NEXUS

FINDINGS BRIEF · 29 OCTOBER 2026

Contrail Case Study: Frankfurt ↔ Boston and Helsinki ↔ Lisbon, 2025

Key Findings

Every finding in this brief is about contrails. Their warming is expressed as CO_2-equivalent (CO_2e) and compared with the CO_2 from the same flights.

1. **Contrails caused more warming than the fuel burned.** Across 1,867 flights, contrails caused 302 kt CO_2e, 1.3× the 234 kt of CO_2 from fuel.
2. **The time horizon changes the size.** Measured over 100 years, contrails are 1.3× the CO_2; over 20 years, 4.5×. The EU has not yet chosen which horizon to use.
3. **A few flights cause most of it.** 8% of flights caused half of all contrail warming; 20% caused 80%.
4. **Time of day matters.** On average, Lisbon → Helsinki flights, arriving after dark, caused 3.5 t of contrail CO_2e for every tonne of CO_2 they emitted. The return leg caused 1.3 t.
5. **Winter makes it worse.** On average, December flights caused 2.2 t of contrail CO_2e for every tonne of CO_2 they emitted. August flights caused 0.6 t.
6. **Short-haul matters as much as long-haul.** Per km flown, Lisbon → Helsinki caused slightly more contrail warming than Frankfurt → Boston.
7. **Same route, very different results.** Per seat, Lufthansa's contrail impact was 3.4–8.5× Condor's, and its total impact 2.2–2.4×.
8. **Priced like CO_2, contrails would add €22.2m** to a €17.2m carbon bill.
9. **Avoidance is cheap.** Rerouting only the 186 flights with the highest contrail impact (10% of all flights) cuts total contrail warming by 60%. Fuel use across all flights rises by just 0.16%.

Scope and Method

All 1,867 flights on two routes in 2025: 1,171 on Frankfurt ↔ Boston (591 to Boston, 580 to Frankfurt) and 696 on Helsinki ↔ Lisbon (349 to Lisbon, 347 to Helsinki). CO_2 is from PACE, calculated on great-circle distance.

Contrails are modelled per flight by Nexus Lab with the CoCiP model, using actual ADS-B flight paths and ECMWF ERA5 weather data. The resulting warming is converted to CO_2e with published factors for each time horizon.

FINDING 01 · SCALE

Contrail Warming Was 1.3× the CO_2 Warming

Across both routes, contrails added more warming than the fuel burned. A CO_2-only view would miss more than half of this sample's climate impact.

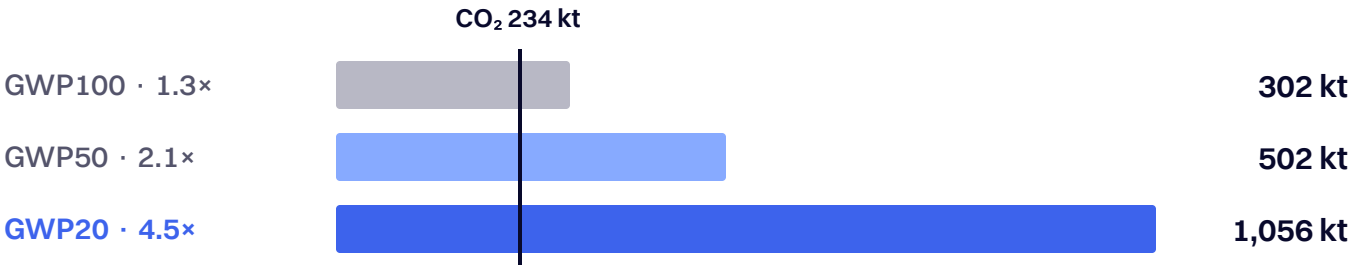


FINDING 02 · METRIC

Over a 20-Year Horizon, Contrail Warming Is 3.5× Larger

To compare contrails with CO_2, their warming is measured over a set time horizon: 20, 50 or 100 years (GWP20, GWP50, GWP100). CO_2 keeps warming for centuries, while a contrail's warming is over within hours. The shorter the horizon, the larger contrails look next to CO_2.

For the same flights, contrail warming is 302 kt CO_2e over 100 years and 1,056 kt over 20 years: between 1.3× and 4.5× the CO_2. Airlines currently report all three to the European Commission, which has not yet chosen the horizon any incentive will use.



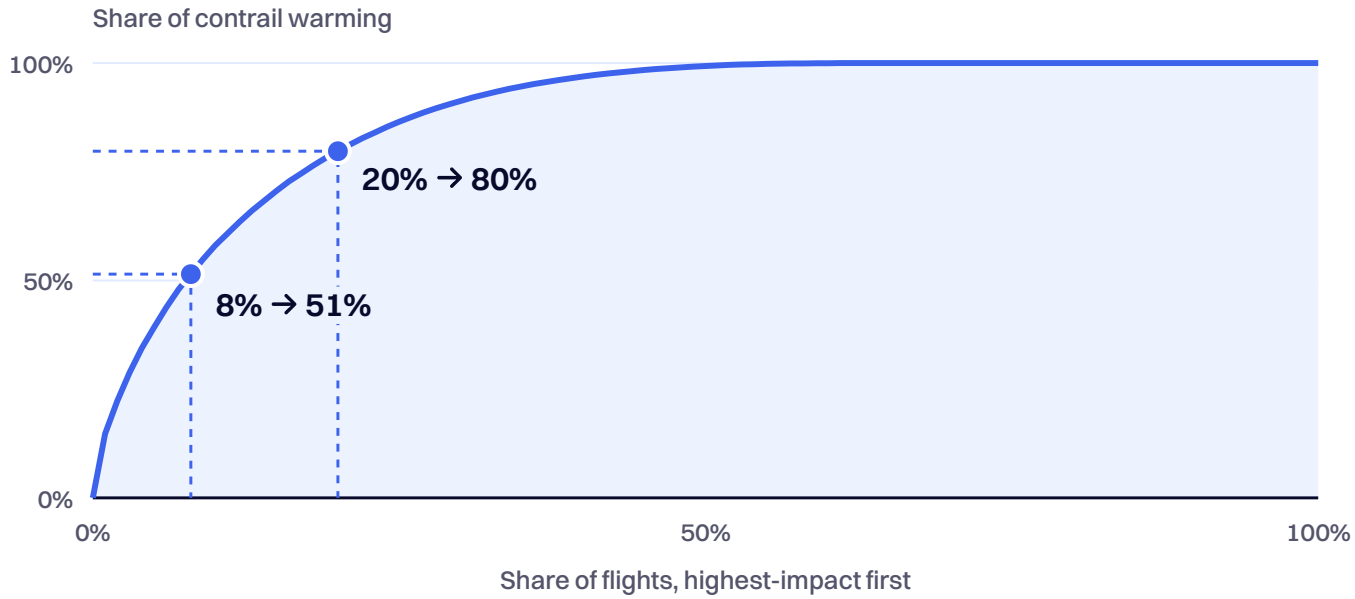
Contrail kt CO_2e for all 1,867 flights on Frankfurt ↔ Boston and Helsinki ↔ Lisbon in 2025, under each time horizon. Line: the same flights' 234 kt of CO_2.

FINDING 03 · CONCENTRATION

8% of Flights Caused Half the Warming

Of 1,867 flights, just 149 (8%) caused half of all contrail warming: 161 kt CO_2e. The worst 19 flights (1%) alone caused 15%. The bottom 37% of flights added no net contrail warming.

This is why avoidance is practical. Airlines do not need to change every flight, only the small number that fly through contrail-forming air, and those can be forecast in advance.



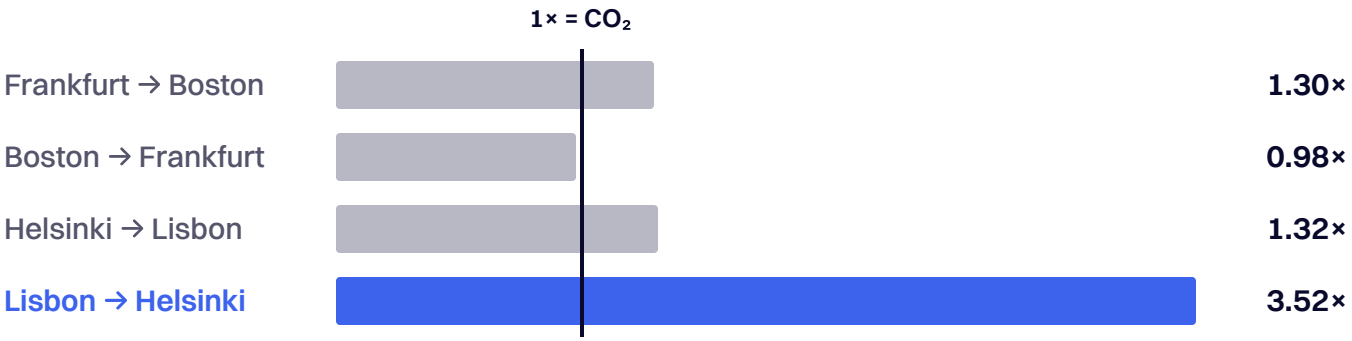
How to read: flights are ranked from highest to lowest contrail impact. Each point shows how much of the total warming the top share of flights accounts for, e.g. the top 20% caused 80%.

FINDING 04 · DIRECTION

Lisbon → Helsinki Stands Out at 3.5×

For every tonne of CO_2 burned flying Lisbon → Helsinki, contrails added 3.5 tonnes of CO_2e. On the return leg it was 1.3. The airports and distance are the same, so the difference comes from timing.

Lisbon → Helsinki departs around 16:00 UTC and reaches northern Europe after dark. By day, contrails reflect some sunlight back to space, which partly offsets the heat they trap. At night there is no sunlight to reflect, so each contrail only warms.



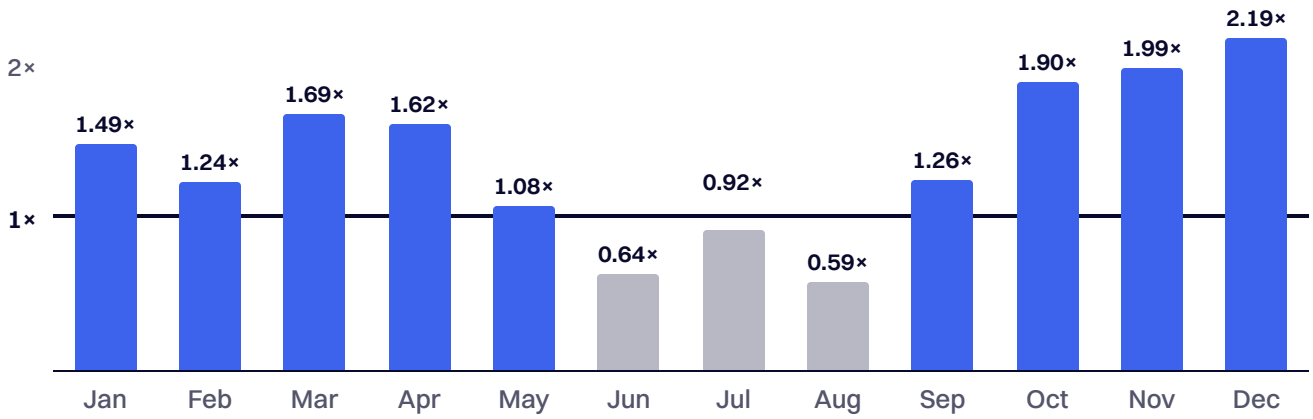
Tonnes of contrail CO_2e per tonne of CO_2, by direction. Line at 1×: contrails equal CO_2.

FINDING 05 · SEASON

Cold Months Multiply the Contrail Impact

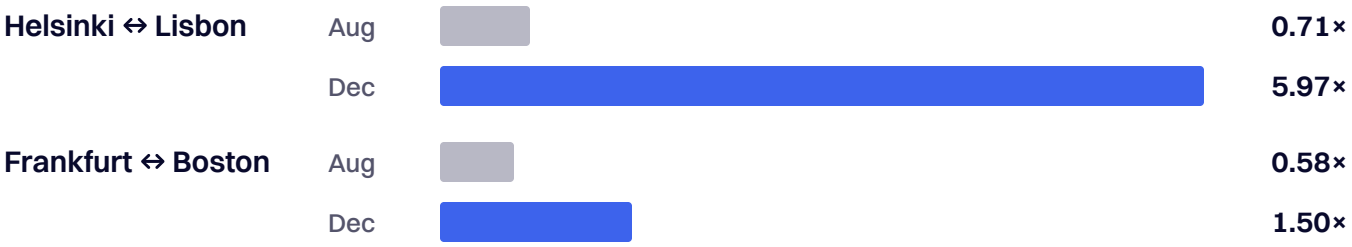
In December, contrails added 2.2 tonnes of CO_2e for every tonne of CO_2 burned. In August it was 0.6. Per flight, that is 271 t of contrail CO_2e in December against 78 t in August.

Winter air at cruise altitude is more often cold and humid enough for contrails to form and persist, and longer nights leave less sunlight to offset their warming. A single annual figure hides this swing.



Tonnes of contrail CO_2e per tonne of CO_2, monthly average across 1,865 flights. Line at 1×: contrails equal CO_2. Blue months: contrails exceeded CO_2.

The seasonal swing is much stronger on the European route. On Helsinki ↔ Lisbon, contrails went from 0.7 tonnes of CO_2e per tonne of CO_2 in August to 6.0 in December, more than eight times higher. On Frankfurt ↔ Boston they went from 0.6 to 1.5.



Tonnes of contrail CO_2e per tonne of CO_2, both directions combined.

FINDING 06 · DISTANCE

Short-Haul Matches Transatlantic per km

Short-haul flights are often assumed to matter less for contrails. Here, each kilometre flown Lisbon → Helsinki produced slightly more contrail warming than a kilometre flown Frankfurt → Boston, a route almost twice as long.

Lisbon → Helsinki · short-haul

40.53 kg

contrail CO_2e per km flown

Frankfurt → Boston · transatlantic

39.19 kg

contrail CO_2e per km flown

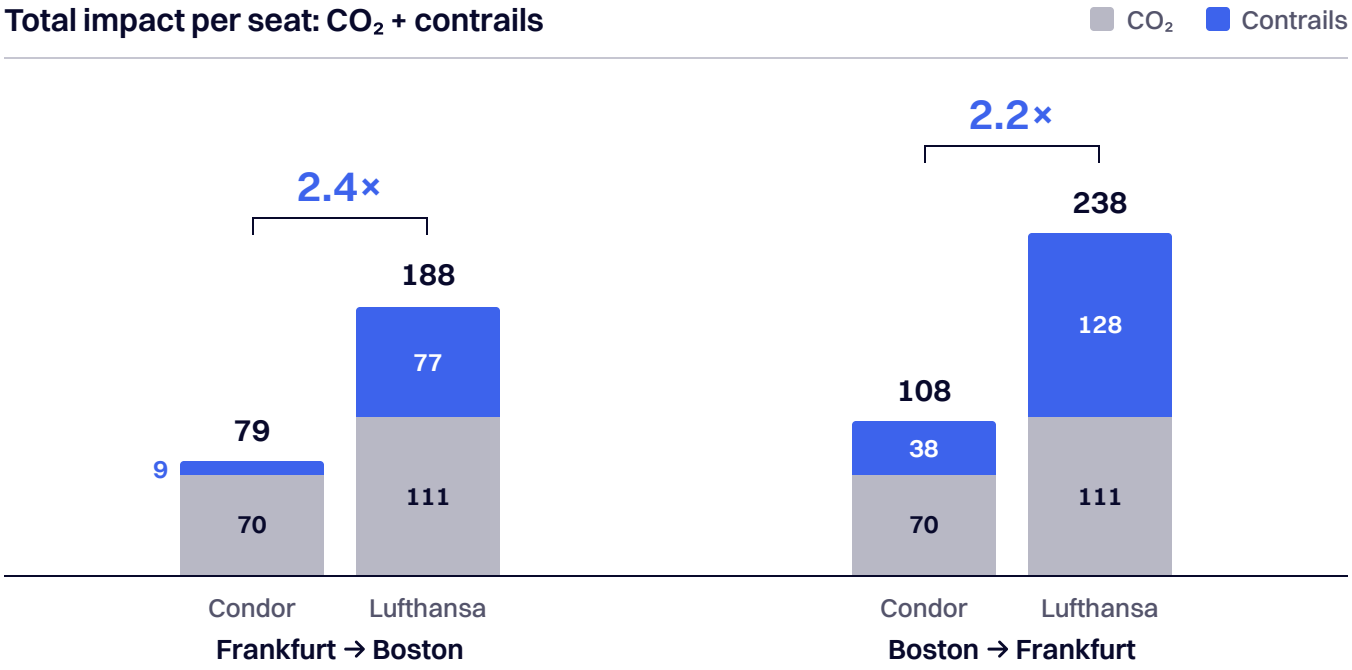
FINDING 07 · OPERATORS

Per Seat, Lufthansa's Total Impact Was 2.2–2.4× Condor's

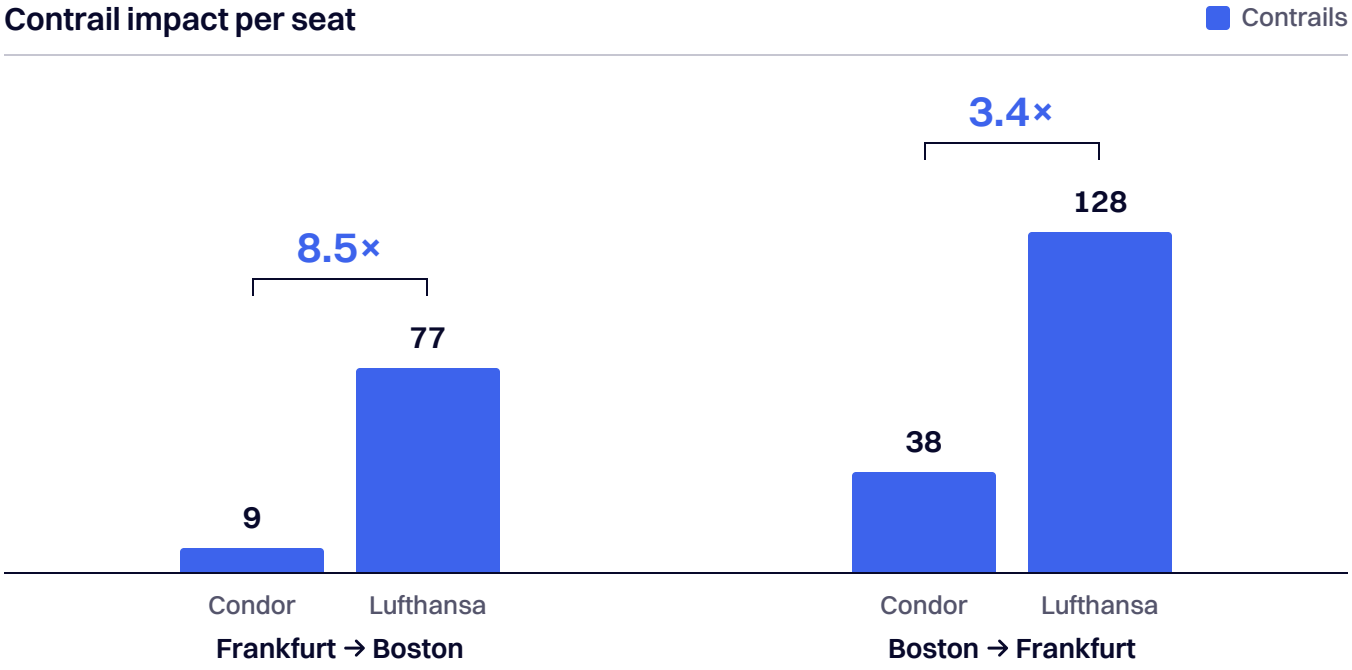
We compared the two airlines' scheduled services on Frankfurt ↔ Boston from May to October 2025. Their departures are about two hours apart, so both fly through similar conditions. The airlines fly a different number of flights with different-size aircraft, so totals would not be a fair comparison. Instead, each flight's impact is divided by its seat-kilometres (published seats × great-circle distance), giving grams of CO_2e per seat per kilometre.

Per seat, Lufthansa's CO_2 is 1.6× Condor's in both directions. That gap is set by the aircraft and stays fixed. The contrail gap is far larger and changes with direction: 8.5× from Frankfurt and 3.4× from Boston. Combined, Lufthansa's total impact per seat is 2.4× and 2.2× Condor's.

Total impact per seat: CO_2 + contrails



Contrail impact per seat



Grams (gr) of CO_2e per seat-km, GWP100; each chart has its own scale. DE2038 vs LH422 and DE2039 vs LH423, May–October 2025. CO_2 from PACE; contrails from Nexus Lab.

FINDING 08 · COST

Priced Like CO_2, Contrails Would Add €22.2m

Under the EU Emissions Trading System, airlines pay for each tonne of CO_2 they emit by surrendering an allowance (EUA). In 2025, an allowance cost €73.45 per tonne on average at auction. At that price, the 234 kt of CO_2 from these flights costs €17.2m.

Contrails are not priced today. If their 302 kt CO_2e were charged at the same rate, they would add €22.2m, taking the bill to €39.4m: 2.3× the CO_2-only cost.

CO_2

€17.2m

Contrails

+€22.2m (+129%)



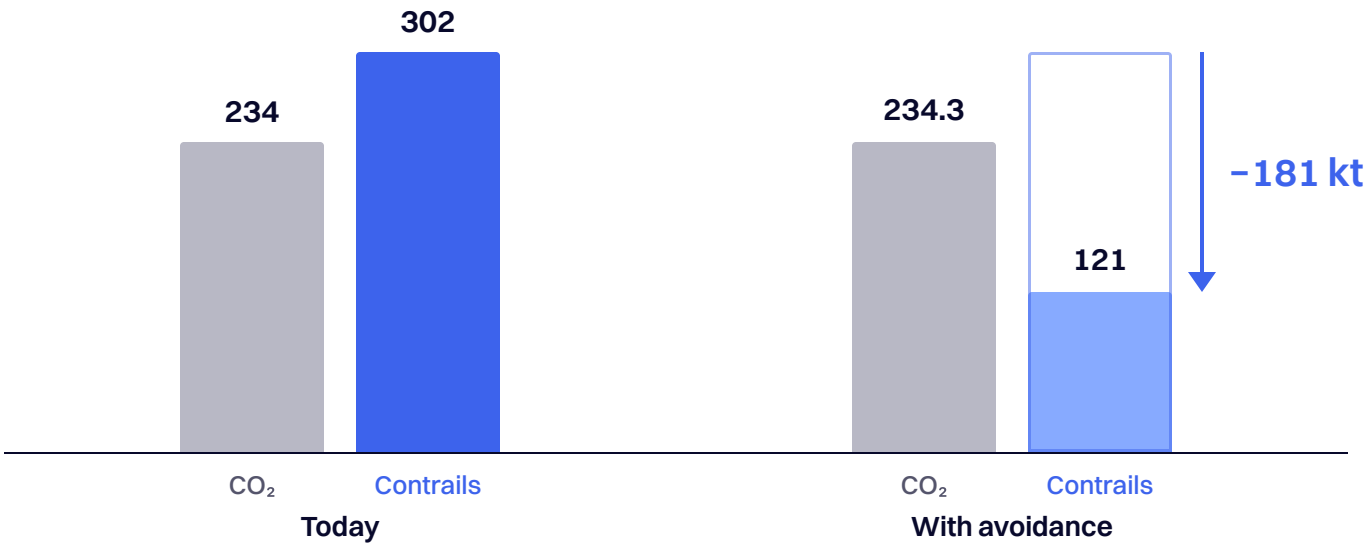
Read with care. This is an illustration of scale, not a forecast. No contrail charge exists today: since 2025 the EU only requires airlines to monitor and report non-CO_2 effects. The figure also prices all 1,867 flights, including the transatlantic ones, which currently fall outside EU ETS.

FINDING 09 · AVOIDANCE

Rerouting 1 in 10 Flights Could Cut Contrail Warming by 60%

We modelled a conservative scenario: only the 186 flights with the highest contrail impact, the worst 10%, are rerouted. Each flies slightly lower the cold, humid air where contrails form, and burns on average 1.25% more fuel to do so. The other 90% fly as they did.

Contrail warming falls from 302 kt to 121 kt CO_2e, a 60% cut worth about €13m at €73.45/t. The extra fuel adds 0.3 kt of CO_2, or 0.16% across all flights. Each extra tonne of CO_2 removes roughly 600 tonnes of contrail CO_2e.



kt CO_2e, GWP100, all 1,867 flights, same scale for both pairs. Outline: contrail warming before avoidance.

−60%
contrail warming

186 flights
rerouted, 1 in 10

+0.16%
extra fuel across all flights