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Flying Cleaner:

The Global Emissions Map of Commercial Aviation

1. Context

- In 2023, aviation accounted for approximately 2.5% of global energy-related CO_2 emissions, reaching 950 Mt of CO_2 (IEA, 2023).

- If aviation were a country, it would rank as the 6th largest emitter globally, between Japan and Germany (EESI, 2022).

- Aviation currently contributes around 3.8% of anthropogenic climate change and is projected to account for 5% to 15% by 2050 if emissions are not mitigated (IPCC, 2023).

- Despite recent efforts by countries to reduce commercial aviation emissions, actions taken to date remain insufficient. Without stronger mitigation policies, emissions are projected to double or even triple by 2050.

Source: IEA, Environmental and Energy Study Institute (EESI), International Civil Aviation Organization (ICAO) and Intergovernmental Panel on Climate Change (IPCC).

2. Objective & Methodology

- The objective is to analyze the CO_2 emissions of the upcoming flight supply over the next few months.

- To this end, a dataset of approximately 100,000 flights was collected from Google Flights, covering a wide range of origin–destination pairs, seat types, and flight types (one-way and round-trip).

- Based on this dataset, a descriptive statistical analysis of emissions per flight was performed.

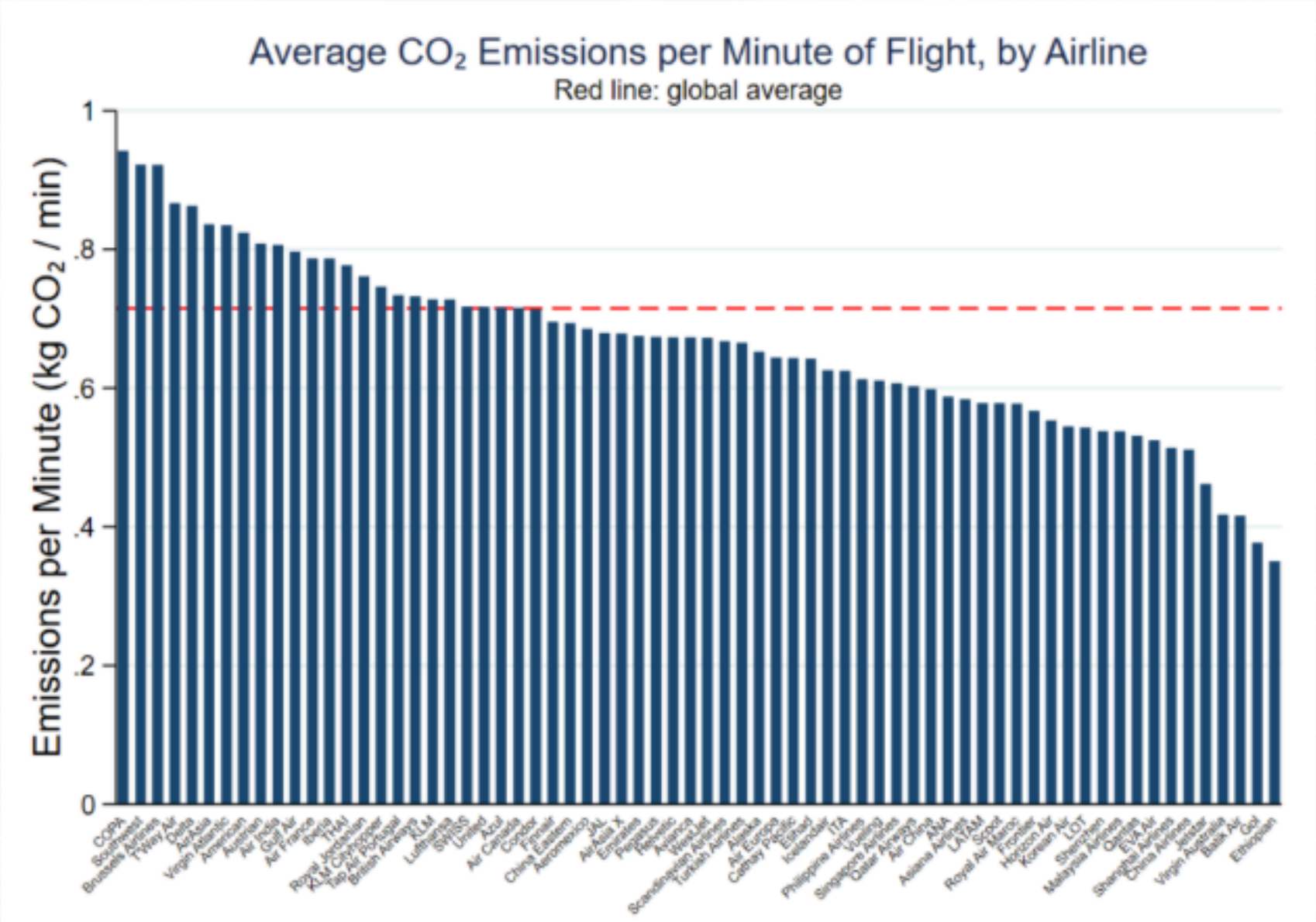
Limitations:

- Emission estimates are provided by Google Flights (based on ICAO and DEFRA models), not actual measured emissions.
- The analysis does not account for load factors (actual passengers onboard).
- Non-CO_2 effects (contrails, NO_x) are not included in the reported CO_2 values.

Note: The ICAO and DEFRA models are used to estimate flight emissions. ICAO provides route- and aircraft-specific values, while DEFRA offers standardized average factors based on distance.

3. CO_2 Emissions per Minute of Flight

- There is heterogeneity in environmental efficiency across airlines.



3. CO_2 Emissions per Minute of Flight

- A number of airlines stand out for having notably higher emissions per minute compared to the industry average. These include COPA, Southwest, Brussels Airlines, T'Way Air, Delta, and Air Asia.

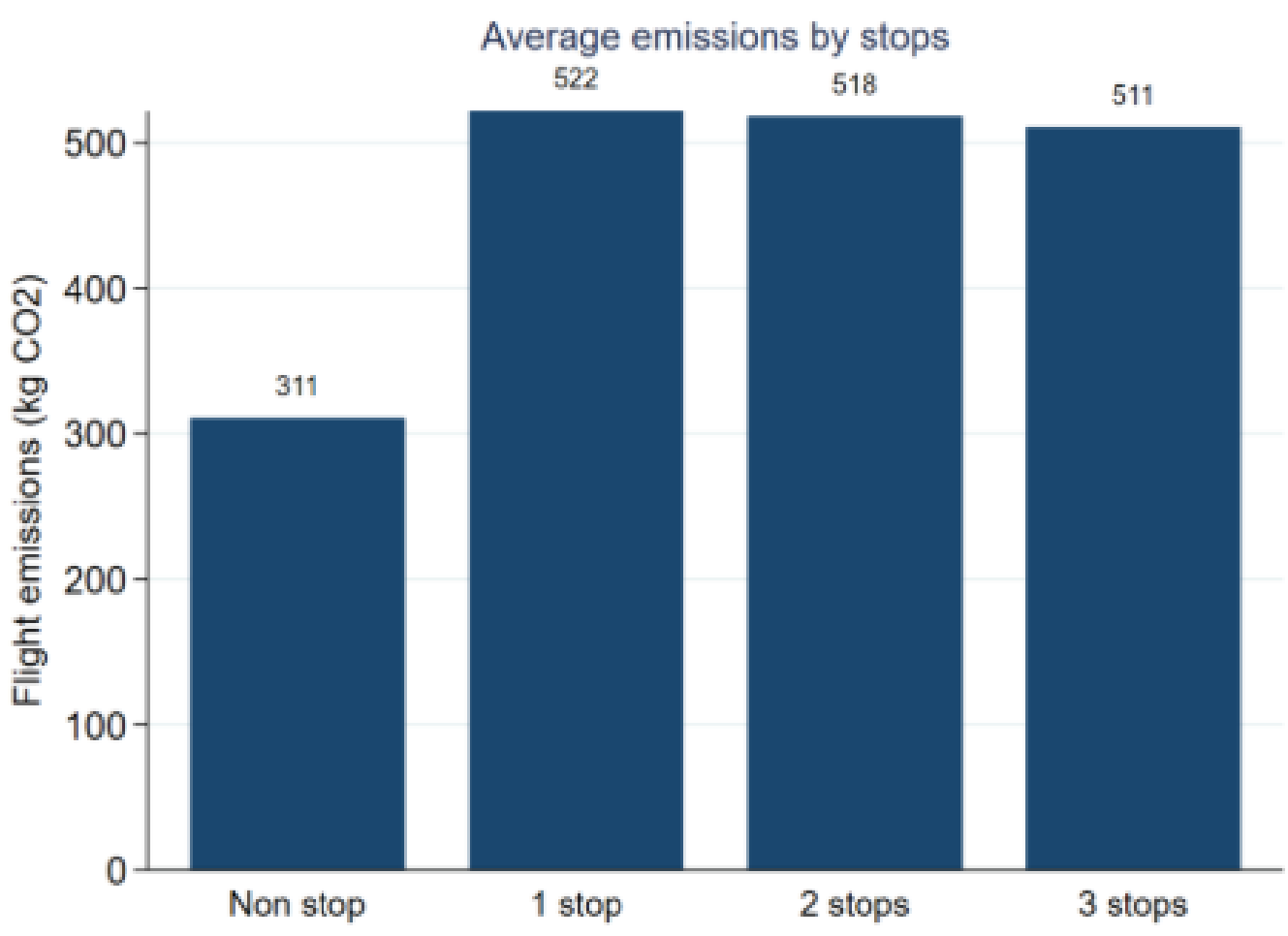
- Asian airlines such as Emirates, Etihad, and Singapore Airlines tend to operate flights that are more efficient in terms of emissions per minute.

TOP 10 Airlines by CO_2 Emissions per Minute	
Airline	**Kg CO_2 / min**
COPA	0.94
Southwest	0.92
Brussels Airlines	0.92
T'Way Air	0.86
Delta	0.86
Air Asia	0.83
Virgin Atlantic	0.83
American	0.82
Austrian	0.80
Air India	0.80

4. Average CO_2 Emissions by Number of Flight Stops

- Flights with stopovers generate significantly higher emissions than direct flights, on average, 68% more than a direct flight.

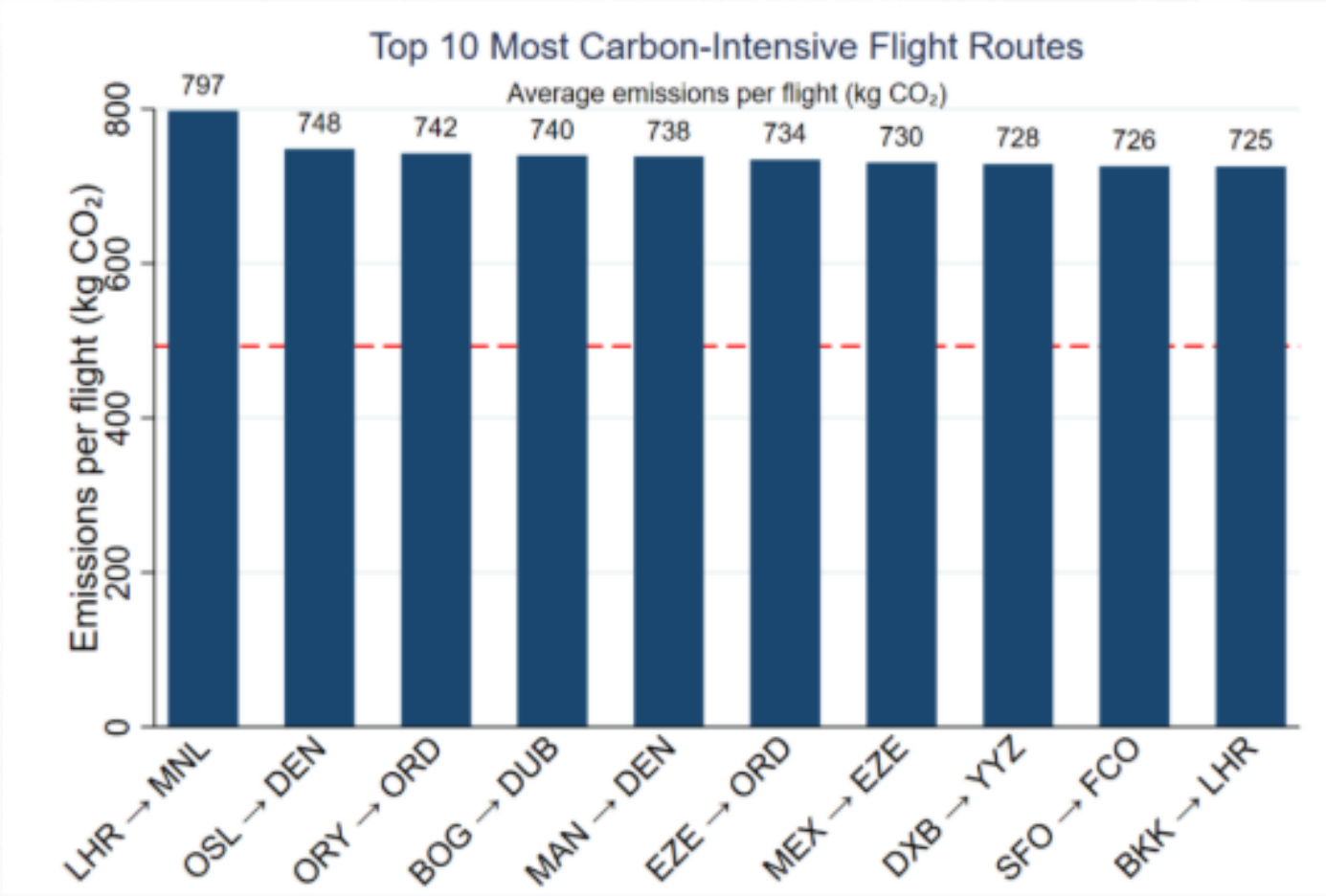
- This impact persists even when controlling for flight duration.



5. Most and Least Carbon-Intensive Flight Routes

- The most carbon-intensive routes are long-haul flights, mainly intercontinental, with emissions close to 800 kg CO_2 per flight.

    - London, UK – Manila, Philippines (797 kg CO_2)
    - Oslo, Norway – Denver, USA (748 kg CO_2).



5. Most and Least Carbon-Intensive Flight Routes

- The least carbon-intensive routes are **short intra-European flights**, with average emissions of around 70–100 kg CO_2 per flight.
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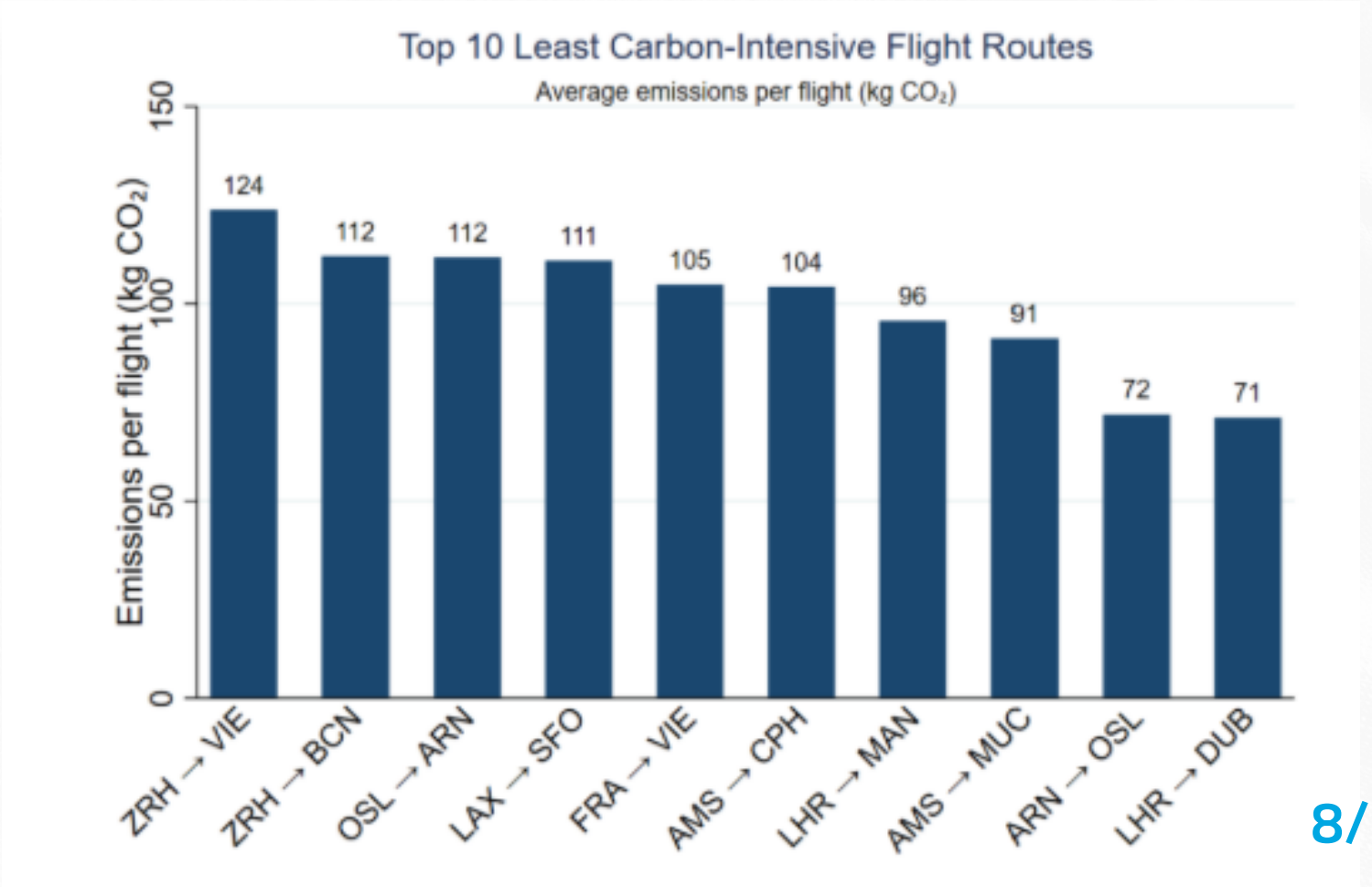
    - London, UK – Dublin, Ireland (71 kg CO_2)
    - Stockholm, Sweden – Oslo, Norway (72 kg CO_2).



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5. How do Emissions Affect Price?

- Surprisingly, flights with higher emissions tend to be slightly more expensive, but the effect is small and consistent even after controlling for flight duration, class, and airline.

- A 1% increase in emissions is associated with a 0.093% increase in ticket price (ceteris paribus).

- Emissions largely reflect underlying flight characteristics such as distance, aircraft type, and service level, which help explain variations in price.