



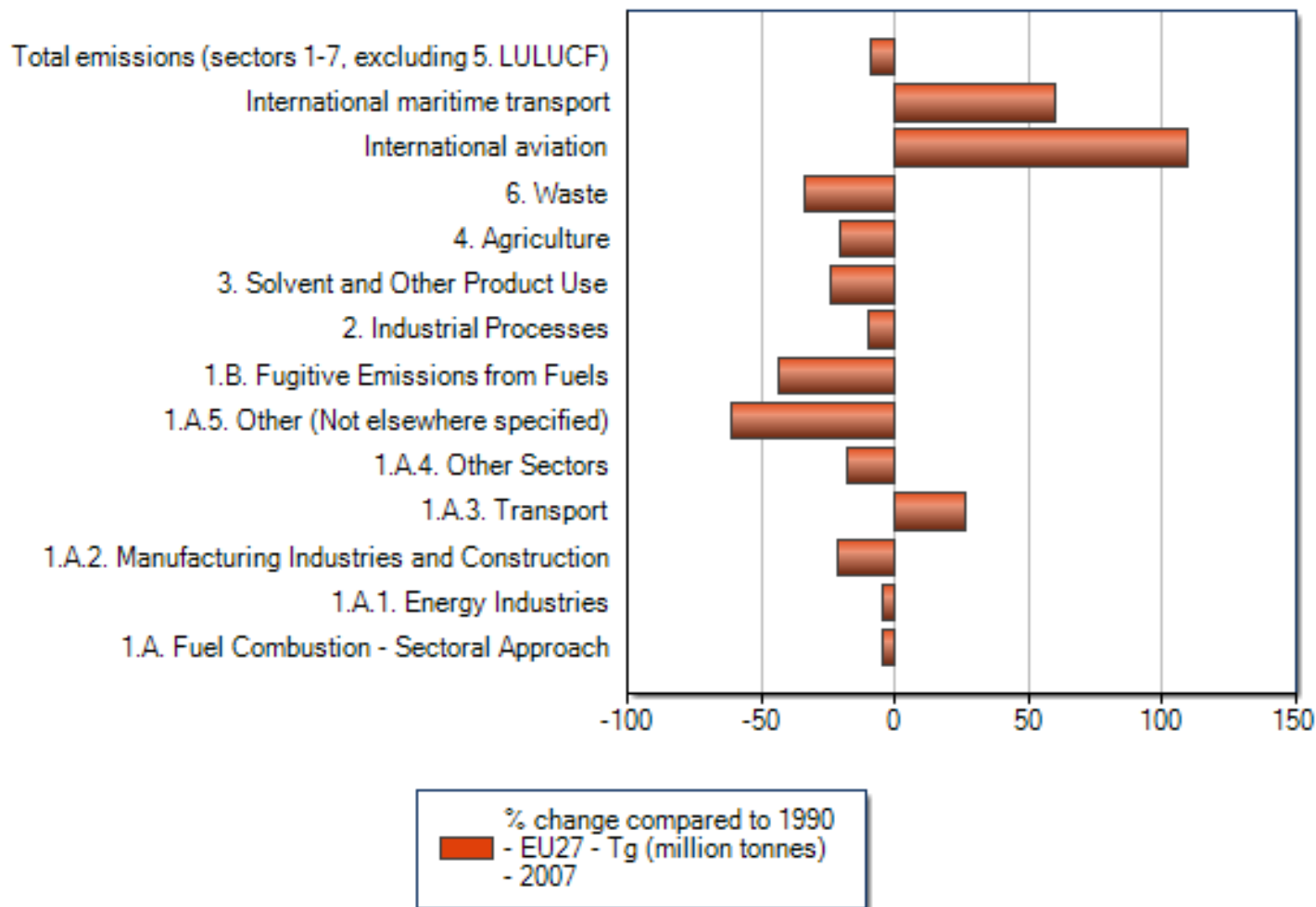
A Comparison of Aviation Greenhouse Gas Emission Mitigation Policies for Europe

Lynnette Dray, Antony Evans, Tom G. Reynolds &
Andreas Schäfer

Institute for Aviation and the Environment, University of
Cambridge

9th AIAA ATIO/ANERS Conference
Hilton Head, 23rd September 2009



- European RPKM growth of ~3%/year forecast (Airbus, Boeing)
- Several EU emissions targets which affect aviation
 - Emissions trading scheme sets cap on CO₂ 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

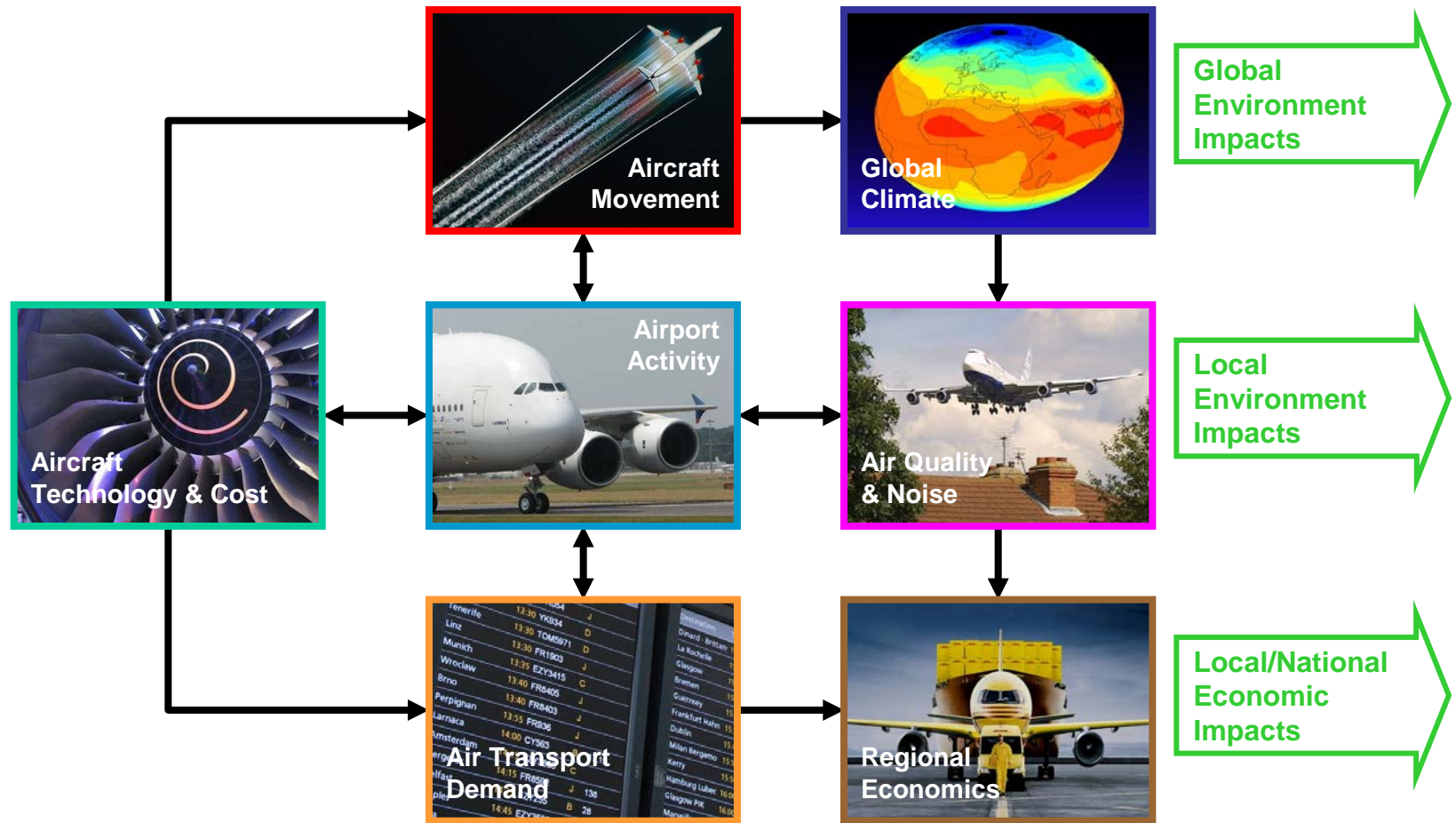


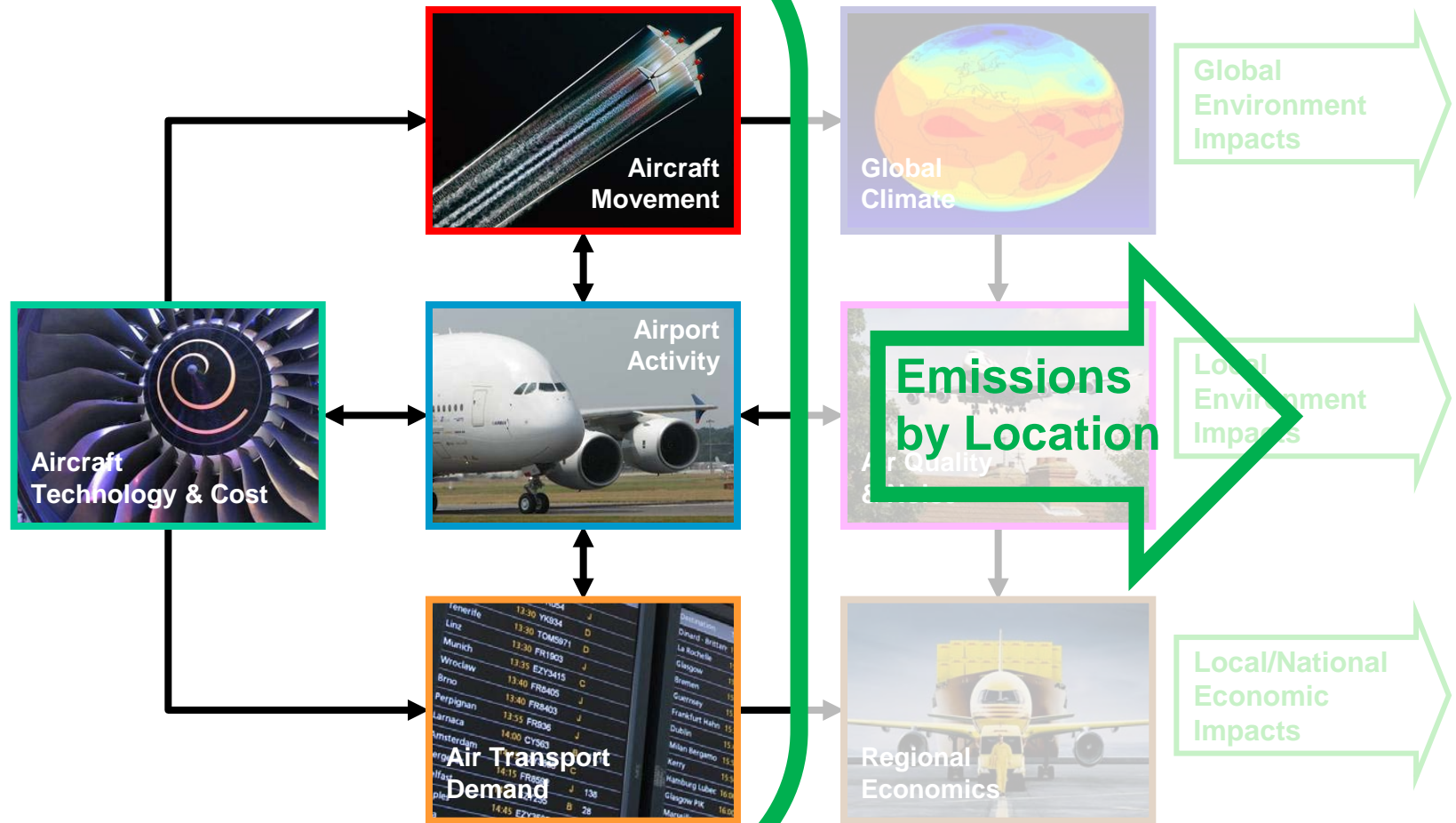
[Source: EEA]

- 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

- 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...

- 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:
 -  **EPSRC**
Engineering and Physical Sciences
Research Council
 -  **NATURAL
ENVIRONMENT
RESEARCH COUNCIL**
- Considerable input from UK OMEGA projects for this study



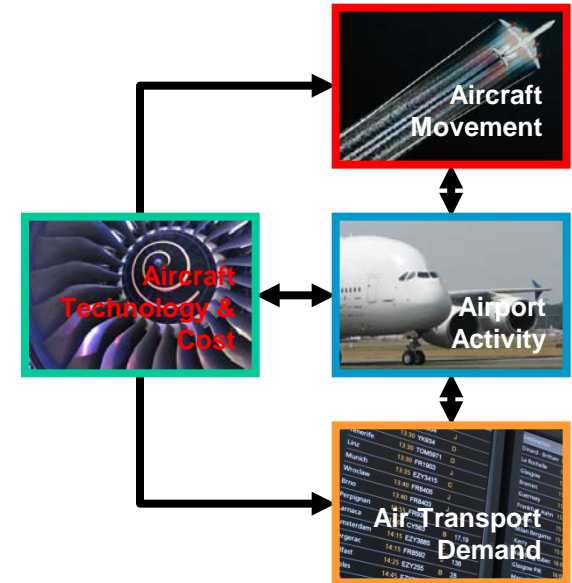


Goals

- 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

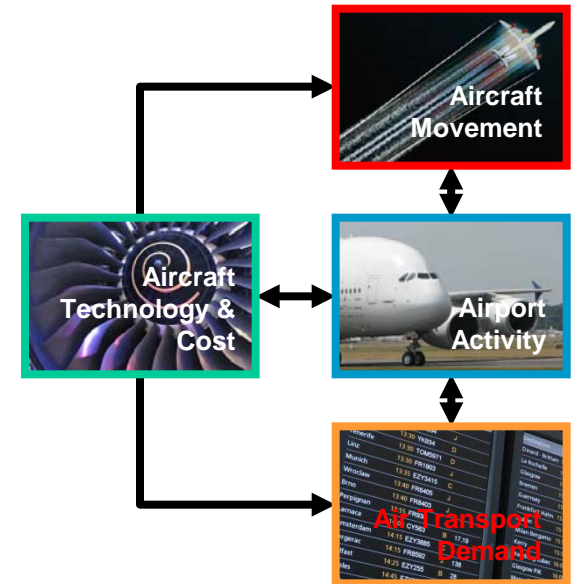


Goals

- 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

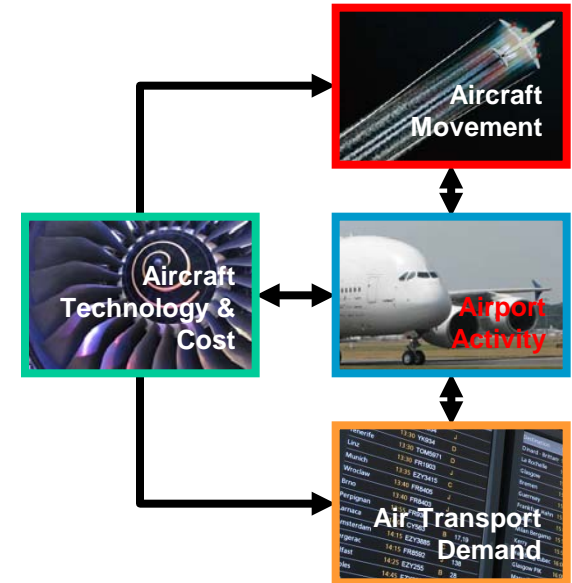


Goals

- 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

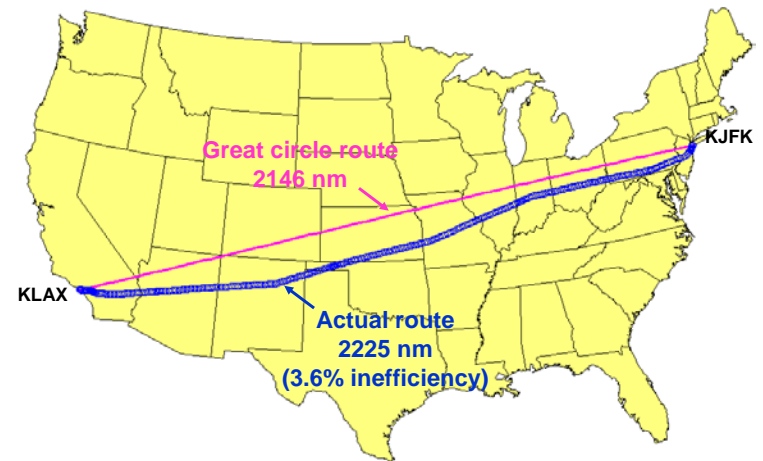
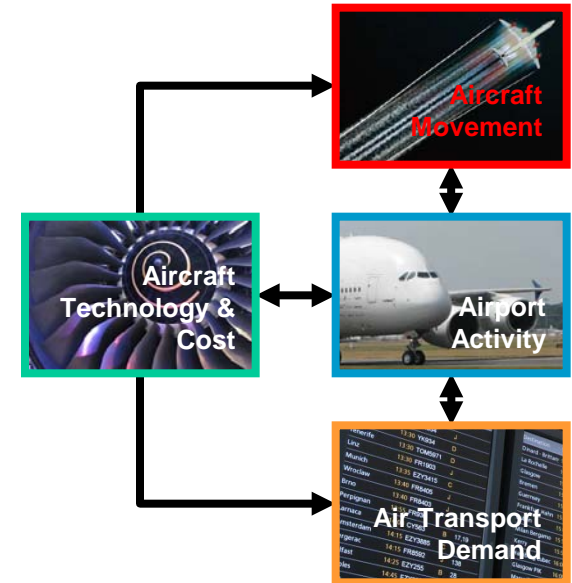


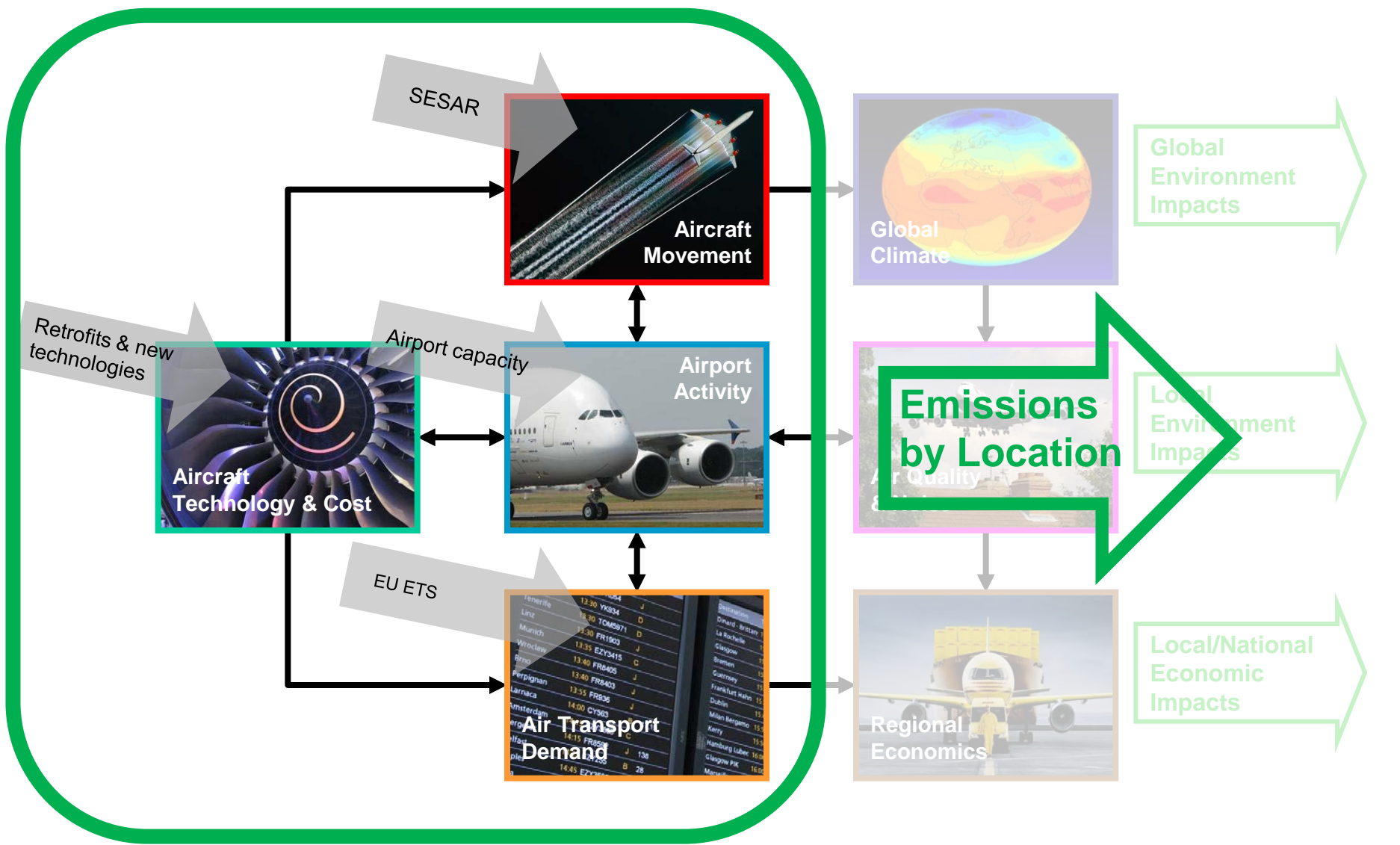
Goals

- 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





- 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

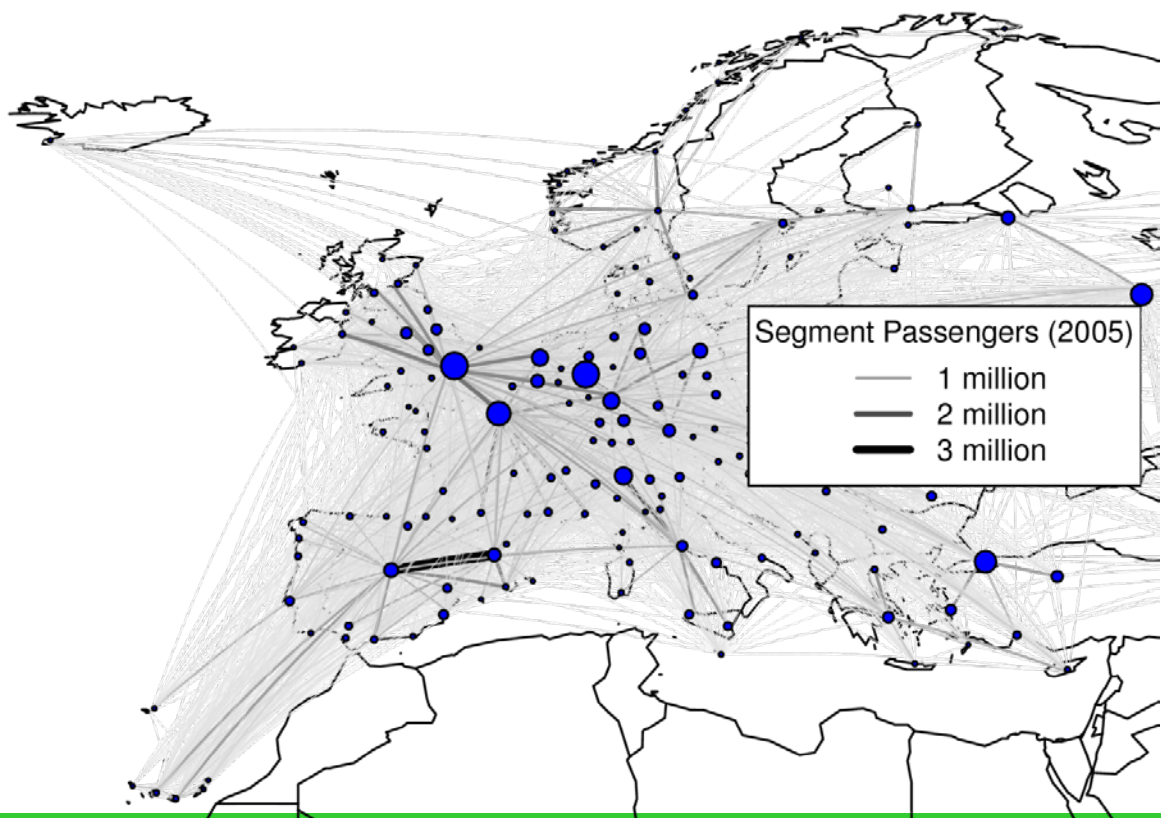


Scenarios use OMEGA data

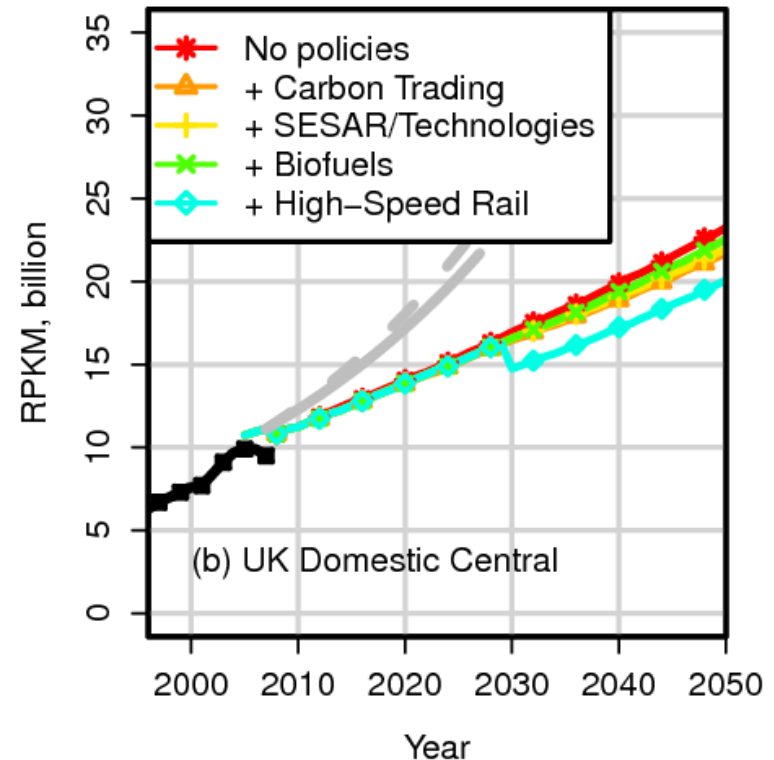
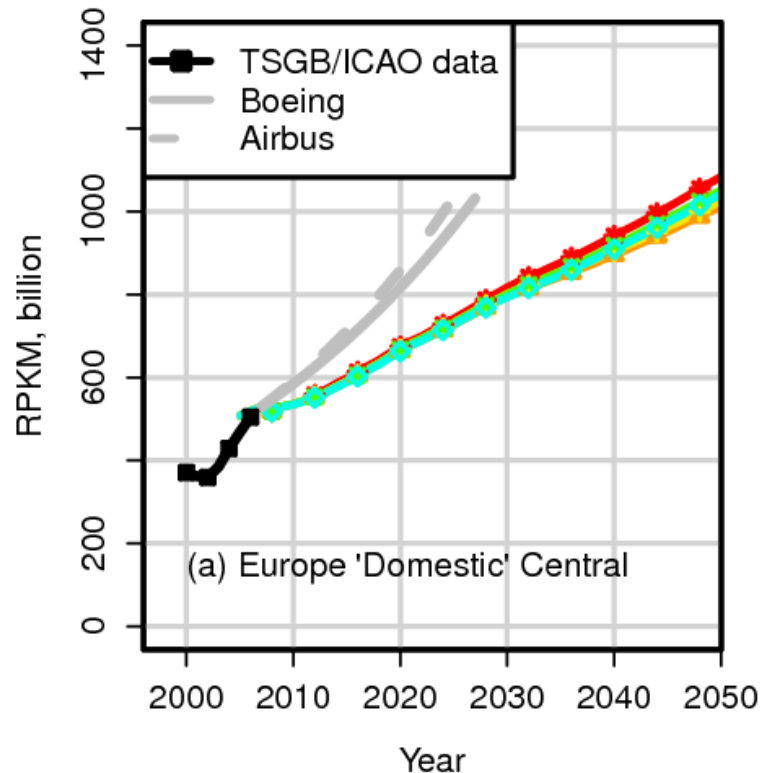
Three main scenarios, using preliminary UK CCC data:

- **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)

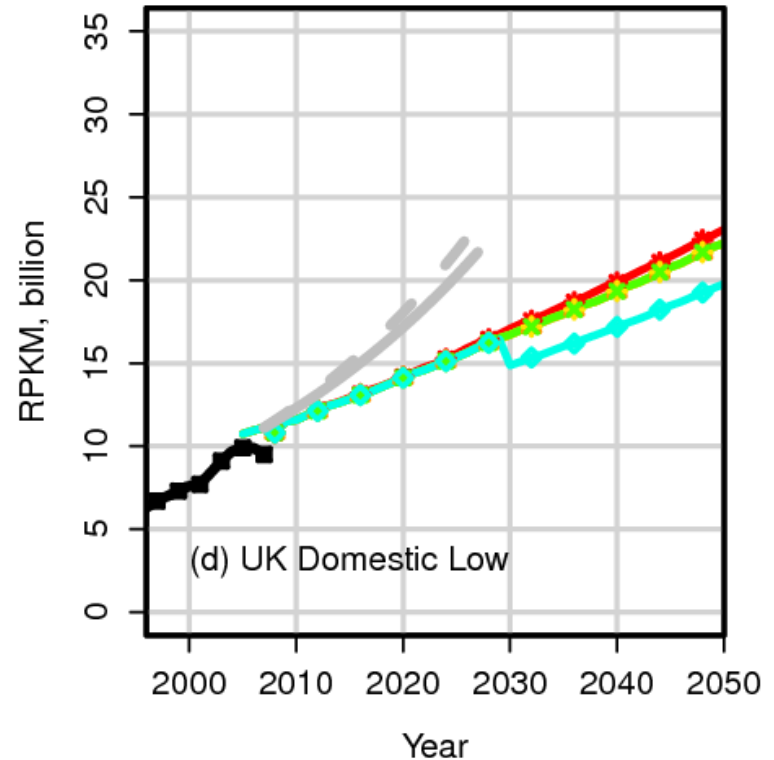
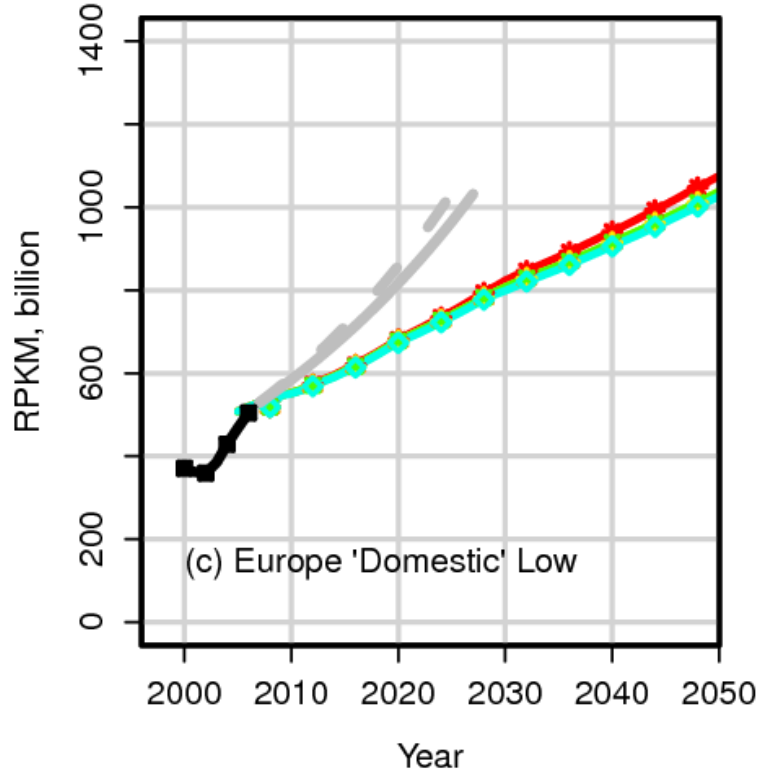
- Europe model: 173 Cities (337 airports)
- UK Subset: 17 Cities (37 airports)
- Other destinations modeled at region level only



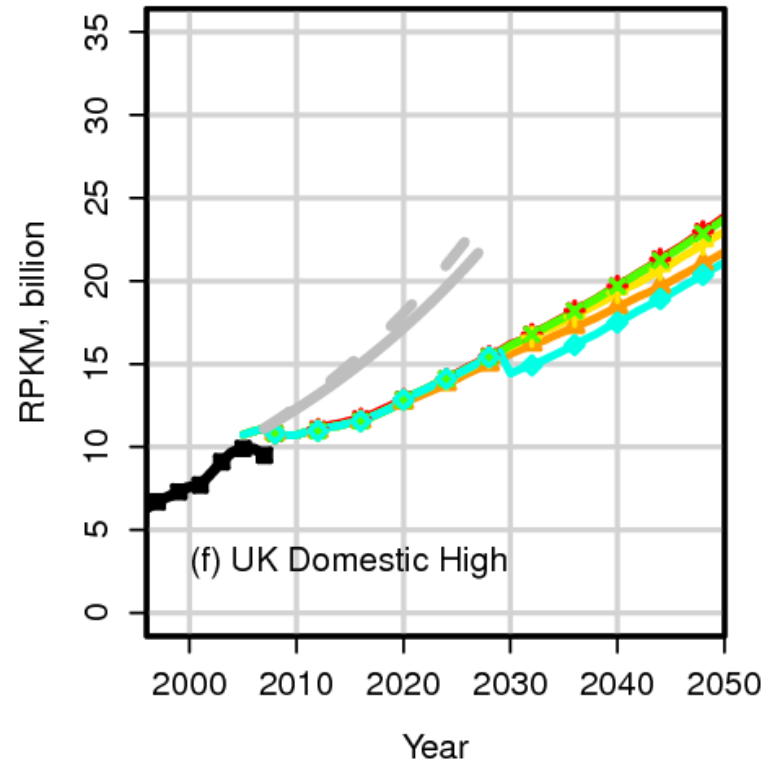
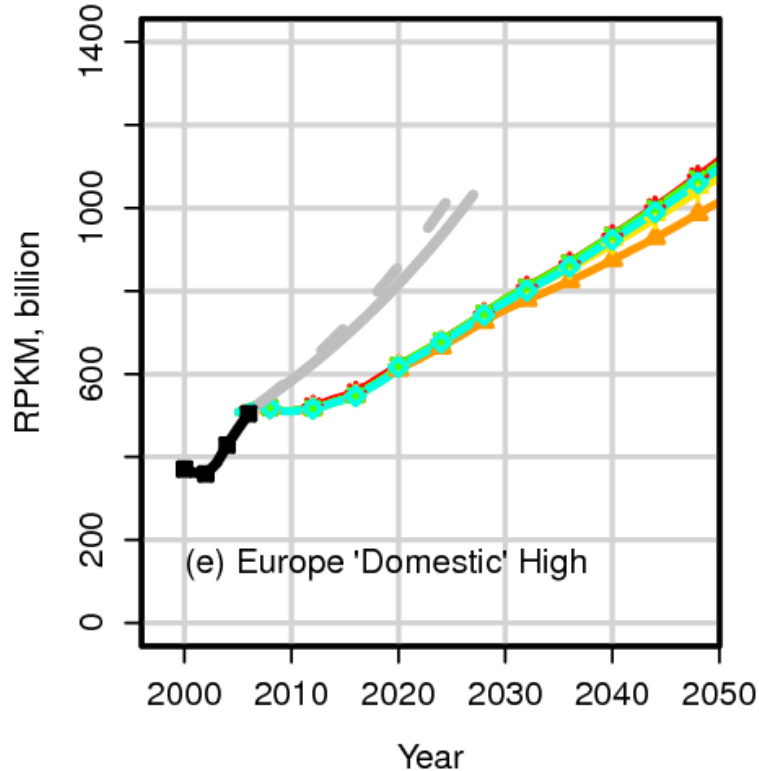
- Most measures have small effect on RPKM only (<10%)
- Greatest effects:
 - Carbon trading with high prices and low technology availability
 - High-speed rail



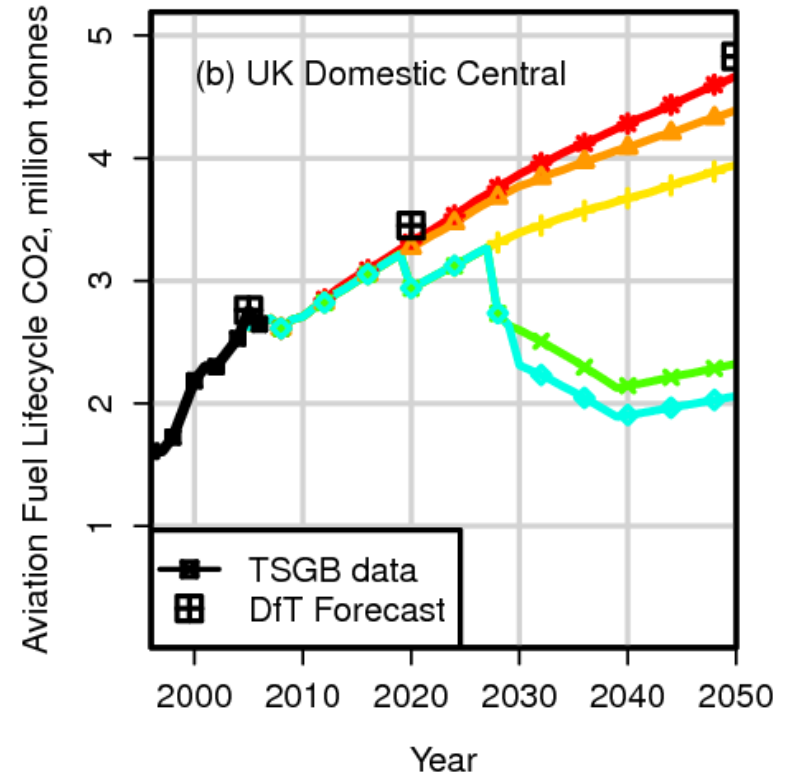
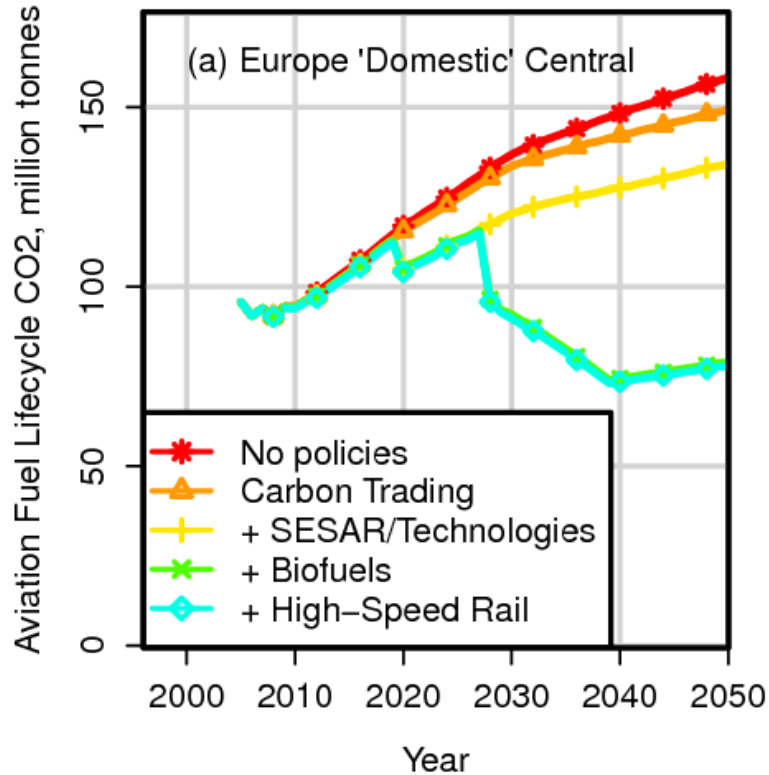
- Most measures have small effect on RPKM only (<10%)
- Greatest effects:
 - Carbon trading with high prices and low technology availability
 - High-speed rail



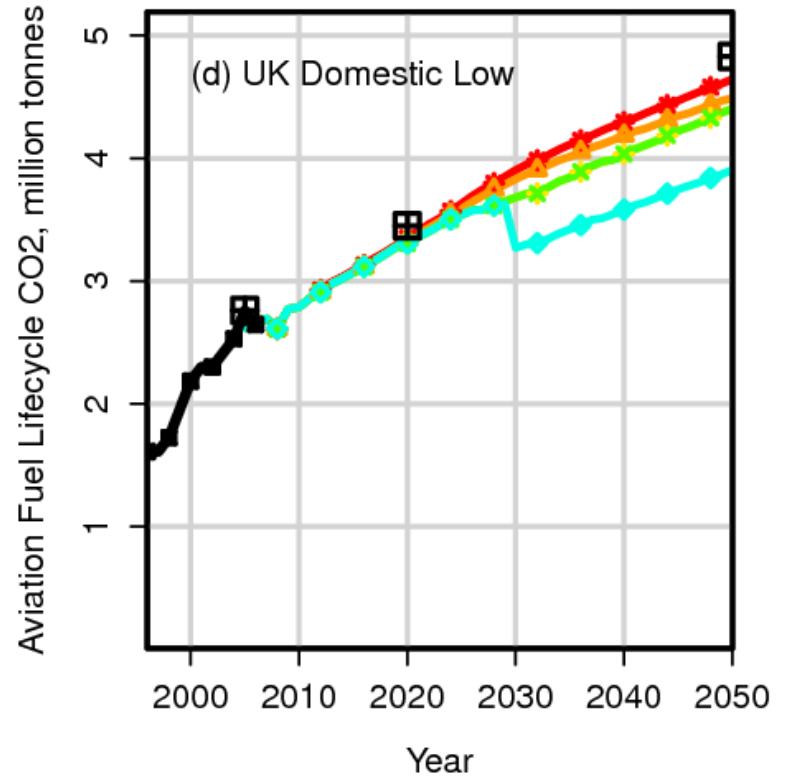
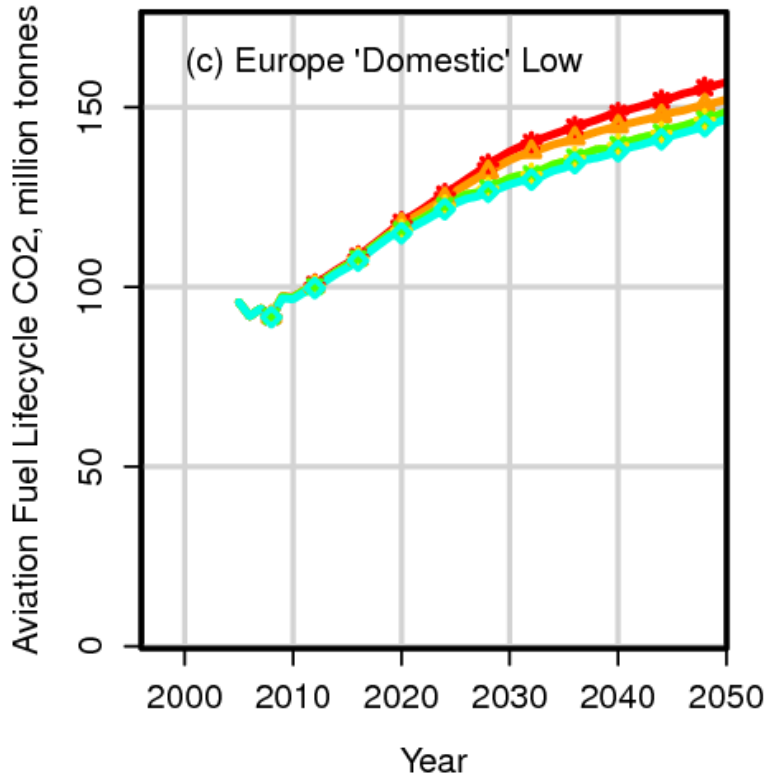
- Most measures have small effect on RPKM only (<10%)
- Greatest effects:
 - Carbon trading with high prices and low technology availability
 - High-speed rail



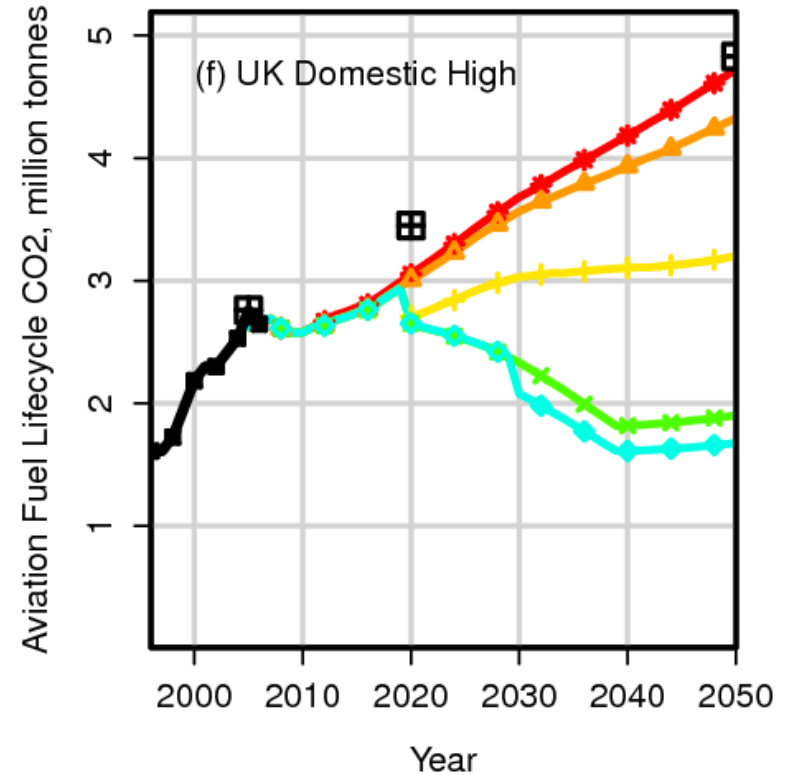
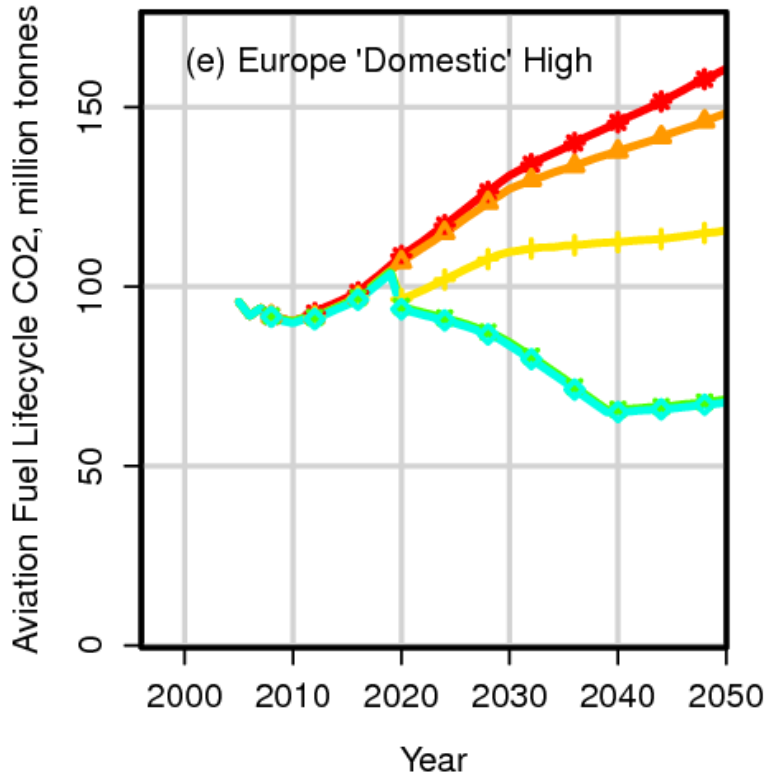
- Results differ strongly by scenario...



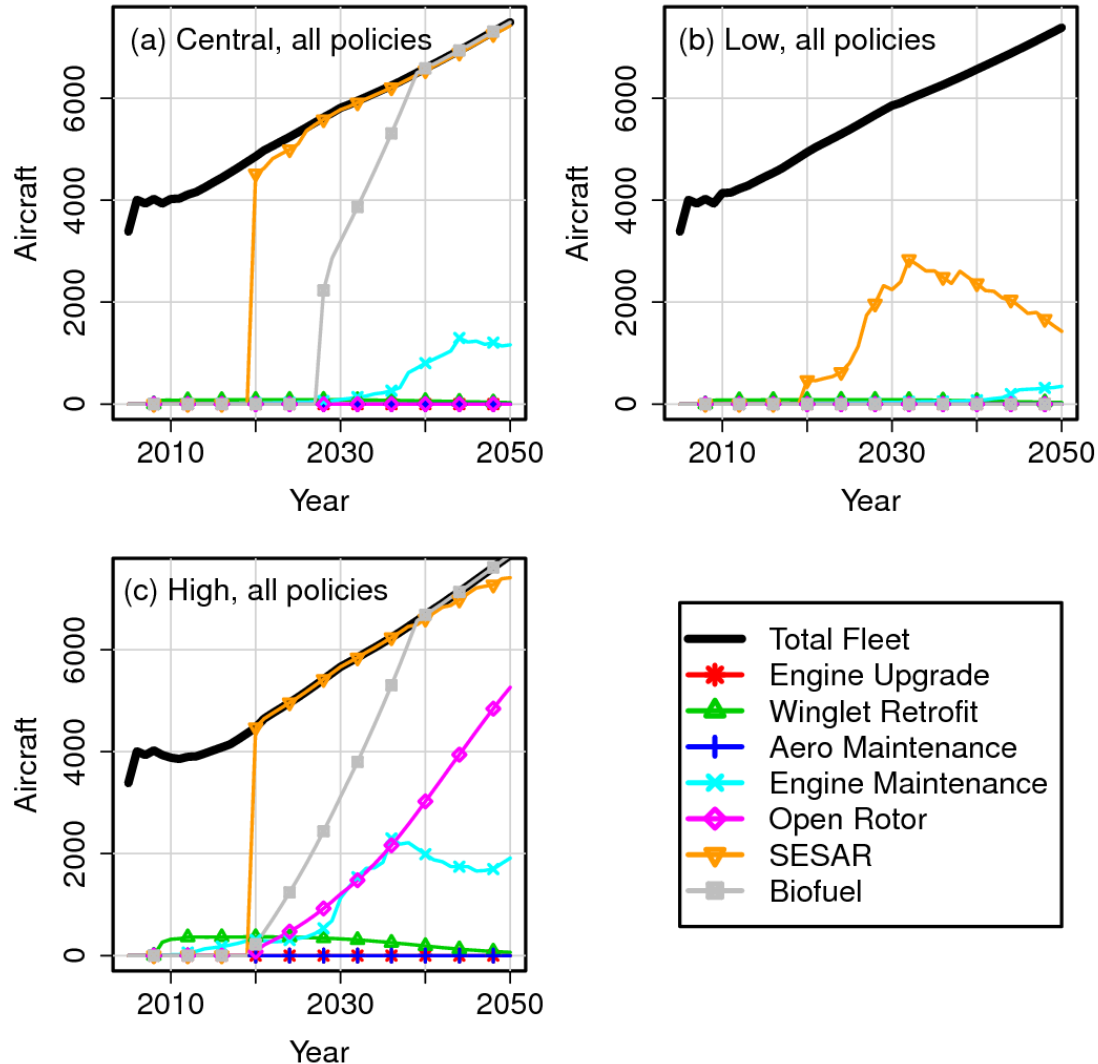
- Results differ strongly by scenario...



- Results differ strongly by scenario...

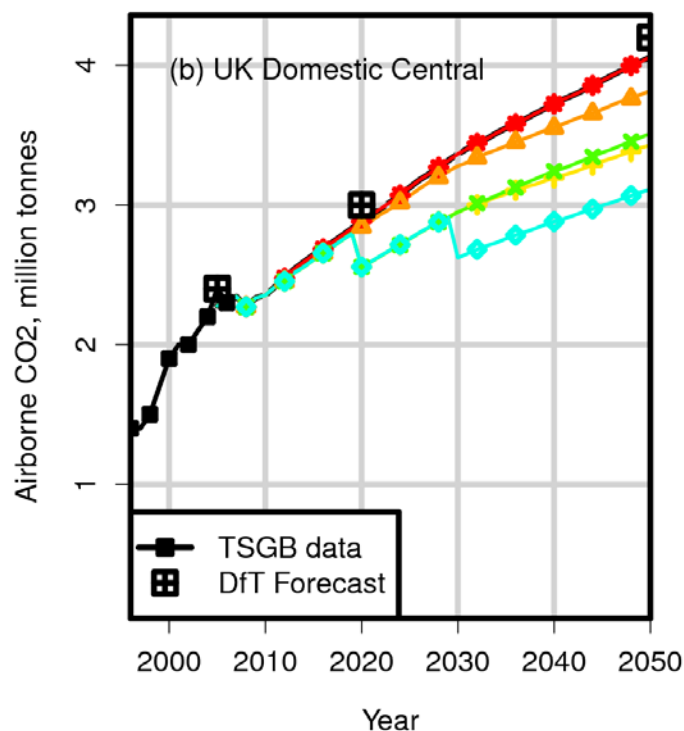
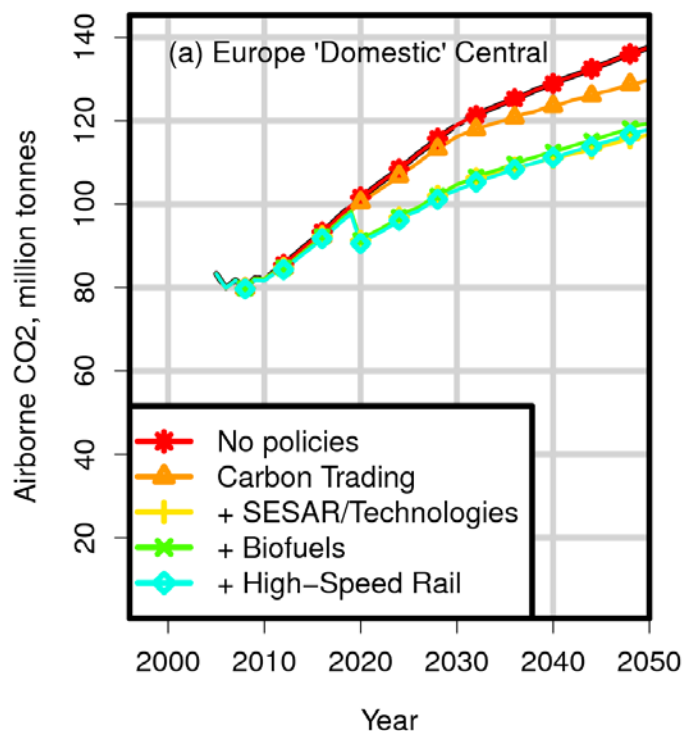


Measure Uptake by Scenario



- Reducing year-2050 fuel lifecycle CO₂ 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

- Biofuel scenarios → reduction in **lifecycle CO₂**
 - Airborne CO₂ little-changed
 - Noise, local emissions also little-changed
- Biofuel land use – by 2050 ~size of England



- 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?

Core team:

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

IAE co-investigators:

- Prof. Bill Dawes (*Engineering*)
- Dr. Chez Hall (*Engineering*)
- Prof. Peter Haynes (*DAMTP*)
- Prof. Roderic Jones (*Chemistry*)
- Prof. John Pyle (*Chemistry*)

Affiliated researchers:

- Prof. Rex Britter (*Air Quality, MIT*)
- 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*)