Making Database Research Sustainable

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August 11, 2026

Inria Lille

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  - Vice-president of the EATCS scholarly society
  - Various environmental roles in conferences
- Some individual action towards sustainability
  - From many flights/year pre-2020 to 1 return flight since 2020
  - Vegetarian (2020–)
  - Not reviewing for conferences with mandatory attendance (2023–)

What I will talk about

Sustainability of our practices in database research

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Sustainability of our **practices** in database research

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Specifically:

- Sustainability and the climate crisis: what is it, how bad it is?
- What can we do about it?
- How database research has negative climate impact?
- How can we reduce its impact (as individuals)?
- How can we change our culture (collectively)?

Online participation

[Checking if it works]

Some preliminary warnings

- Disclaimer: **not a researcher in climate science**, psychology, or politics
- Contents may be **uncomfortable** (bad news)
- Not intended as **criticism** of other efforts towards sustainability
- Mostly a **collective action problem** (not easy to act alone)
  - Not everyone can act at the **same pace** / on the same issues
  - Junior community members are **especially not responsible** for the current situation

→ I don't have the perfect solution, the goal is to **start a discussion**

Our unsustainable trajectory

Many kinds of unsustainability

- Exceeding planetary boundaries, such as:
  - **Greenhouse gas emissions** such as CO_2
  - **Biodiversity loss**, species extinction
  - **Land use change**, deforestation
  - **Pollution**: PFAS, microplastics, ocean plastics, heavy metals, air quality...
  - **Water scarcity**
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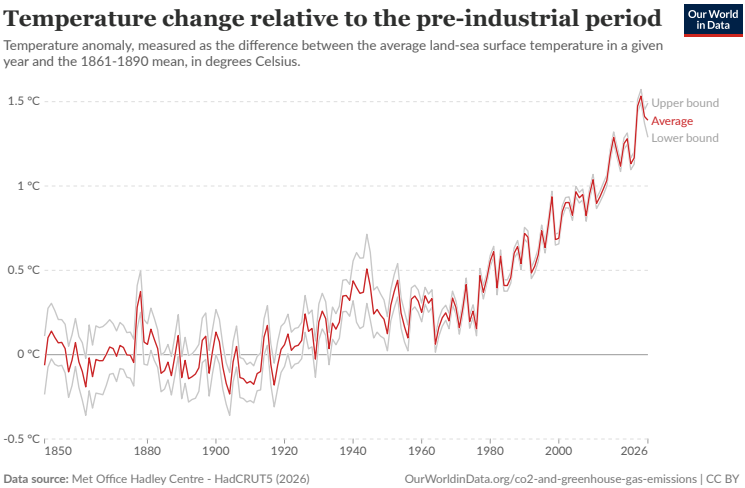
→ This talk only focuses on **greenhouse gas emissions** (but it is a debatable choice)

Most visible consequence: Average temperature increase



Consequences:

- Heat waves
- Extreme weather events
- Droughts
- Reduced crop yields
- Biodiversity loss
- Sea level rise

→ Famine, migration, war...

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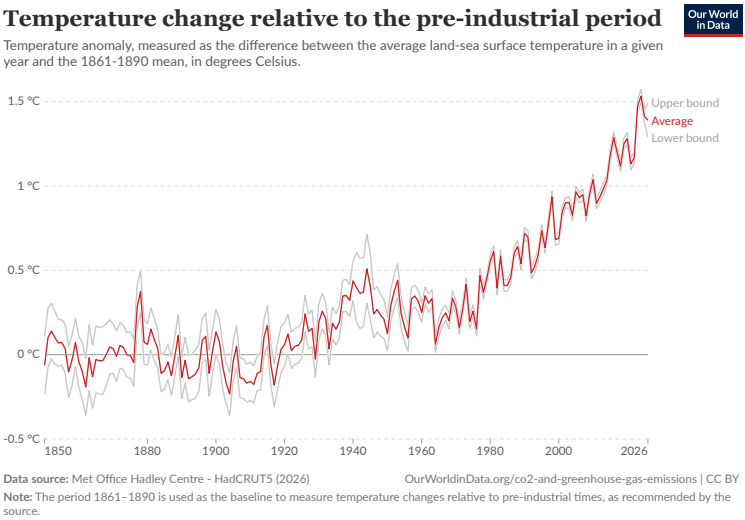

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Paris Agreement (2015):
"Keep global warming well below 2°C, aim for 1.5°C"

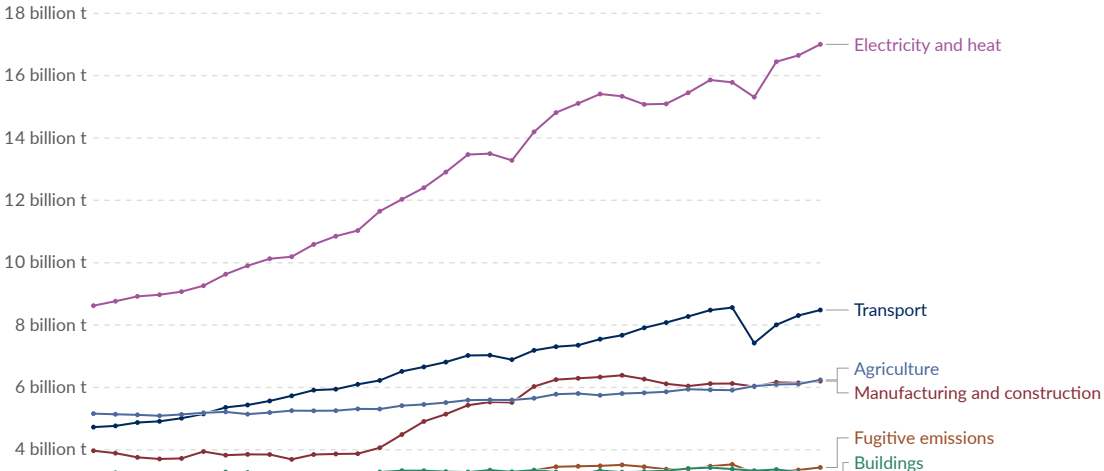
Online question

What is the current trend of worldwide greenhouse gas emissions?

Greenhouse gas emissions by sector World

Our World in Data

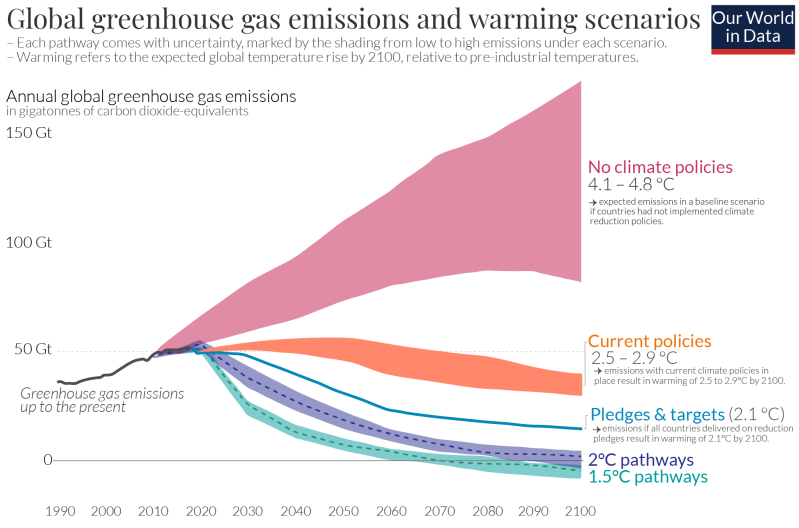
Greenhouse gas emissions are measured in tonnes of carbon dioxide-equivalents over a 100-year timescale.



Online question

Which average temperature increase by 2100 (in degrees Celsius) if countries follow their current policies?

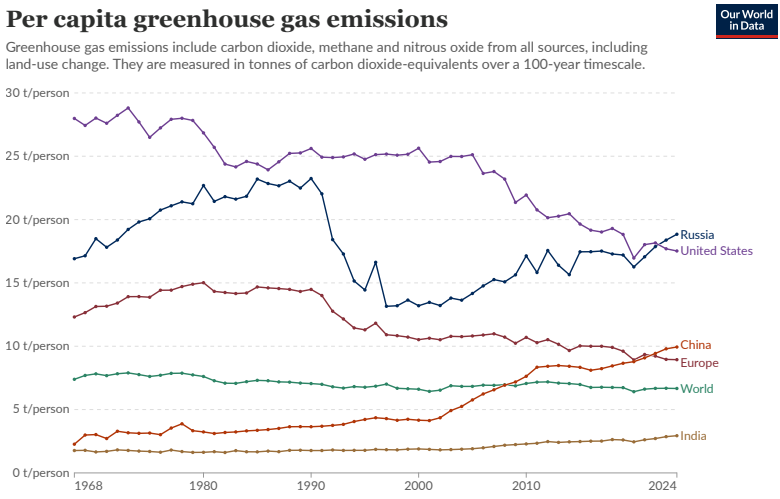
Solution: Lower the emissions



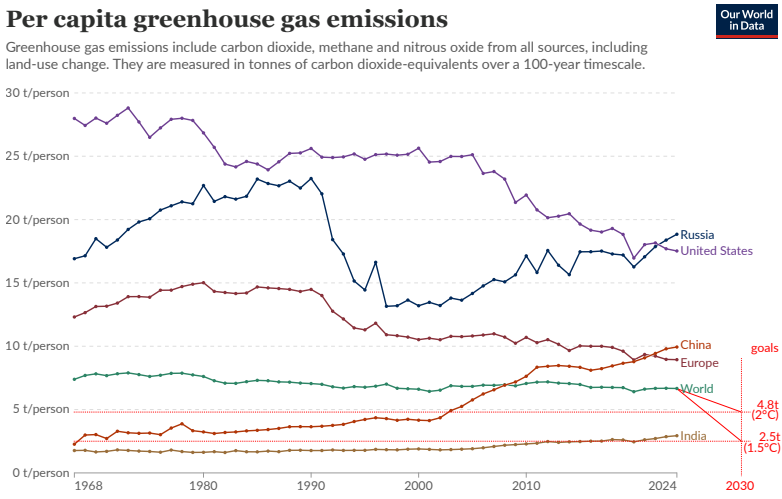
Online question

What is the current trend of per-capita greenhouse gas emissions?

Per-capita emissions have peaked in some countries



Per-capita emissions have peaked in some countries but are still too high



Per-capita targets in 2030 for 2100 goals:

- ~4.8 tons CO_2e for 2.0°C
- ~2.5 tons CO_2e for 1.5°C

Online question

How do you feel about climate change and greenhouse gas emissions?

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- Some level of **environmental consciousness** (though often misguided)

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- Investment is **easily attracted** by competing directions that are harmful for climate (cryptocurrencies, AI, etc.)

What can we do?

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Personal perspective: hard to take sustainability advocacy seriously if there is no **concrete change in how we are doing things**

Online question

Did you change something in your life / job / research topic because of climate change?

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Changing how we do research

Online question

What emits greenhouse gases in our research work?

Impact of our research

How do our research activities cause greenhouse gas emissions? At least four types

- Local logistics:
  - Building construction, electricity, heating and AC
  - Work-home commuting, food (canteens), etc.

  → Best dealt with at a **local level**; not the focus of this talk (but often not negligible!)

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- **Effects of our work**, e.g., causing more data center deployments in the future
  - → Won't be discussed further

Online question

What emits greenhouse gases when organizing an event (conference, summer school…)?

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  - → Plane travel: **∼225 kgCO_2e** for 1000 km
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  - → Negligible

Online question

How many tons of CO_2e is a Paris-New York economy return flight?

Do flights matter?

At a **global level**:

- Flights overall cause an estimated **3.5% of total man-made radiative forcing**
  - Less than half is CO_2: other effects dominate (contrails...)
- Traffic **doubles every 15 years** and trend is expected to continue
- Planes are **already very efficient** and **hard to decarbonize** in the short term

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- Flights overall cause an estimated **3.5% of total man-made radiative forcing**
  - Less than half is CO_2: other effects dominate (contrails…)
- Traffic **doubles every 15 years** and trend is expected to continue
- Planes are **already very efficient** and **hard to decarbonize** in the short term

At your **individual level**:

- A Paris–New York economy return flight emits about **2.7 tons CO_2e**
  - Compare to the yearly target of **2.5 tons CO_2e/capita** for 1.5°C
  - Compare to server use: **1.5 years continuous use** of a 370W server in Poland
- If you fly regularly, it is probably the **main** part of your GHG footprint

Online question

Which CS conferences / events did you attend in person in 2026?

Online question

How many hours (roughly) did you spend flying for professional reasons in 2026?

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One hour on a plane is about 150 $kgCO_2e$

Solution: Modal shift from air to rail?

Answer is a bit tricky:

- For short distances: rail has a $\times 10$-$\times 100$ smaller footprint
  - $\rightarrow$ This is in fact already done by many people in academia
  - $\rightarrow$ Switching to low-carbon high-speed trains is easier in Europe than elsewhere

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$\rightarrow$ Unfortunately, for long-haul flights the only solution is to do less of them

Online question

How many tons of CO_2e emitted for student travel to the VLDB'26 summer school on sustainability?

Case study: The VLDB'26 summer school on sustainability

From the registration data

- 22 non-local students and 9 local students
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For large international conferences the share of non-substituable flights is higher:

- Typically $\sim$80% or more of the footprint comes from non-substituable flights
- Hence: modal shift by itself can only save 20% or less

Flying less

Online question

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How to improve our footprint in the current system? focus on the **first three reasons**

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→ Conference talks nowadays mostly have **social benefits**:

- **Entry point** for outsiders
- Feeling of **community**
- Getting **motivated** about a topic
- Possibility to **ask questions** and meet the speaker

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No good substitute to in-person conferences for this. How to minimize the footprint?

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- Do **combined trips** (multiple conferences, research visit) or **longer stays** if possible
- You can get the "conference experience" (and surprisingly good scientific value) out of **more local meetings** (e.g., national conferences) when they exist

Reason 3: Publication

- Conferences with proceedings: **prestigious journal** with in-person meeting attached
- Sometimes your main goal is to **publish your research** and not the meeting itself
- Big potential savings: **only attend events you are genuinely interested in attending!**
- Problem: traveling to the meeting is often **mandatory**

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So if your goal is to publish, your choices are:

- Choose your conferences depending on **location** or whether they allow **publication without travel**
  - → Competes with prestige and with thematic fit
- Publish in **journals** directly
  - → Often very slow / unpredictable timeline
  - → Loses the opportunity of a conference publication
- Have **coauthors** or colleagues present the work to minimize the number of trips

Why do you travel to conferences?

Your paper is accepted at VLDB! Normally the work is published in the proceedings and you can attend VLDB and present. But what if you had to choose?

Changing our culture

When organizing conferences with proceedings: Make attendance optional

Current policies:

- VLDB: technically a journal (PVLDB), but attendance at VLDB is mandatory
- SIGMOD: technically a journal (PACMMOD), attendance should not be required but the call for paper does not make it explicit (source: email discussion in 2023)
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Cognitive dissonance: is our research really helping sustainability if we continue to do it in a way which is inherently not sustainable?

Online question

How do you feel about emitting tons of GHG emissions per year as a CS researcher?

Other reasons not to require in-person attendance

Our community focus on in-person conferences has other adverse effects:

- Excludes people who cannot pay for travel / conference registration fees
  → Also a problem for journals: open access charges of 2590 EUR per paper at VLDB Journal

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That said: conferences usually **more accommodating** towards imperative reasons (visa); whereas refusing to fly is often perceived as a **deliberate choice**

For conference organizers: Other improvements

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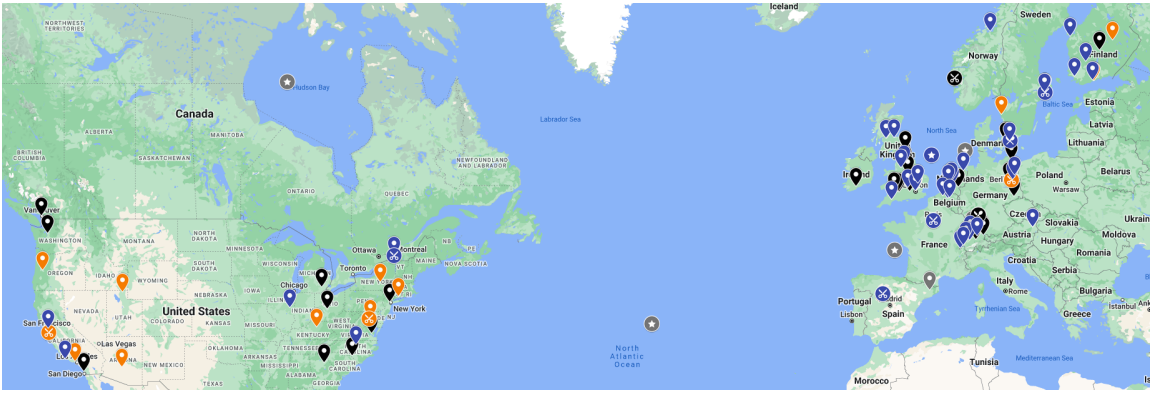
No matter what: Attending international conferences every year is **still unsustainable**

For universities: Local initiatives

More and more **universities** measure their CO_2 footprint and commit to reducing it



Source: `https://www.google.com/maps/d/viewer?mid=1v49WXCeLrpWkeQFvl2xIak8qrTvV7jGe` (2022)

Inspiring examples: ETH Zürich, University of Montreal, IRIF

Also `https://apps.labos1point5.org/transition-1point5`

For other actors: Action at various levels

- National communities, e.g., Labos1point5 in France
- Funding agencies could measure the impact of the research that they finance
- Community initiatives: TCS4F `https://tcs4f.org`, low-CO_2 paper badge

More pointers: *Towards Climate Sustainability of the Academic System in Europe and beyond*, report by ALLEA (European Academies of Sciences)

For the community: Move our culture online

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  → Example: Stack Overflow and Stack Exchange, Zulip, Discord, Reddit, Mastodon…
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- My long-term hope:
  - A **lively online community** where we discuss problems, exchange papers, etc.
  - An **online** (and open-access) publication process (like PVLDB!)
  - In-person social events as a welcome addition (focusing on the social benefits)

Online question

What should we do overall to make database research sustainable?

Conclusion: Who can make this happen?

- As young researchers, you have:
  - Huge career pressure to be visible and publish
  - More benefits to reap from in-person attendance
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Thanks for your attention!

Backup slides

Aside: How to compute the carbon footprint of an event?

`https://tcs4f.org/how-estimate-your-conferences-carbon-footprint`

- Ask participants **at registration** their origin/destination and means of transportation
- Optionally: take into account whether they are also traveling for a different purpose
- **Data cleaning**, infer missing values…
- **Geocode** indicated locations to determine the origin-destination of each trip
- Compute the **distance** and convert it to CO_2e figures using **existing conversion factors** (e.g., from the French ADEME)

I don't know of an existing tool to do this easily (for now)

Reasons not to care

- Hope that technological advances will fix climate change (aka techno-optimism)
  - Identified levers: efficiency gains, renewables, CCS, nuclear fusion power, AI...
  - Unanticipated changes: unknown unknowns

  → Tempting rhetoric: accelerate now, fix the problem later (cf effective accelerationism)

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- **Hopelessness**: “it’s too late”, “I cannot do anything”, etc.
- Hope that **you won’t be affected**:
  - If you are **rich enough** (poorer countries will bear the brunt)
  - If you are **old enough** (and you don’t care about future generations)

Carbon footprint of plane travel

Why does **plane travel** emit greenhouse gases?

- Immediate: **burning fuel** (often the only thing considered):
  - 3.16 tonnes of CO_2 for 1 tonne of aviation fuel burned[1]
  - Consumption per trip depends on engine model, winds, plane weight, distance…
  - Consumption per passenger depends on **load factor** and **class** (economy, business…)
- Also: **indirect emissions** from fuel production (refining)
- Also: **life-cycle emissions** of producing the aircraft, other airline operations…
- Also: other effects such as **nitrogen oxide** emissions and **contrails** (water vapor)

$\rightarrow$ Several methodologies, more or less precise[2]

As of 2021, total emissions estimated at about **3 times** the effect of CO_2[3]

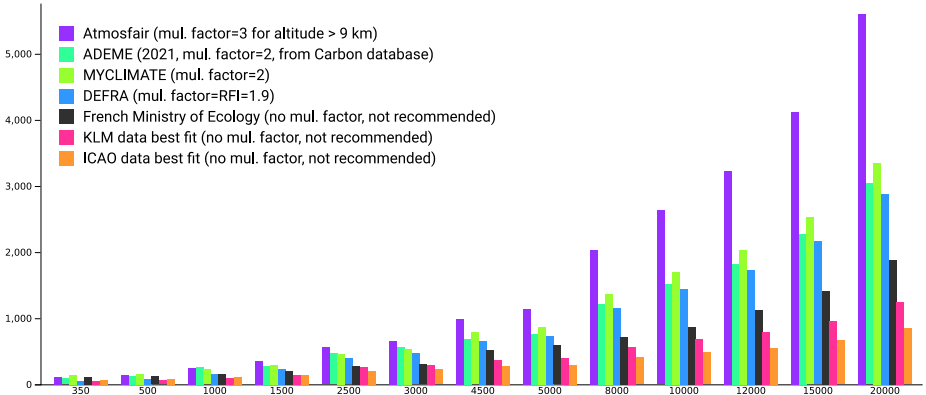
[1] ICAO Carbon Emissions Calculator Methodology v11

[2] See the notion of "Tier" in the 2006 ICPP Guidelines, Volume 2, Chapter 3, Section 3.6.

[3] Lee et al., The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018, Atmospheric Environment, 2021

Carbon footprint of plane travel: uncertainty

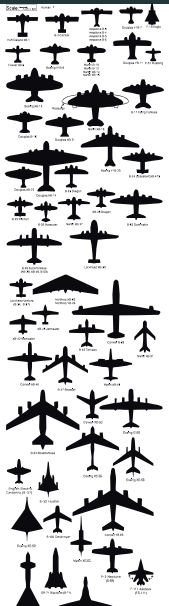
Considerable difference in estimates! More research needed!



CO_2 equivalent emissions (kg) as a function of distance (km) flown in one continuous leg.

Source: https://travel-footprint-calculator.irap.omp.eu/

Cleaner aviation prospects



- Continuous **efficiency gains** on fuel consumption (but already heavily optimized)
- **Aviation biofuels**, partly based on non-fossil biomass, not always sustainable
- **Electrofuels**, using **renewable** electricity to produce standard fuels
- **Further prospects**: electric aircraft, hydrogen-powered aircraft
- Design alternatives, e.g., composite aircraft
- Other marginal gains: route optimization, ATC optimization, ground operations, etc.

Opinion: this is **encouraging** but **unlikely to matter much by 2030** → we must fly less

Overall impact of air travel

- Overall estimated contribution: **3.5% of total man-made radiative forcing**[4]
- 11% of international transportation is **business and professional travel**[5]
- Traffic **doubles every 15 years** and trend is expected to continue[6]
- The emissions of international flights are not part of **national emissions targets**[7]
- Also **inequalities**: many people do not fly, reducing flights is easier than, e.g., food
- Plane technology can **improve** but probably not much by 2030

→ We must fly less!

[4] Lee; et al. (2021), "The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018", Atmospheric Environment

[5] https://www.e-unwto.org/doi/pdf/10.18111/9789284422456

[6] Airbus Global Market Forecast, 2019

[7] Peeters et al., “Are technology myths stalling aviation climate policy?”

Problems of political action

- Global problem: must get countries to agree to large and individually disadvantageous measures
- International meetings: problems of representativity and transparency
- Technically complex problem: often poorly understood by citizens and decision-makers
- Long-term issue: other more pressing problems (COVID pandemic, energy crisis, war in Ukraine, etc.)
- Gradual problem: no clear tipping point (“boiling frog”)
- Greenwashing: difficult to identify real impact

Other difficulties

- Sometimes **debate** on the best solutions (e.g., nuclear power vs renewables)
- **Rebound effect**: efficiency gains sometimes cause larger consumption
- **Carbon offsets**: “reducing” emissions by sponsoring actions that presumably reduce carbon emissions elsewhere
- There is more to **ecology** than GHG emissions and climate change: biodiversity, pollution…

See for instance Lamb et al., “Discourses of climate delay”, Global Sustainability, 2020

Other in-system approaches

- Fossil fuel divestment: organizations that commit not to fund fossil fuel projects
  - → But how to identify them? Precise accounting required!
- Carbon emission trading: give a price to GHG emissions and make emission quotas tradeable, to make it economically valuable to emit less
- Other effects: instability of fossil fuel prices, geopolitical aspects (e.g., gas during the Ukraine war)

Acknowledgements

Acknowledgements: Thanks to Lê Thành Dũng (Tito) Nguyễn and Marie Larochelle for feedback on these slides

Sources

- Slide 6: “more urgent problem”: we are not expected to run out of fossil fuels for the next 50 years at least https://en.wikipedia.org/wiki/Reserves-to-production_ratio and burning all of them would exceed desirable climate scenarios https://pubs.rsc.org/ea/article/4/4/435/807245/What-happens-if-we-burn-all-the-carbon-carbon
- Slide 7: https://ourworldindata.org/grapher/temperature-anomaly
- Slide 9: https://ourworldindata.org/co2-and-greenhouse-gas-emissions
- Slide 11: https://ourworldindata.org/co2-and-greenhouse-gas-emissions

Sources

- Slide 13: https://ourworldindata.org/grapher/per-capita-ghg-emissions?tab=line
  - Target GHG emissions: see Slide 11, dividing by an estimated world population of 8.5 billion in 2030
- Slide 15: some ideas from Hannah Ritchie, *Not the End of the World*, 2024 (not a blanket endorsement)
  - Population peak: https://en.wikipedia.org/wiki/Human_population_projections
  - Comparison to GDP: https://ourworldindata.org/co2-and-greenhouse-gas-emissions?insight=many-countries-have-reduced-their-co2-emissions
- Slide 16:
  - Concern has plateaued: EU Eurobarometer surveys (2023 vs 2025); https://www.pewresearch.org/global/2025/08/19/global-climate-change-as-a-threat/,

Sources

- Slide 20:
  - Manufactured hard drives: https://www.statista.com/statistics/398951/global-shipment-figures-for-hard-disk-drives/
  - Network bandwidth energy efficiency: https://onlinelibrary.wiley.com/doi/full/10.1111/jiec.12630
  - Internet traffic: https://blogs.cisco.com/sp/the-history-and-future-of-internet-traffic
  - Compute per Joule: Koomey's law
  - Total computations: https://www.researchgate.net/publication/49826525_The_World's_Technological_Capacity_to_Store_Communicate_and_Compute_Information/link/0fcfd50fda57556589000000/download https://www.sciencedirect.com/science/article/pii/S2589004226002518

Sources

- Slide 24:
  - Hotel nights: `https://nosgestesclimat.fr/en/documentation/logement/vacances/empreinte-hotel-par-nuit`
  - Meals: `https://etiquettablepro.eco2initiative.com/blog/astuces/72` `https://pmc.ncbi.nlm.nih.gov/articles/PMC9590375/`
  - Plane travel, train travel: `https://impactco2.fr/outils/transport` (using data from ADEME)
  - Videoconferencing has negligible impact: Tao et al., *Trend towards virtual and hybrid conferences may be an effective climate change mitigation strategy*, Nature Communications, 2021

Sources

- Slide 26:
  - Estimated footprint of aviation: cf Lee et al. (2021), *The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018*, Atmospheric Environment. Our World in Data says 4%
    `https://ourworldindata.org/global-aviation-emissions`
  - Traffic: Airbus Global Market Forecast, 2019
  - Paris–New York return flight: Estimation by `atmosfair.de`. Note that, e.g., the ICAO calculator estimates 660 kg CO_2e (in particular it does not account for non-CO_2 effects)
- Slide 31:
  - Share of non-substituable flights:
    `https://discovery.ucl.ac.uk/id/eprint/10124211/`
- Slide 41: "Attendance by women increased **between 60% and 260%** at ICLR, AAS and NAMS VCs compared to the [in-person conference] baselines", Skiles et al., *Conference demographics and footprint changed by virtual platforms*, Nature Sustainability, 2021

Sources

- Slide 42:
  - PODC and DISC study: https://drive.google.com/file/d/1EGrxTpMDR_8y1ZKyPxjdpr-aktTzdS_Z/view
  - Carbon footprint computations:
    https://highlights-conference.org/#carbon-emissions
    https://icalp2022.irif.fr/?page_id=1092
    https://arxiv.org/pdf/2603.02694
    https://api.repository.cam.ac.uk/server/api/core/bitstreams/9e339d1d-bcdc-426d-9017-e7b13c8ea64c/content
  - Optimizing onsite arrangements: See for instance the handbook of the ICEP'19 conference
  - NeurIPS'25 second location: https://blog.neurips.cc/2025/07/16/neurips-announces-second-physical-location-in-mexico-city/