Addressing the Climate Change Challenge in the Transportation Sector

The Future Transport System
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Summary

- Key Sector Characteristics
  - Already vast scale, but continuous growth in absolute and relative terms
  - (Socio-)economic forces have pushed transportation system towards higher energy intensities
  - Risk management: capital intensity, design trade-offs, consumer acceptance → slow technological change
- Demand side
  - Steady growth in total mobility since industrialization
  - Systematic shift toward faster modes
  - Societal trends and changing demographics
- Supply side
  - Increasing electrification of surface and eventually air vehicles (investments into renewables > fossil fuel power)
  - Emerging transportation technologies (automated vehicles, on-demand air travel, drones, etc.)
  - New business models offering seamless mobility services
- Opportunities and Challenges
  - Compared to a decade ago, set of GHG mitigation options has increased – and more options emerging
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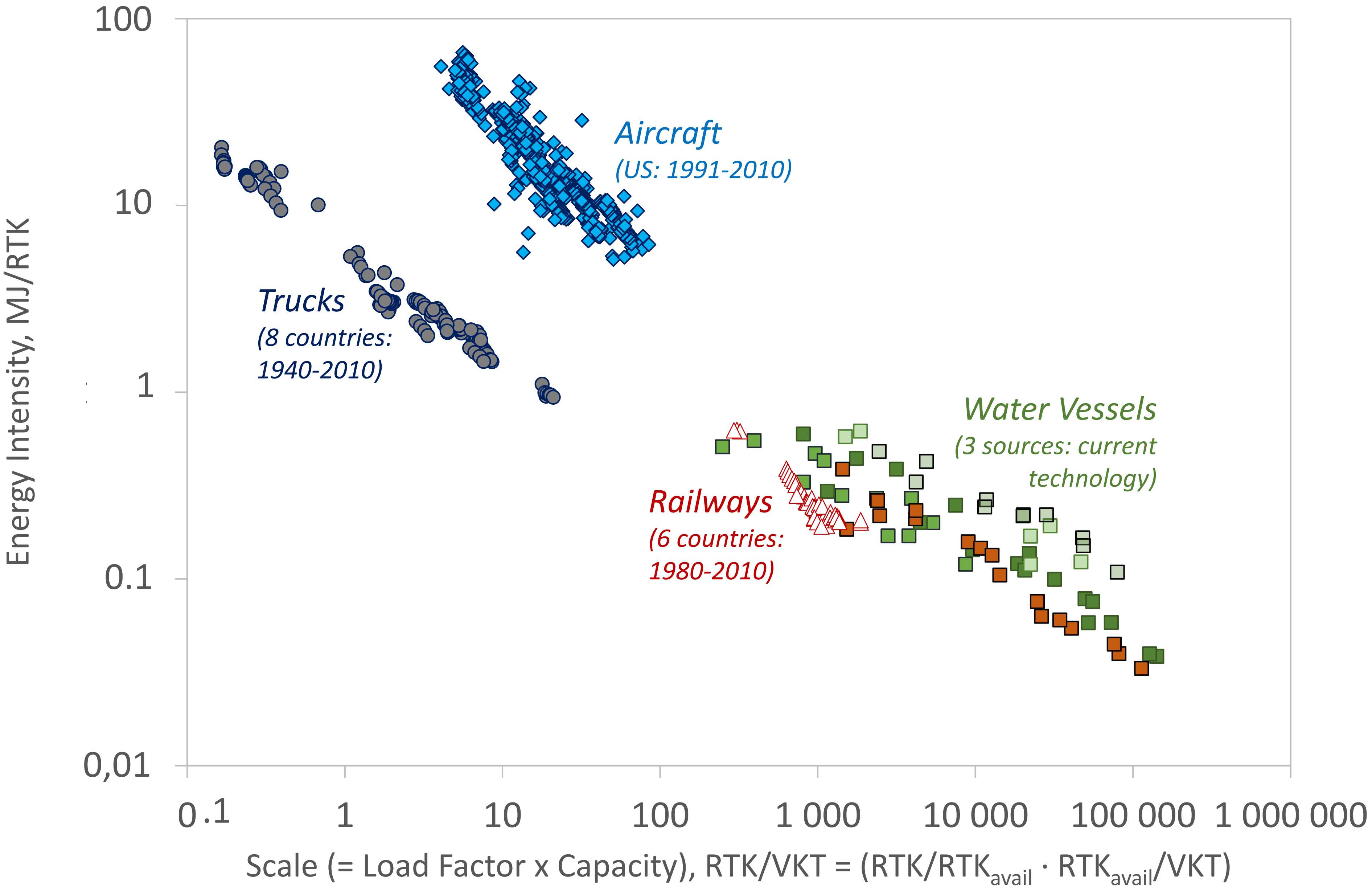
H_2 Production Requirements: 15 EJ of Gasoline Equivalent

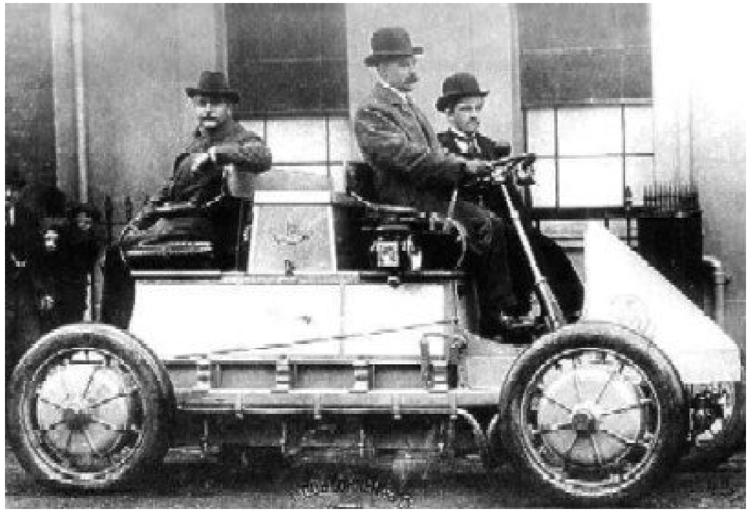
Number of additional 1 GW_{el} nuclear reactors to satisfy current US LDV energy demand via water electrolysis-based H_2

Energy Intensity and Transportation Systems Scale



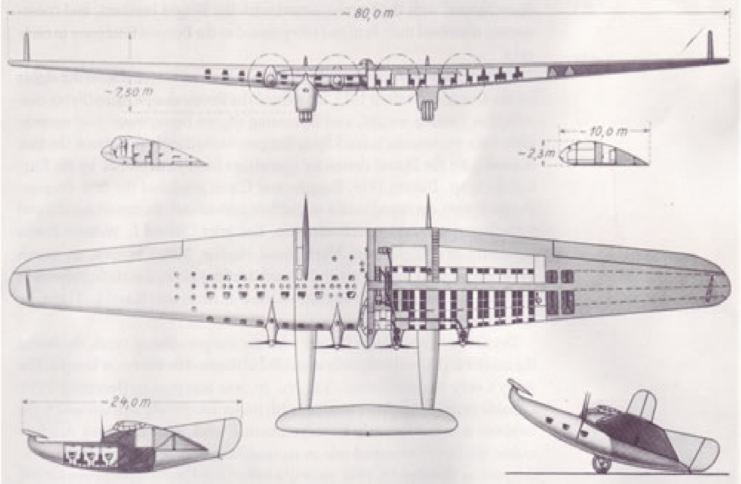
Gucwa M., Schäfer A., 2013. The impact of scale on energy intensity in freight transportation, Transportation Research Part D: Transport and Environment, August.

Long Times Scales from Concept/Design to Product



Gasoline-electric Lohner-Porsche, 1900.
http://www.hybrid-vehicle.org/hybrid-vehicle-porsche.html

95 years



Hugo Junkers' 1924 design for a giant flying wing. The wing was to accommodate 26 cabins for 100 passengers, carry a crew of 10, and have enough fuel for 10 hours of flight.
http://www.century-of-flight.net/Aviation%20history/flying%20wings/Early%20Flying%20Wings.htm

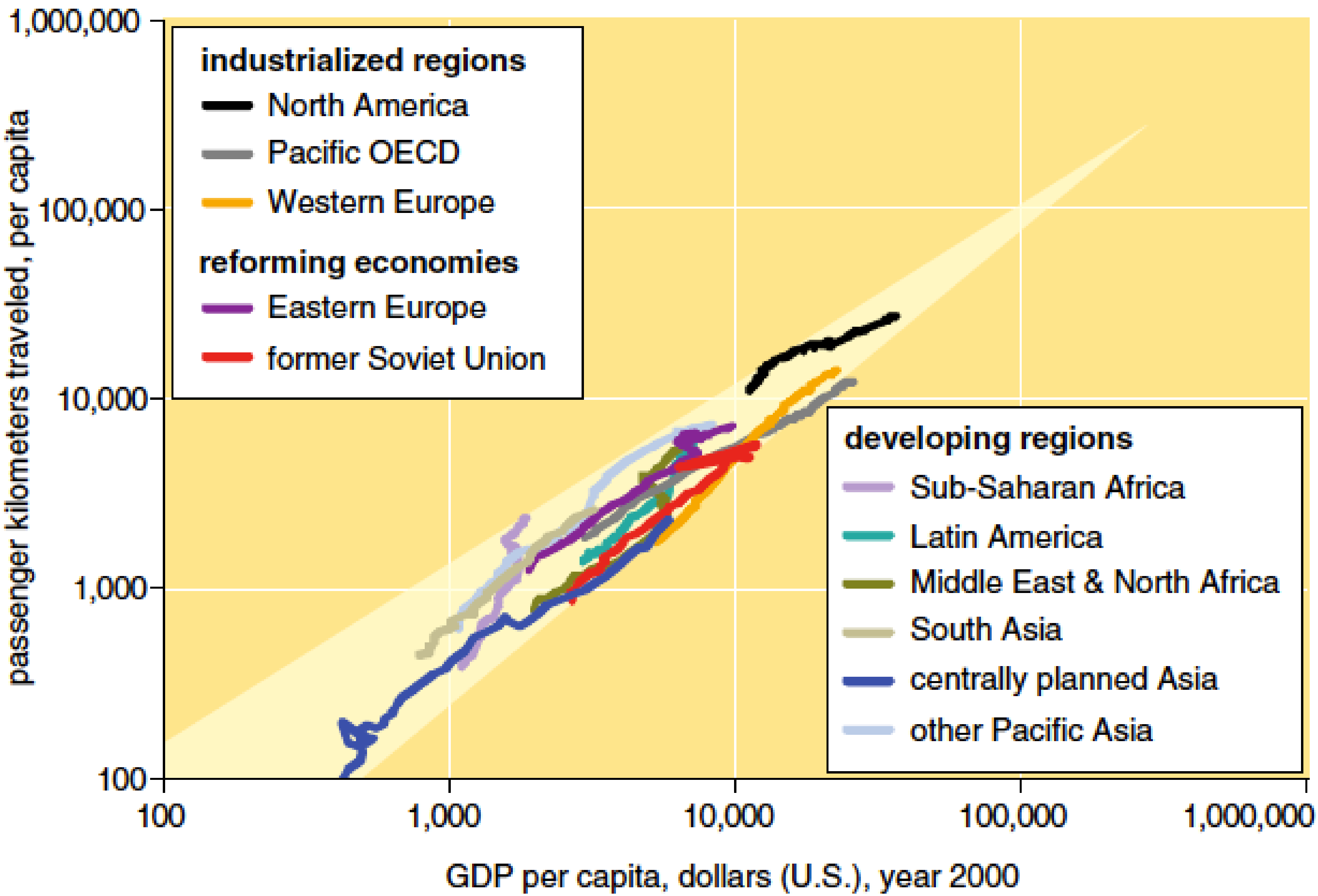
73 years

Greenhouse Gas Emissions Identity

$$\underbrace{GGE}_{\text{Greenhouse Gas Emissions}} = \underbrace{\frac{GGE}{E}}_{\text{Fuel Composition}} \cdot \underbrace{\frac{E}{PKT}}_{\text{Energy Intensity}} \cdot \underbrace{PKT}_{\text{Travel Demand}}$$

Demand Side

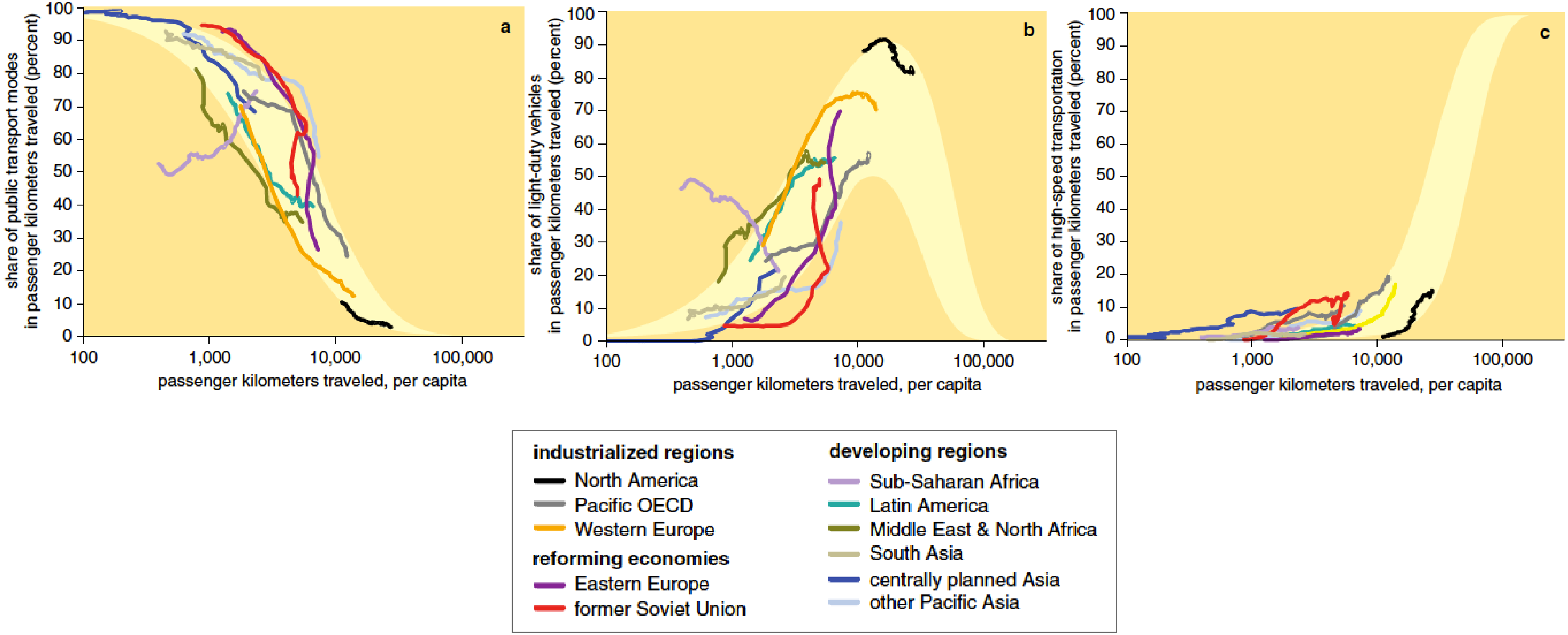
Total Passenger Mobility Growth (1950-2005)



Schäfer A., Heywood J., Jacoby H.D., Waitz I.A., 2009. The other Climate Threat, American Scientist, Nov-Dec.

Shift Toward Faster Modes (1950-2005)

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



Schäfer A., Heywood J., Jacoby H.D., Waitz I.A., 2009. The other Climate Threat, American Scientist, Nov-Dec.

Potential Disruptive Changes to Baseline Development

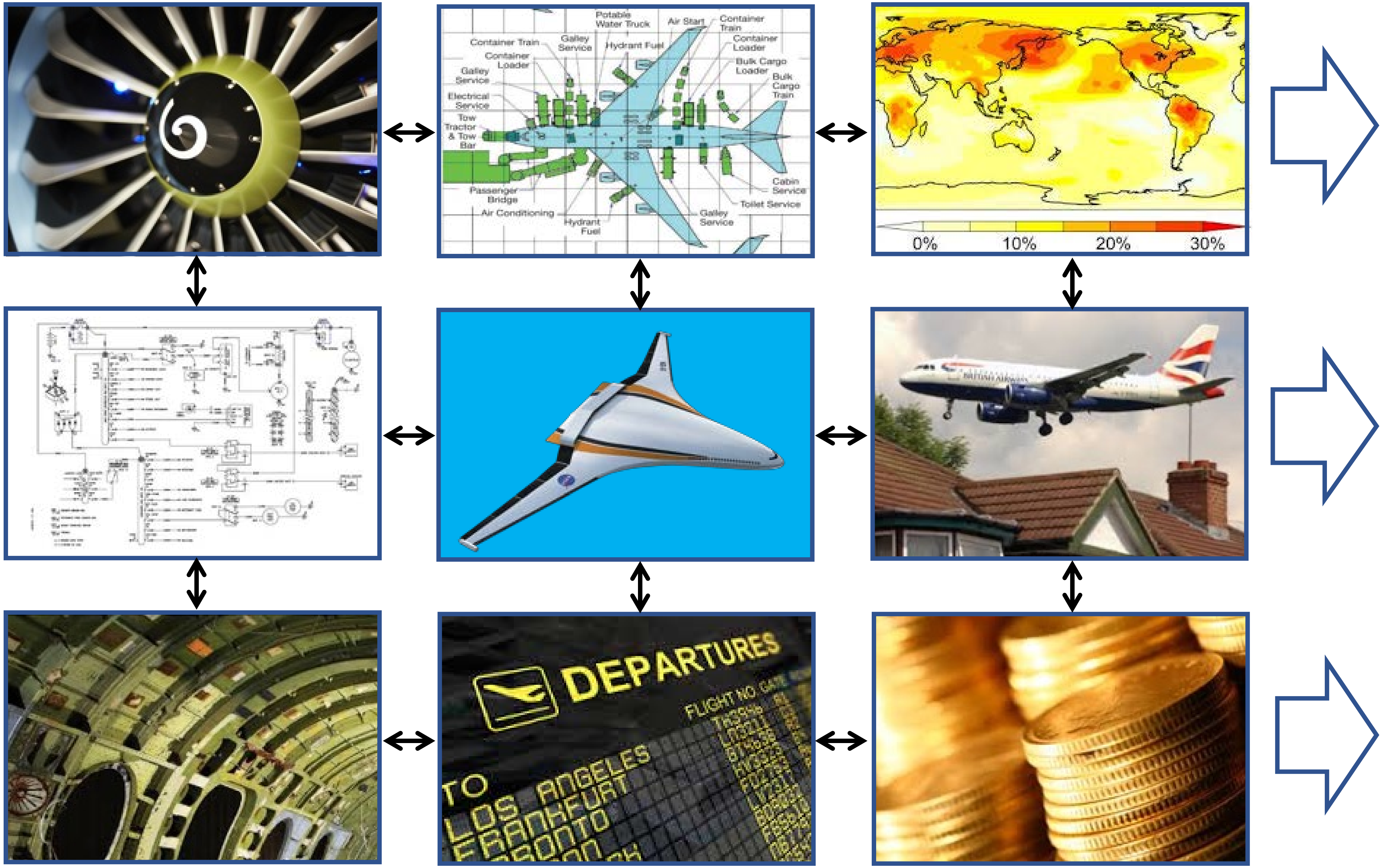
- Supply Side
  - Telecommunication: substitute vs. complement
  - Autonomous vehicles (AVs): shared vs. privately owned
- Demand Side
  - Sharing economy
  - Societal trends & changing demographics
- New Opportunities for Balancing Demand and Supply
  - Electrified, shared AVs in urbanized areas
  - New mobility services and actors, e.g. Mobility as a Service (MaaS)
- Can above factors change the natural dynamics underlying travel demand?
  - Model results: privately owned AV can lead to significant increase in travel
  - AV usage scheme (shared vs. privately owned) can be a critical factor
  - Ultimate determinants: human values, lifestyles, policy measures, etc.

Supply Side

Low-Carbon Alternative Fuels

- Hydrogen
  - Technologically feasible
  - Vast capital expenditures for H2-infrastructure (levelized costs manageable)
  - Conversion losses > 50% for electric propulsion (electricity → H2 → electricity)
- Biofuels
  - 1. generation: main benefit is large oil displacement potential for most processes
  - 2. generation: up to 80% reduction of lifecycle CO_2 emissions, reduced food vs. fuel conflict, US cell. ethanol ~ $2.15/gal (NREL), BTL requires more time and investment
  - 3. generation: algae-based fuels still in laboratory phase, potentially vast resource
- Surface and air vehicle electrification
  - Currently highest battery energy density (Li-Ion) ~ 250 Wh/kg (2% of oil products)
  - Sufficient for automobiles, but not for aircraft (3-8X → different chemistry)
  - Target for cost parity of either mode ~ $100/kWh (currently: $250-300/kWh, 20% cost reduction/yr since 2005)

Electric Aircraft Ecosystem

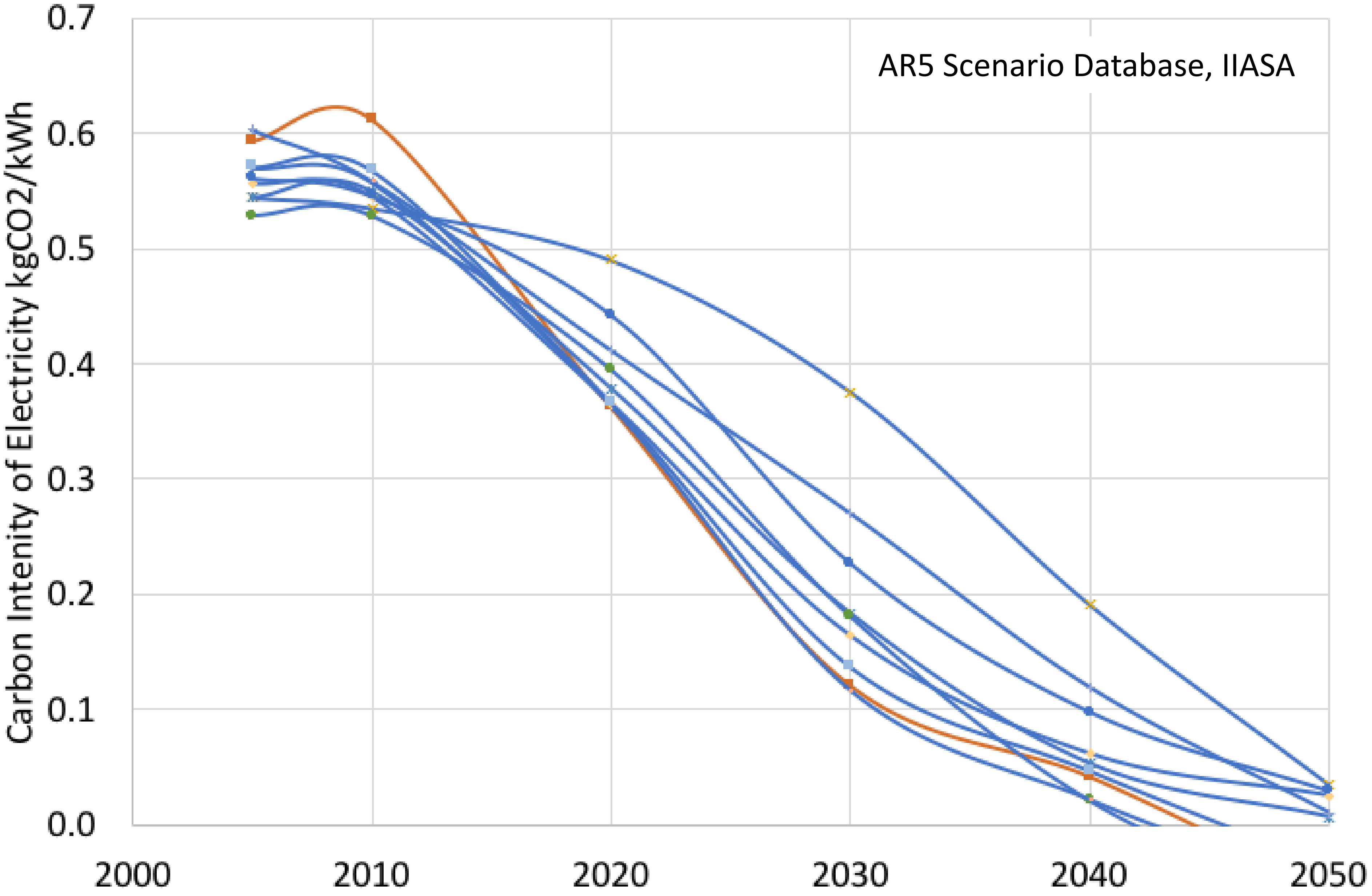


Emissions
(lifecycle perspective)

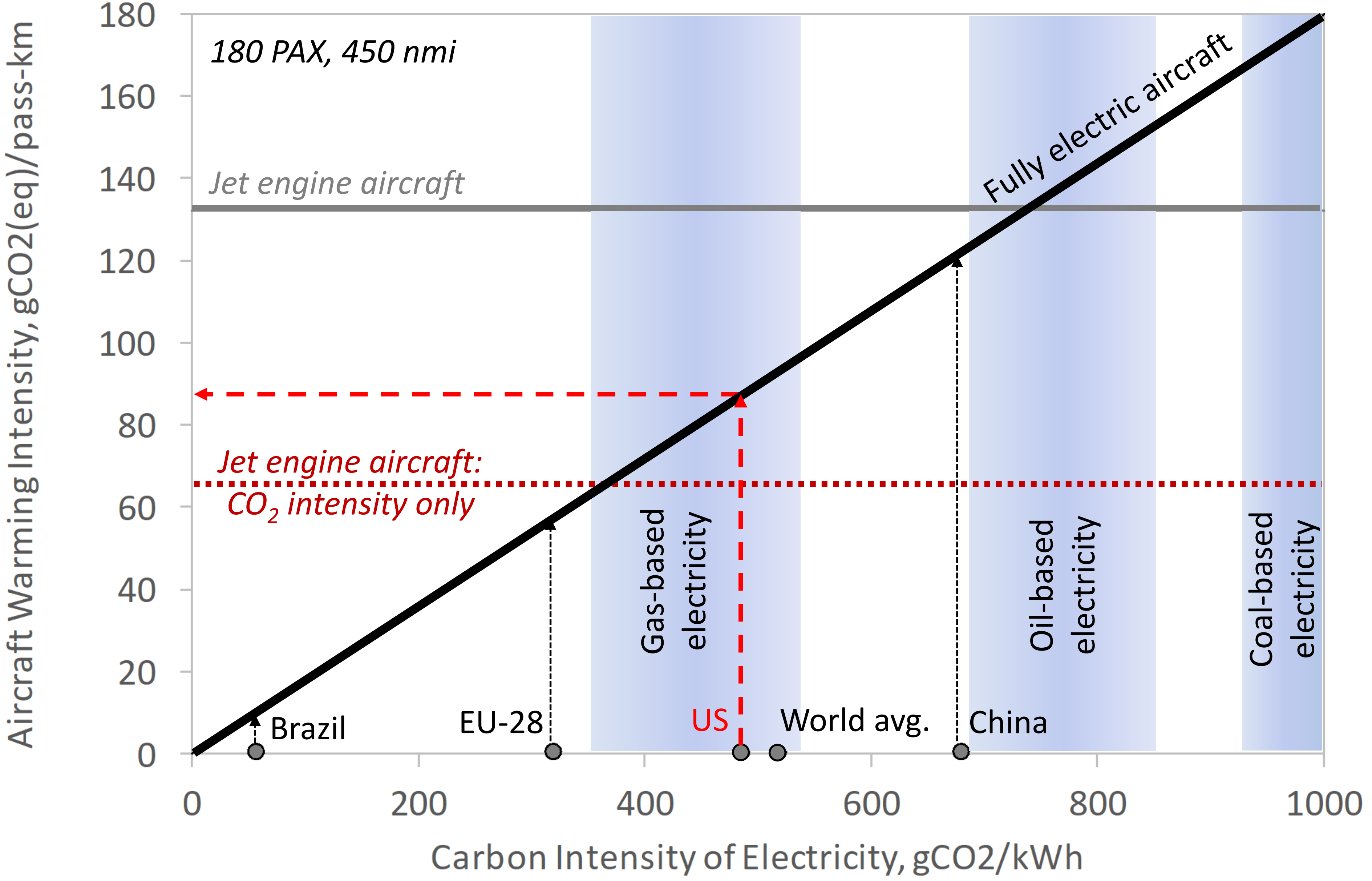
Aircraft noise

Fleet adoption
Flight network
Business models
Airline competition
Industrial competitiveness

Projected CO_2 Intensity of Electricity: 450ppm (EMF27)

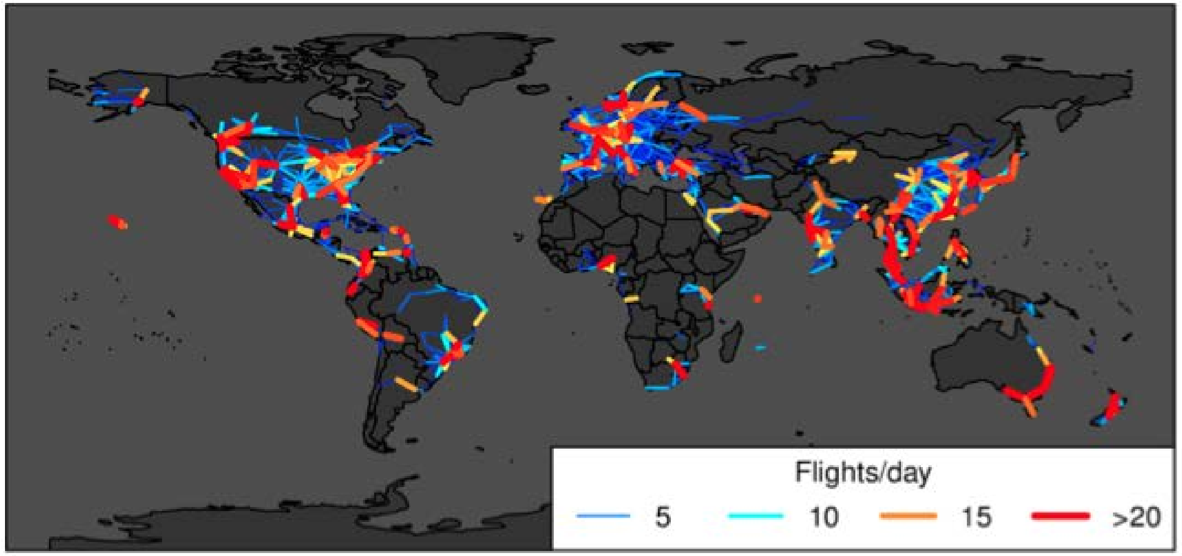


Electric Aircraft Warming Intensity

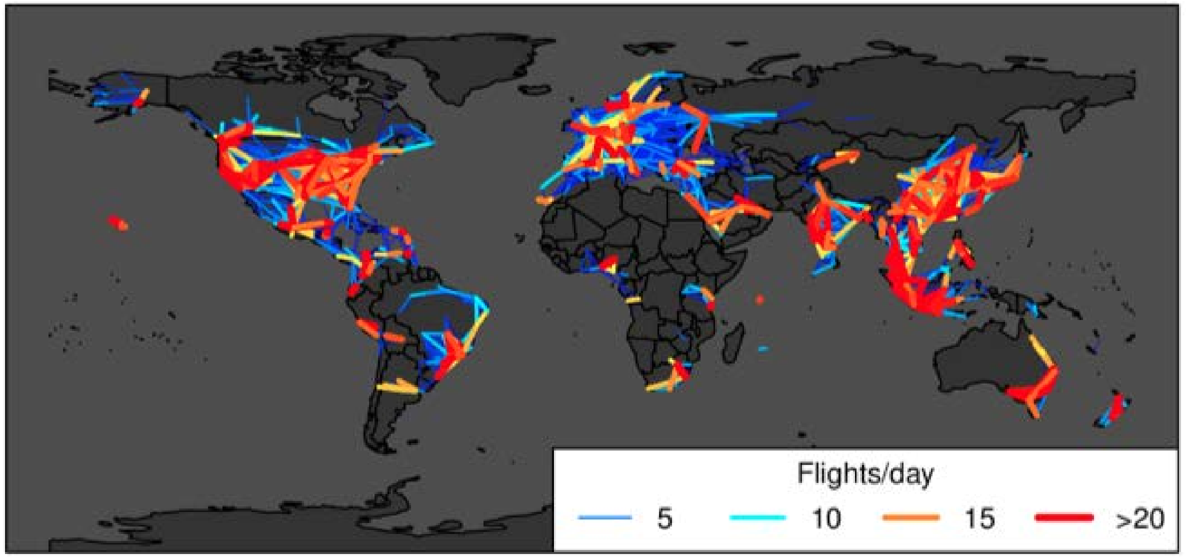


UCL ATSLab

180 PAX Aircraft, Maximum Range 450 nmi



Direct Flights:
41% of flights, 33% of passengers, 9% of RPK



One-stop Flights:
67% of flights, 59% of passengers, 24% of RPK

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