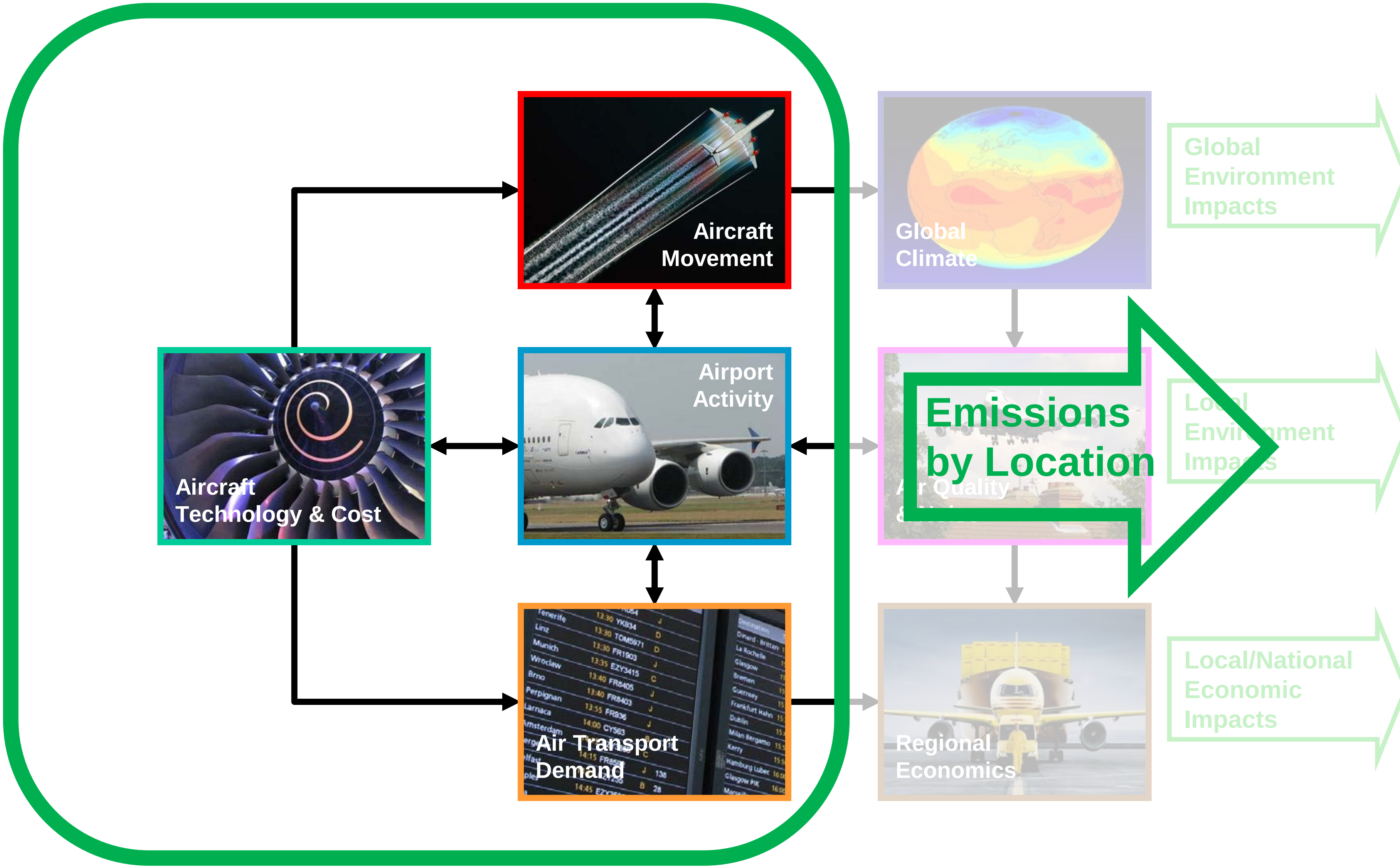
- Goal: Develop integrated assessment tool for aviation, environment & economic interactions at local & global levels, now and into the future
  - Assess policies to strike appropriate balances between economic benefits and environmental impact mitigation
  - Independent & transparent tool for mediating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

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

AIM Policy Assessment



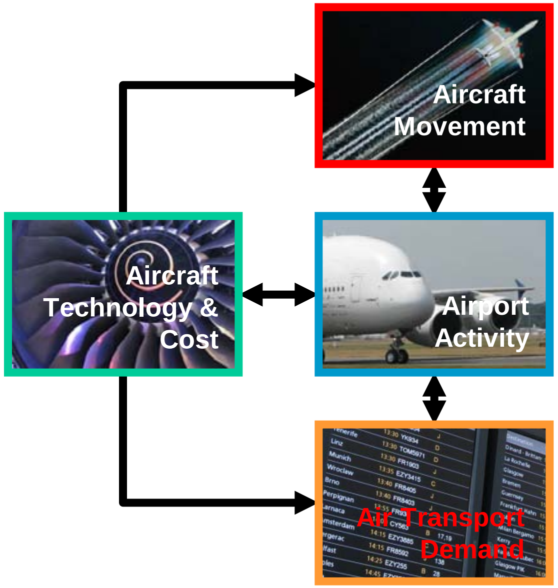
AIM Policy Assessment



Air Transport Demand

Goal

- Forecast true origin-ultimate destination passenger and freight 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

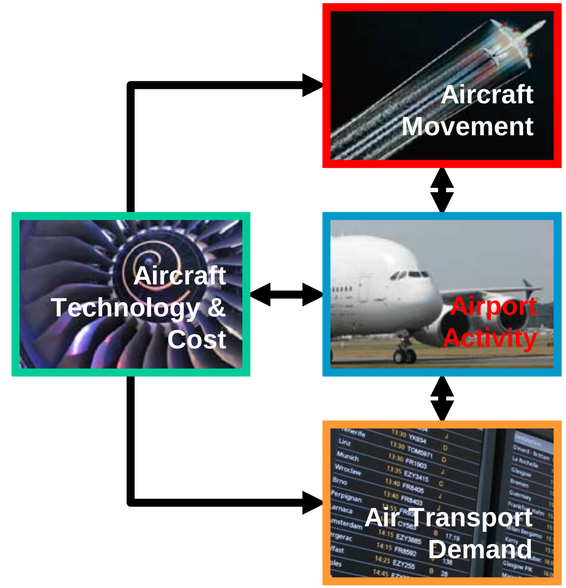
Airport Activity

Goal

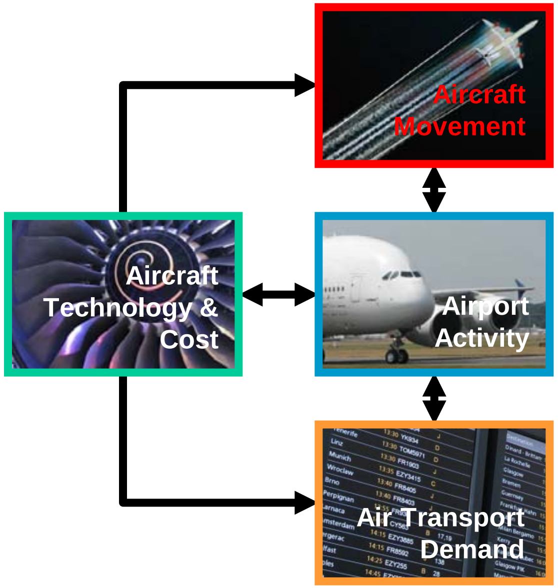
- Generate flight schedules
- Predict delay and LTO emissions

Methodology

- Flight routing and scheduling 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 delay modelled using queuing theory
- LTO emissions estimated according to schedule, delays, and engine emission rates



Aircraft Movement

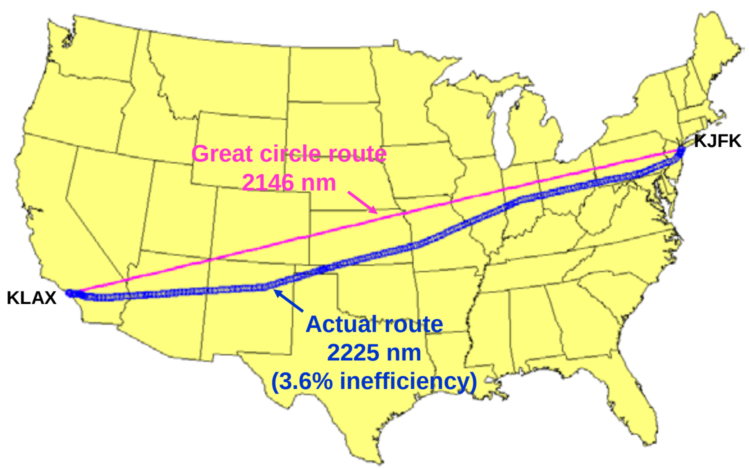


Goal

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

Methodology

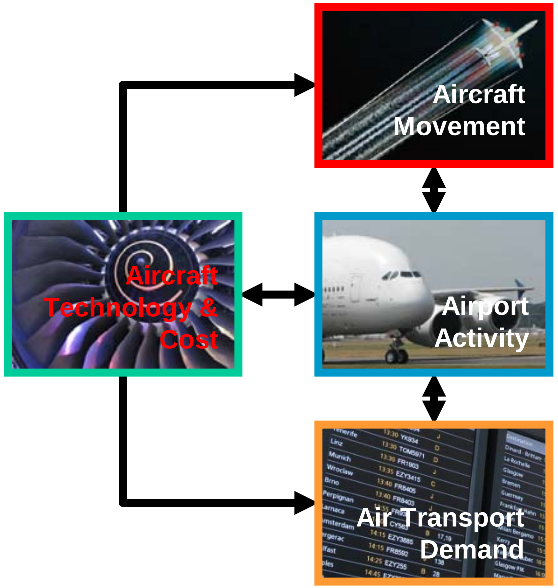
- Calculate optimal routes between given city pairs, e.g. great circle
- Add "inefficiency factors" to account for air traffic control
- Optional ATC improvements (e.g. SESAR)



Aircraft Technology & Cost

Goal

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

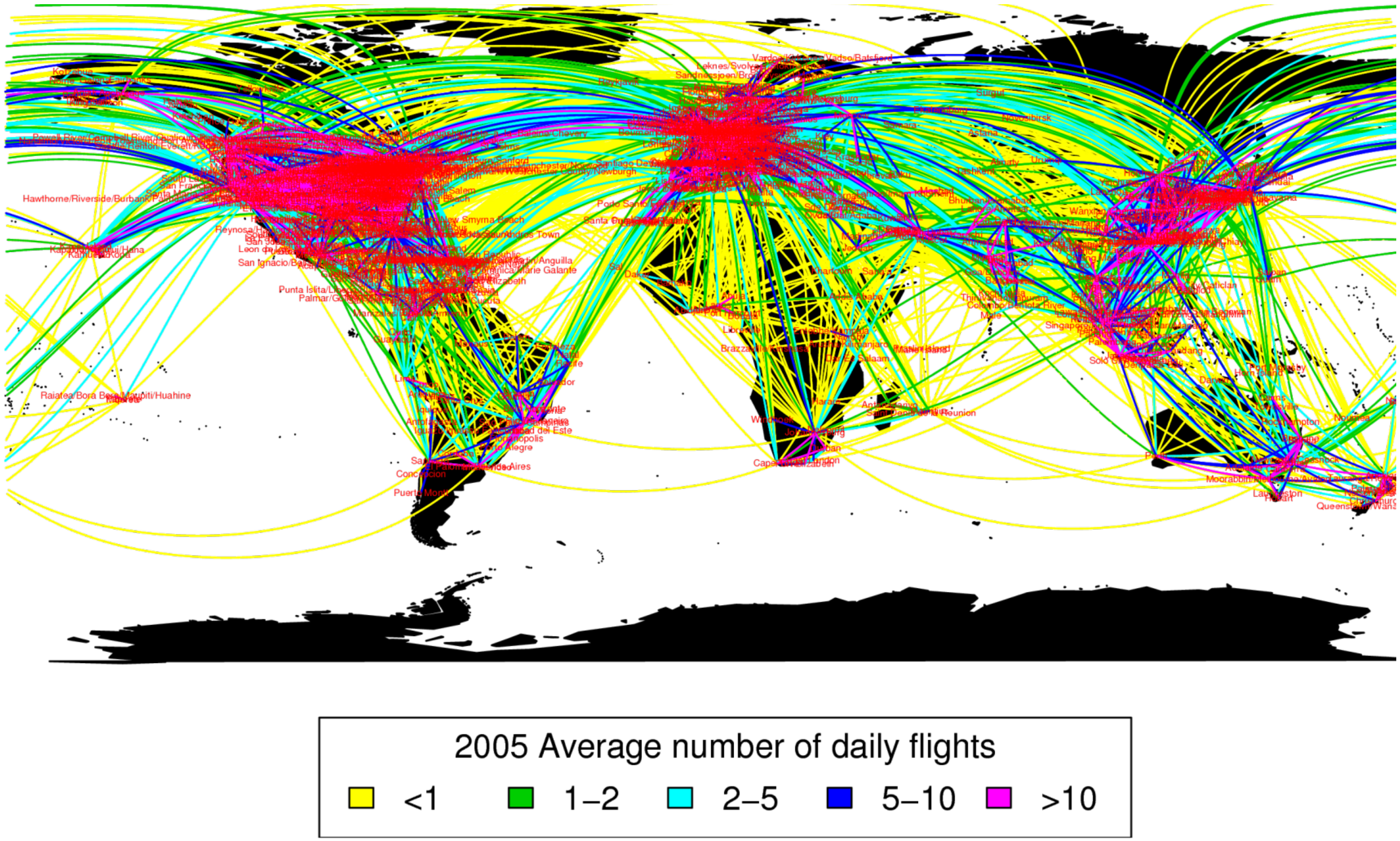


Methodology

- Below 3000 feet: ICAO Exhaust Emission Data, Reference LTO Cycle
- Above 3000 feet: Eurocontrol Base of Aircraft Data (BADA)
- Fleet turnover model for retirements and introduction of new technology (Dray & Morrell 2008)
- Optional retrofits, new aircraft types, alternative fuels

Geographic Scope

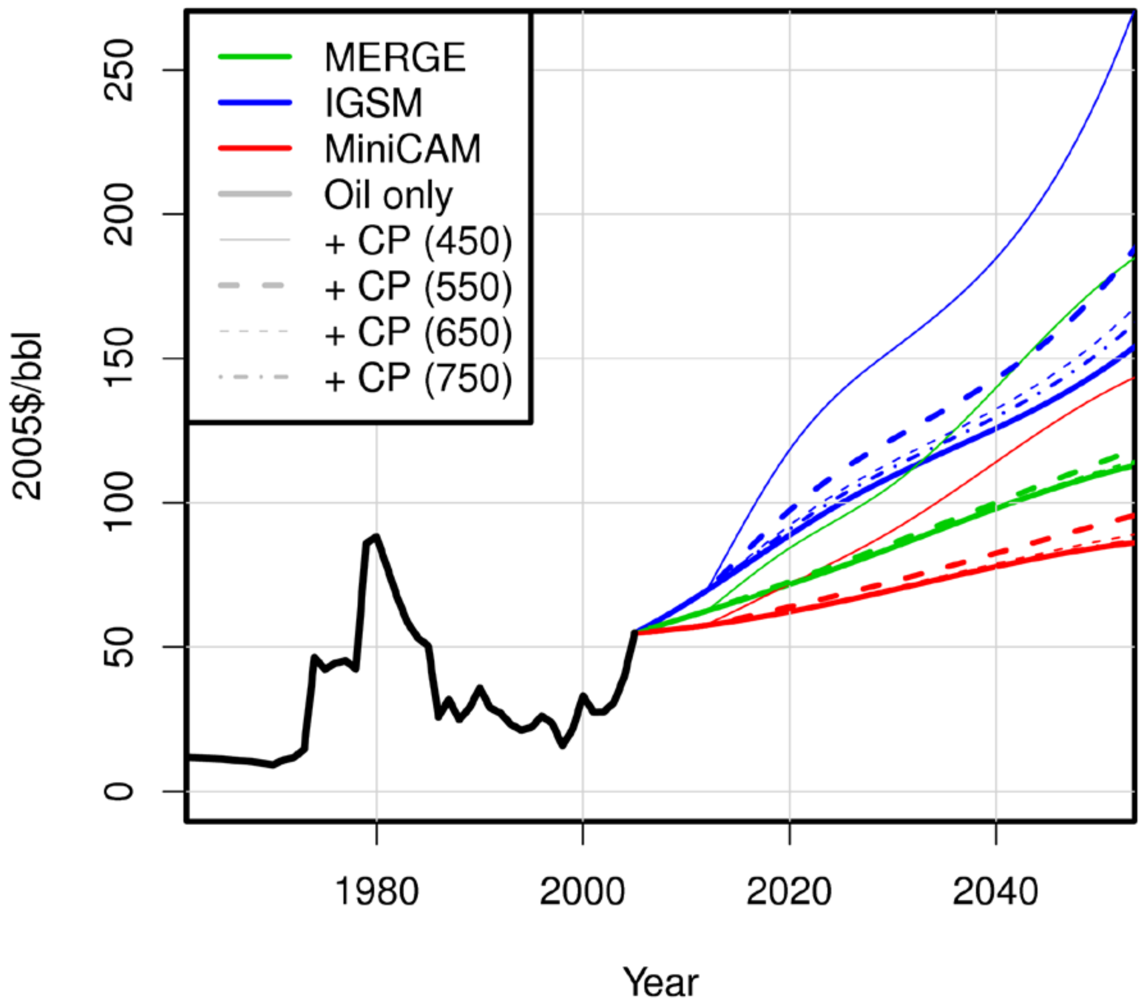
- Global model – 95% of scheduled RPK



[Data: OAG(2005)]

Future Scenarios

- Use CCSP (2007) scenarios for 2010-2050 development of:
  - Oil & fuel price
  - Carbon price
    - If modelling emissions trading
    - 450 – 750 ppm stabilisation levels
  - GDP
  - Population



[Data: CCSP(2007)]

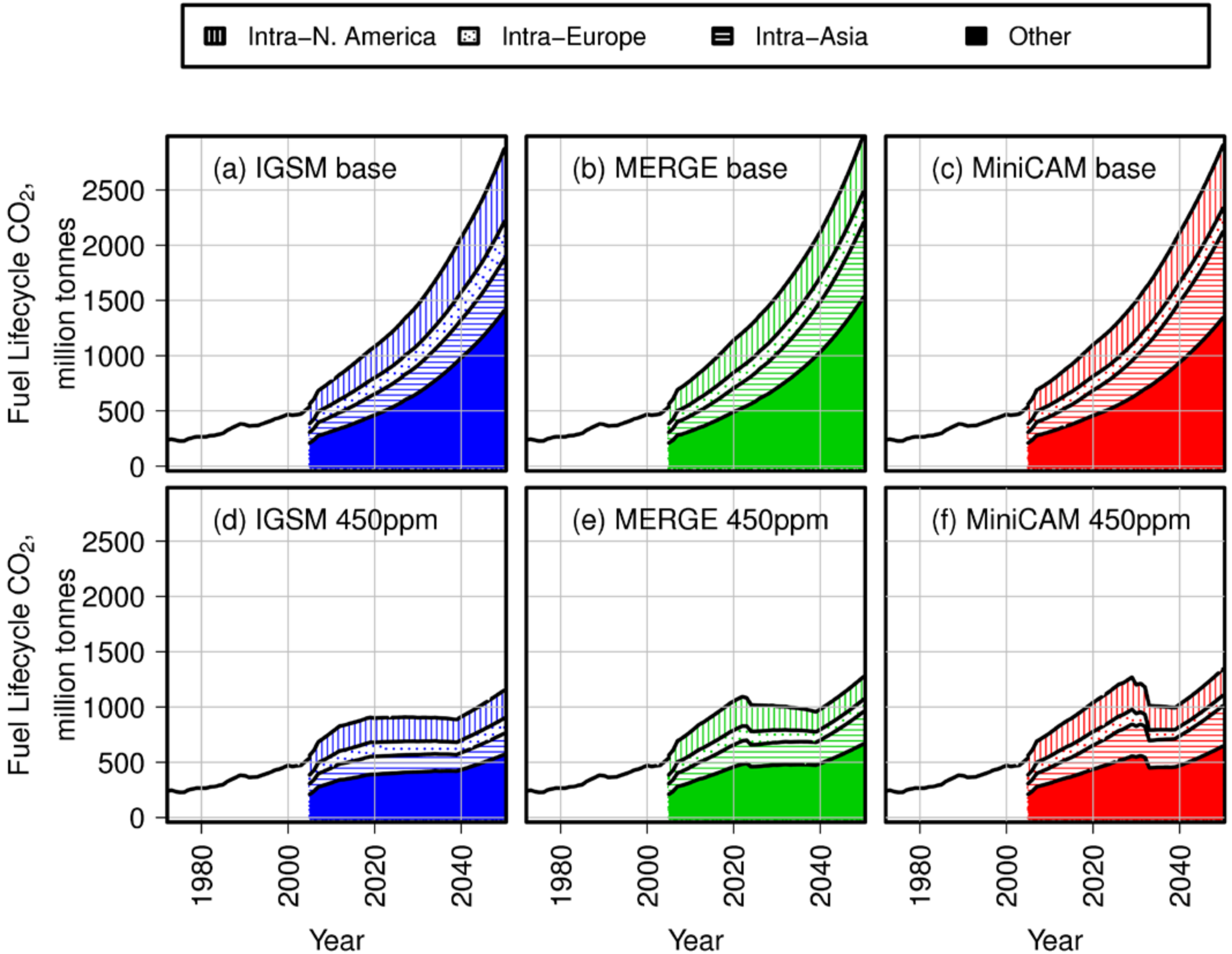
Two test cases

- How does emissions trading interact with technology adoption?
  - Use CCSP scenarios: no emissions trading and four different emissions stabilisation targets
  - Assume alternative technologies available, including retrofits, open rotor engine narrowbodies, cellulosic biomass fuel
  - Details in Dray et al (2010).
- What practical reduction in global emissions is achievable by the current/future generation of composite-material aircraft, and over what timescale?

Results- Fuel Lifecycle CO_2

No Emissions Trading

Global Emissions Trading with 450 ppm Stringency

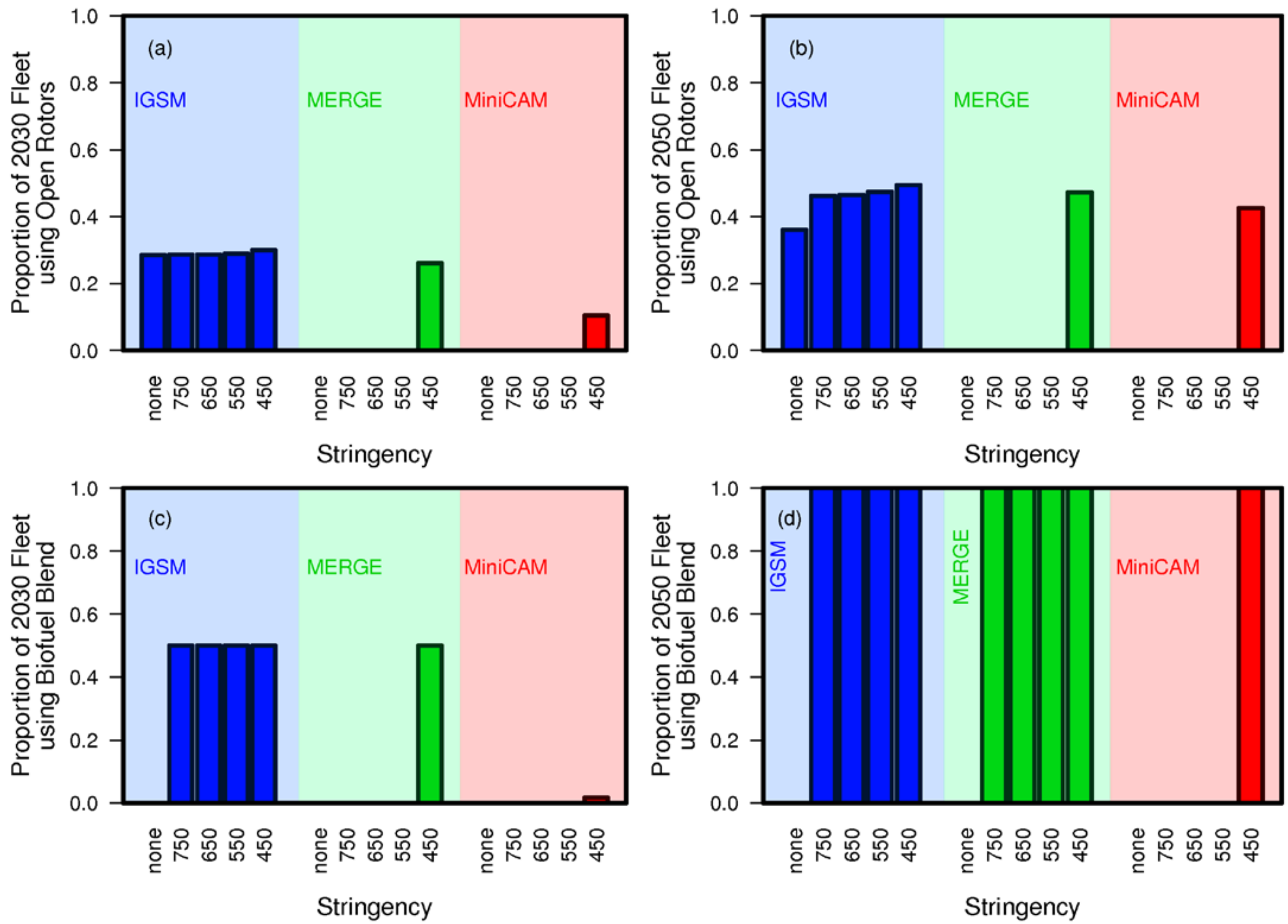


[Past data: IEA]

Adoption of Key Technologies

Open Rotor Aircraft

Biofuels



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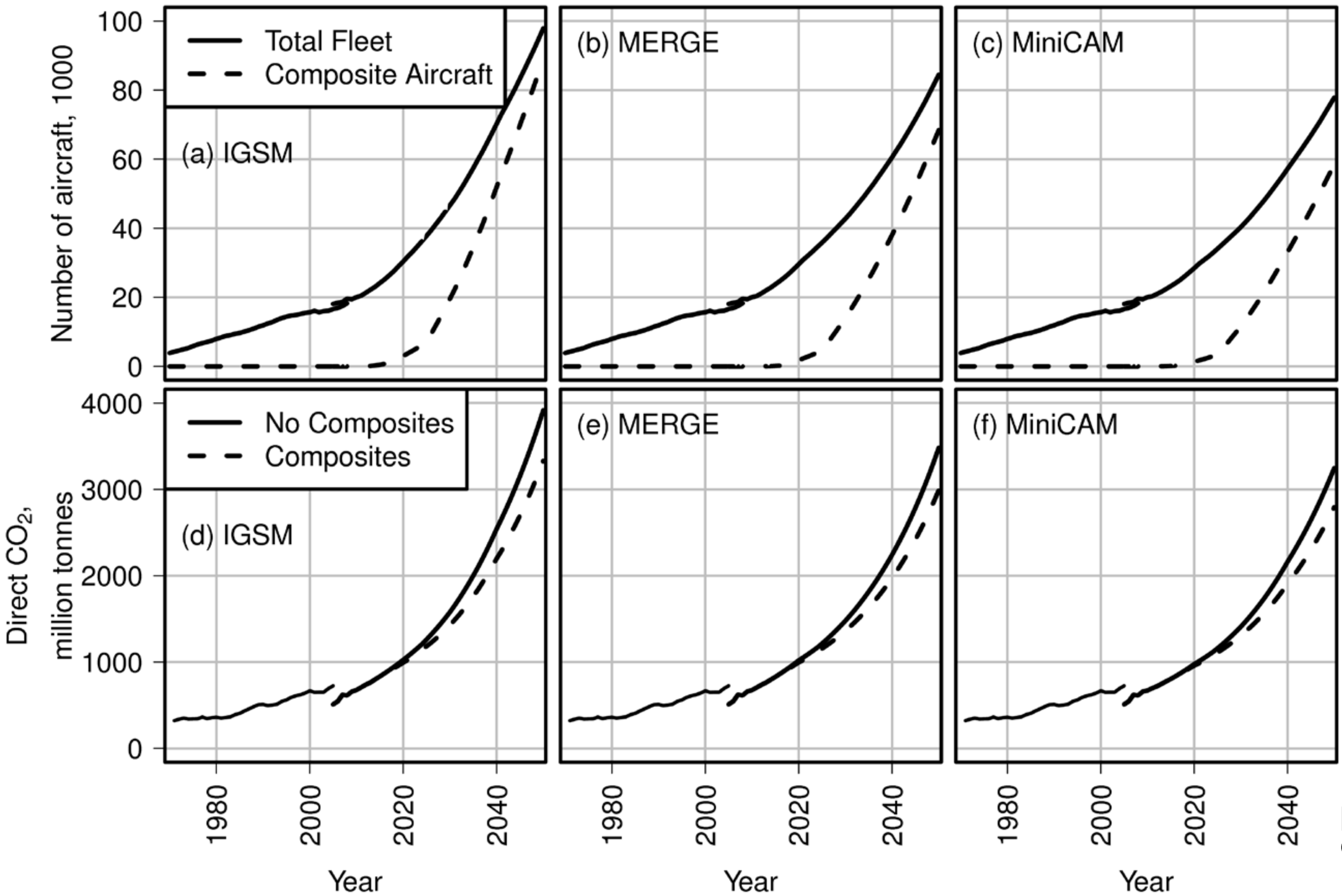
Use of Composites

- Introduction of new composite-material aircraft technology, e.g.
  - **TOSCA project composite narrowbody from 2025**
  - **Boeing 787 from 2011**
  - **Airbus A350 from 2017**
- Fuel burn, purchase price, maintenance costs etc. from published manufacturer/project data
- Compare to ‘frozen’ existing technology, e.g. Boeing 777, Airbus A330, A320
  - Frozen technology gives an upper limit on emissions
- Airline costs typically lowered, leading to lower ticket prices, higher demand

Use of Composites



[Past data: OAG (2009); IEA(2007)]

Conclusions

- Integrated modelling is important
  - Interactions between aspects of aviation system, second-order and feedback effects
- Emissions trading test case: Aviation emissions likely to grow, even in scenarios with strong policy intervention
  - However, emissions will decrease in other sectors with emissions trading
  - Largest reduction in test case 2050 emissions relative to no-trading case: ~60% (450 ppm, IGSM) – combination of demand reduction, alternative fuels, new technologies
- Composites test case: a 14-15% global CO_2 reduction by 2050 from frozen-technology scenarios
  - Lower than expected due to demand rebound and fleet turnover
  - Include other technologies/policies as well for faster reductions

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)*

More details and publications at:

http://www.aimproject.aero

IAE co-investigators:

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

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- Dr. Marcus Köhler *(Global Climate, King's College London)*
- Dr. Tom Reynolds *(Air Traffic Control/Management, MIT/Lincoln Labs)*
- Dr. Zia Wadud *(Regional Economics, Bangladesh University of Engineering and Technology)*
- Dr. Steven Barrett *(Air Quality, MIT)*