Policy brief

The Airport Tracker

Uncovering aviation emissions

Sam Pickard and Ipek Gençsü
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Key findings

The aviation sector would have been the sixth-largest emitter of CO_2 in 2018 if it were a country, responsible for 2.5% of global emissions, growing 5% annually since 2013. Despite the disruption caused by the pandemic, the sector remains off-track for limiting global heating to 1.5°C.

This brief accompanies the launch of the Airport Tracker, an online tool that maps the climate impact of 1,300 airports, covering 99% of passenger flights. This is the first global attempt to focus on the infrastructure that enables air travel and leads to more CO_2 emissions in future decades.

Airport Tracker data reveals that just 20 airports were responsible for 27% of CO_2 emissions from air passenger transport, 44 airports each created more CO_2 over the course of a year than a coal-fired power station, and nearly two-thirds of air passenger CO_2 emissions were created by just 100 of the 1,300 airports.

The Airport Tracker visualises aviation's deep socioeconomic inequalities: the above airports are overwhelmingly located in the Asia-Pacific, North America and Europe, while passenger flights from just 20 cities created CO_2 emissions equivalent to a mid-sized economy, such as Spain.

Inequality also exists within regions. Of the 346 European airports analysed, just 10 account for 42% of the region's passenger CO_2 emissions, and 4 of these 10 are in just two countries (the UK and Germany).

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Contributors and the Airport Tracker Project

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The Airport Tracker (www.airporttracker.org) is an ongoing project attempting to visualise the climate impact of the world's largest airports. We make this data available to help those working to limit the aviation sector's climate impact and to provide transparency, accountability and comparability for global airport infrastructure-related emissions. The data provide policy-makers and campaigners with robust estimates of the climate impact of existing airport capacity to inform discussions around proposed capacity expansions, and to better understand how the aviation industry can align with a climate-safe world.

Details on how to use the tracker and how the data was compiled are available on the Airport Tracker pages. This is an ongoing project and we welcome ideas for collaboration and to improve and expand the data and analysis provided.

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Executive summary

The aviation sector is a major and growing source of greenhouse gas (GHG) emissions. Aviation emissions of carbon dioxide (CO_2) reached 1 billion tonnes in 2018, 2.5% of the global total (IEA, 2020a; Lee et al., 2021). This would make aviation the sixth-largest emitter of CO_2 if it were a country (Friedlingstein et al., 2020). Aviation also creates non-CO_2 warming effects and overall was responsible for 3.5% of global heating in 2018 (Lee et al., 2021). Flights from rich countries account for nearly two-thirds of passenger emissions (Graver et al., 2019), with less than 1% of the global population likely responsible for half of the sector's climate impact (Gössling and Humpe, 2020).

Prior to the Covid-19 pandemic, aviation emissions increased 5% annually as passenger growth outstripped technological and operational efficiency gains (Graver et al., 2020). How the sector will recover from the pandemic is unclear, yet to limit global heating to 1.5°C, total net GHG emissions must halve by 2030 and fall to zero by 2050 (IPCC, 2018). International aviation was omitted from the first round of pledges countries made to limit the GHG emissions driving global heating. The sector has proposed alternative fuels, new engine technologies and its own offsetting scheme, but altogether these have little chance of curbing emissions fast enough (IEA, 2020a). Put simply, aviation poses a serious threat to meeting global climate targets.

Infrastructure decisions made in the next few years will dictate whether we are on a path to a climate-safe future (NCE, 2016). The government incentives, subsidies and public financing provided in line with such infrastructure decisions give strong signals to industry and other key stakeholders about the future of the sector (e.g. European Commission, 2014). Although it is obvious that additional airport capacity unlocks passenger demand and thereby creates emissions, a major barrier to limiting aviation's climate impact has been the lack of publicly accessible data on the total emissions that airports create. Current reporting standards are preoccupied with the climate impact of airport terminals and ground operations, ignoring the much larger emissions that arise from the flights that airports generate. To remedy this, a collaborative team built the Airport Tracker, an interactive web-based tool that publishes the passenger-related CO_2 emissions created by 1,300 airports, covering 99% of all passenger travel.

The purpose of this policy brief is to illustrate Airport Tracker's utility and the opportunities it creates for those working for a climate-safe aviation sector. Headline findings include the following:

- **Much of the sector's climate impact is concentrated in a few, large airports**. Just 20 airports were responsible for 27% of CO_2 emissions from air passenger transport, 44 airports each created more CO_2 over the course of a year than a coal-fired power station, and nearly two-thirds of air passenger CO_2 emissions were created by flights from just 100 of the 1,300 airports.

- **There is stark spatial inequality between airports globally and within regions**. Eighty-six of the 100 largest airports are located in the Asia-Pacific, North America and Europe; just one is in Africa. Within Europe, 10 airports account for 40% of passenger traffic and 42% of emissions. Of these 10, 4 are found in just two countries (the UK and Germany). Accounting for locations that are served by multiple airports, air passenger transport from the 20 largest airport cities was responsible for 32% of global passenger emissions.
- **Some airports facilitate extremely carbon-intensive travel**. Nearly all airports created more than five times as much CO_2 than travelling the same distance by rail would produce, and the average carbon intensity at 70 airports (5% of the total) was at least ten times that of rail. Dominated by short-haul flights, most of these airports are relatively small, but 15 created more than 100,000 tonnes of CO_2 in 2019, nine of which are in the United States.

The brief also presents five examples of how the Airport Tracker can support diverse avenues of research and advocacy. These are:

1. challenging airport expansion;
2. contesting airports' self-reported GHG emissions;
3. exploring aviation inequality between different geographies;
4. linking airports to local and national climate plans; and
5. opportunities for replacing short-haul flights with other travel options.

The Airport Tracker fills a long-standing gap in our understanding of the link between infrastructure and climate impact in the aviation sector. It visualises the stark global inequality of the source of air travel's CO_2 emissions, illustrates their impact, and provides key data to support those working to address the many challenges these issues create.

1 Introduction

The aviation sector is hampering the fight against climate change

Prior to the Covid-19 pandemic, between 2013 and 2018 CO_2 emissions from the aviation sector grew by 5% per year to reach 1 billion tonnes, accounting for 2.5% of global CO_2 emissions (IEA, 2020a; Lee et al., 2021). If it were a country, this would make aviation the sixth-largest emitter of CO_2 annually (Friedlingstein et al., 2020). Burning aviation fuel also creates other greenhouse gases (GHGs). These non-CO_2 emissions generate additional warming effects that effectively triple the sector's contribution to climate change, meaning its combined impact is responsible for 3.5% of global heating (Lee et al., 2021).

Technological and operational innovation has increased the fuel efficiency of flying, limiting the increase in GHGs arising from the rapid growth in civil aviation unlocked by the building of new airports and runways. However, in recent years efficiency gains have been outstripped by traffic growth, with passenger traffic increasing nearly four times faster than fuel efficiency has improved (Graver et al., 2020). 'Sustainable Aviation Fuels' may reduce the CO_2 warming effects of jet fuel but are unlikely to eliminate them (Lee et al., 2021), and their impact on non-CO_2 warming is still under investigation. Most importantly, scaling them up from their current level of less than 0.1% of aviation fuel (IEA, 2020a) to 5% in 2030 (European Commission, 2021) would only help curb emissions growth, not reduce absolute emissions. In the future, battery electric aircraft may be suitable for shorter flights and hydrogen-powered aircraft hold more promise for longer-haul journeys. However, since even the leading manufacturers believe traditional jet engines will dominate until 2050 (Hepher and Frost, 2021), these technologies are unlikely to arrive in time to limit the sector's climate impact to meet global decarbonisation targets.

International aviation was not included in the first series of Nationally Determined Contributions (NDCs), which saw countries pledge to reduce emissions in line with the 2015 Paris Agreement, nor have governments generally levied taxes on the fossil fuels used for these flights (CE Delft and European Commission, 2019). In 2016, the International Civil Aviation Organisation (ICAO), the United Nations (UN) agency tasked with safety and coordination in the sector, finalised the Carbon Offsetting and Reduction Scheme for Aviation (CORSIA). CORSIA is voluntary for its first six years, only becoming mandatory from 2027, and early analysis has shown that it would cover less than one-third of emissions from international flights (Olmer and Rutherford, 2017).

More recent work for the European Commission assessed how different emissions-reduction proposals would limit the sector's climate impact in practice. This concluded that, of all proposed schemes for the aviation sector, implementing CORSIA in Europe would be the worst option for the climate with patchy international coverage and an oversupply of cheap and questionable offsets leading to a global increase in aviation emissions (Transport & Environment, 2021).

With policy options unable to constrain the market and limited technological options to mitigate aviation's contribution to global heating, demand and emissions from the aviation sector are forecast to grow in the coming decades. How growth will be affected by the global pandemic is unclear, yet a return to business as normal is incompatible with climate targets. Using industry projections from 2018, Gössling and Humpe (2020) suggest that passenger traffic would quadruple between 2018 and 2050, and that emissions would nearly triple. That the aviation sector must curb its GHG emissions is indisputable in the face of the climate emergency, given that total emissions must fall rapidly, halving by 2030 and reaching net zero by 2050, to limit global heating to 1.5ºC (IPCC, 2018). This disconnect explains why the International Energy Agency (IEA) concludes that the aviation sector is not on a climate-compatible pathway (IEA, 2020a), as has long been recognised and recently reiterated by a wide range of constituencies, from academics (Gössling and Humpe, 2020) and activists (AEF, 2021) to city planners (Barcelona Regional, 2021) and national civil servants (CCC, 2020), all of whom are working to secure a sustainable future.

It is well known that building unsustainable infrastructure unlocks new GHG emissions and then locks them in for the following decades (NCE, 2016). Despite this, recent evidence shows that governments continue encouraging the growth of aviation emissions by providing substantial subsidies to airport infrastructure (EnergyPolicyTracker.org, n.d.). Although hundreds of airport infrastructure projects had been identified prior to the pandemic (Stay Grounded, n.d.), one of the largest barriers to limiting aviation's climate impact has been the lack of publicly accessible data on the total emissions that airports create. Without such data, it is hard for policy-makers, campaigners, industry representatives and other key stakeholders to put into perspective the impact of airport infrastructure decisions, and any related funding. Current reporting standards are preoccupied with the climate impact of airport terminals and ground operations, ignoring the much larger emissions that arise from the flights that airports generate. To remedy this, we have built a global Airport Tracker, using suggestions from the constituencies listed above,[1] to support existing efforts and promote new approaches in this space. This policy brief aims to illustrate how the data in the Airport Tracker can be used, and to invite those working on these themes to engage with the data and use it to support their work.

The next chapter outlines the data challenges that the Airport Tracker aims to overcome. Chapter 3 presents high-level findings from the Airport Tracker. Chapter 4 illustrates examples of how the Airport Tracker and its underpinning data may be used by others to drive forward measures to limit the sector's climate impacts. Chapter 5 offers conclusions and next steps. An Appendix provides an outline of the methodology and data sources used in the policy brief.

1 We are grateful to the 56 individuals who provided suggestions and insight during a survey in spring 2021.

2 Overcoming a lack of data on the climate impact of airports

To ensure the aviation sector contributes its fair share in the fight against climate change, we need to understand where its emissions come from. To date, the sector's emissions reporting has been a patchwork of regulations and levels of aggregation that mostly only allow a top-down view. For example, we know aviation fuel consumption at the country level (e.g. OECD, n.d.; UNFCCC, n.d.) and for some companies (e.g. Transport & Environment, 2020a). We also know that commercial passenger flights dominate the sector's emissions (Gössling and Humpe, 2020). Yet even though departure and arrival airports are the major factor defining emissions from a flight, we have no systematic way of understanding individual airports' contribution to climate change, how each contributes to the overall total, or if there are better ways to operate transport systems in a climate-constrained world.

In most cases, airports only report emissions they claim to have direct control over (i.e. emissions from the airport itself), largely ignoring emissions from flights and therefore vastly underreporting their total climate impact (AEF, 2021). Powering terminal buildings with low-carbon electricity and using electric vehicles for ground operations is clearly part of the required transition, but focusing on just a few percent of the emissions an airport creates is an unhelpful distraction given the scale and pace of societal decarbonisation required. The practice is also outdated, given that even fossil fuel producers are now having to report the emissions that their products create (George, 2021), but it explains how 91 European airports have been able to claim they will be net zero emitters by 2030 (ACI, 2021).

To fill this gap and support those working to ensure aviation achieves its fair share of reductions required to limit global heating to 1.5°C, we present the Airport Tracker, a web-based tool that shows the airport-level CO_2 emissions from more than 35 million passenger flights in 2019 (see Box 1).

In the next chapter, we provide some high-level findings generated by the Airport Tracker.

Box 1 The Airport Tracker: a tool to support the transition to a sustainable aviation sector

The Airport Tracker is an interactive web-based tool that provides summary data for passenger-related emissions from the 1,300 largest commercial airports, accounting for 99% of all passenger-related emissions. Flights are assigned to the airport they departed from.

The Airport Tracker's start page is a zoomable global map with all 1,300 airports represented by a bubble. The bubble's size shows the airport's total passenger-related emissions; its colour represents the airport's average carbon intensity.

Each airport also has a summary page. These can be accessed by clicking on the airport on the interactive map or by choosing a country and then an airport from the dropdown selectors in the top-left of the page. An airport's summary page shows the number of revenue passenger kilometres (RPKs; a proxy for an airport's size) and its total passenger-related CO_2 emissions. The top-right of the screen shows the airport's national rank in terms of CO_2 emissions. To make the emissions more relatable, we show how many cars being driven for a year they equate to. The tracker also disaggregates RPK and emissions data by short-haul (<1,500 km), medium-haul (1,500–4,000 km) and long-haul (>4,000 km) flights. For the airport as a whole and for each of these distance segments, total emissions are divided by RPKs to provide the average carbon intensity of flights (gCO_2/pkm).

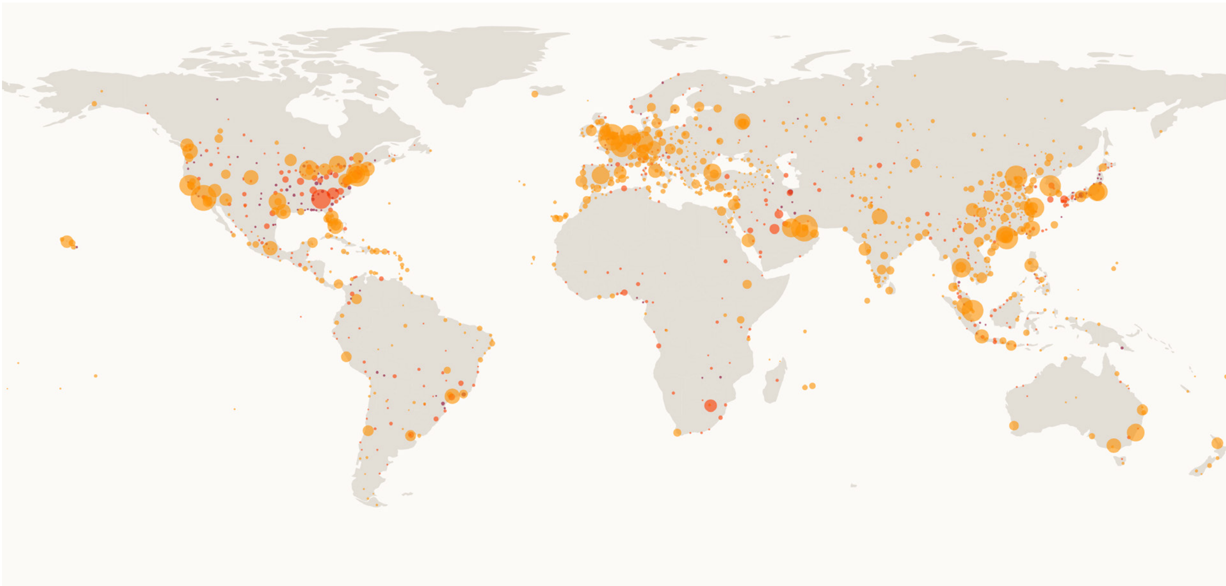
Interactive country summary pages are also available. These aggregate the data on the airport summary pages for all airports within a country, and show where emissions are generated within a country.

The key findings from the Airport Tracker, detailed in Chapter 3, aim to support those working to ensure a sustainable aviation sector. But a key aspect of our wider project is to promote deeper analysis of the much richer dataset that underpins the Airport Tracker, which can be done through accessing the data directly.

3 High-level findings

3.1 The global inequality of airport emissions

Figure 1 Map of all airports' passenger CO_2 emissions (Airport Tracker main page)



Source: Airport Tracker (www.airporttracker.org)

The spatial inequality of airport emissions is clear from the global map that forms the Airport Tracker main page (Figure 1). This shows that most airports lie within a clustered band running from North America to China, in contrast to a few dots in sub-Saharan Africa and South America. The size of the bubbles also makes clear that the climate impact of airports varies, and is heavily concentrated in the so-called Global North. This visualises previous findings that 62% of aviation passenger emissions were created in high-income countries and 28% in upper-middle-income countries (Graver et al., 2019).

> **"Twenty mega-airports create a large country's worth of emissions"**

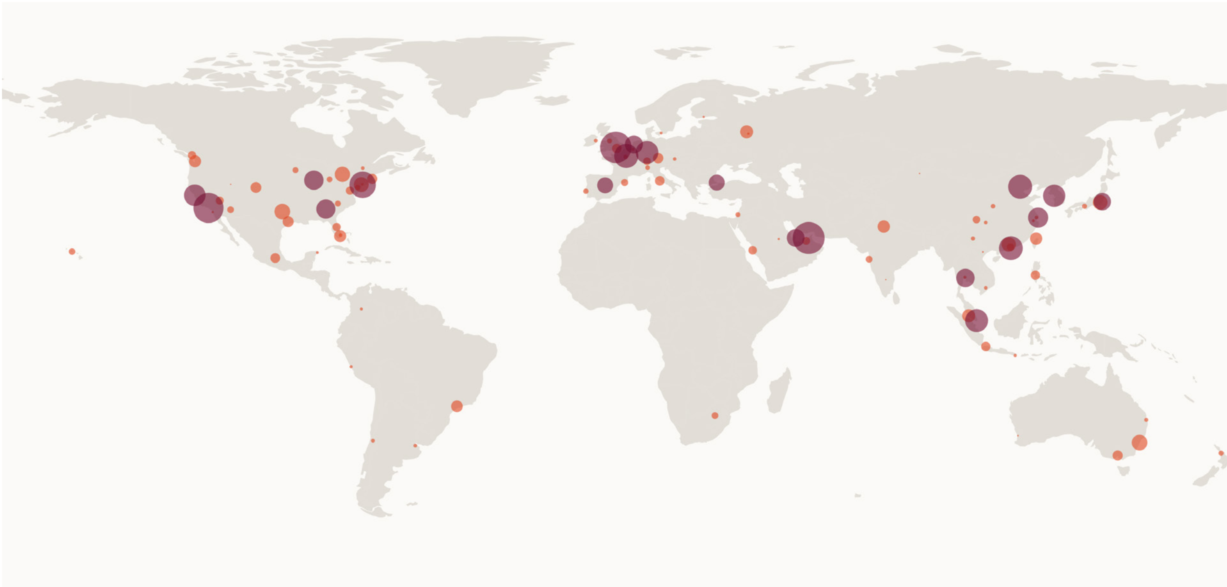
Together, passenger flights from the 20 most polluting airports (i.e. those that created the most CO_2 emissions) created 210 million tonnes of CO_2 ($MtCO_2$) emissions in 2019 from 2.3 trillion passenger kilometres. This is equivalent to 27% of both total passenger traffic and total passenger aviation emissions (from 1,300 airports) and more than the total annual emissions of, for example, the Netherlands or the United Arab Emirates.

Table 1 The 20 airports that generated the most CO_2 emissions from passenger transport in 2019

Airport	Airport code	Country	Passenger emissions ($MtCO_2$)
Dubai International	DXB	United Arab Emirates	16.6
London Heathrow	LHR	United Kingdom	16.2
Los Angeles International	LAX	United States	15.3
New York | John F. Kennedy International	JFK	United States	12.9
Paris Charles de Gaulle	CDG	France	11.5
Beijing Capital International	PEK	China	11.4
Hong Kong International	HKG	Hong Kong	11.3
Singapore Changi	SIN	Singapore	10.8
Frankfurt	FRA	Germany	10.6
Seoul | Incheon International	ICN	South Korea	10.4
San Francisco International	SFO	United States	10.0
Shanghai Pudong International	PVG	China	9.2
Chicago | O'Hare International	ORD	United States	8.8
Hartsfield-Jackson Atlanta International	ATL	United States	8.7
Bangkok | Suvarnabhumi	BKK	Thailand	8.4
Amsterdam Schiphol	AMS	Netherlands	8.1
Doha | Hamad International	DOH	Qatar	8.0
Tokyo | Narita	NRT	Japan	7.8
Istanbul	IST	Turkey	7.1
Adolfo Suárez Madrid-Barajas	MAD	Spain	7.1
Total			**210.2**

Note: $MtCO_2$ = million tonnes of carbon dioxide.
Source: Airport Tracker (www.airporttracker.org)

Figure 2 The 100 most polluting airports, including 20 most polluting airports (red bubbles)



Source: Airport Tracker (www.airporttracker.org)

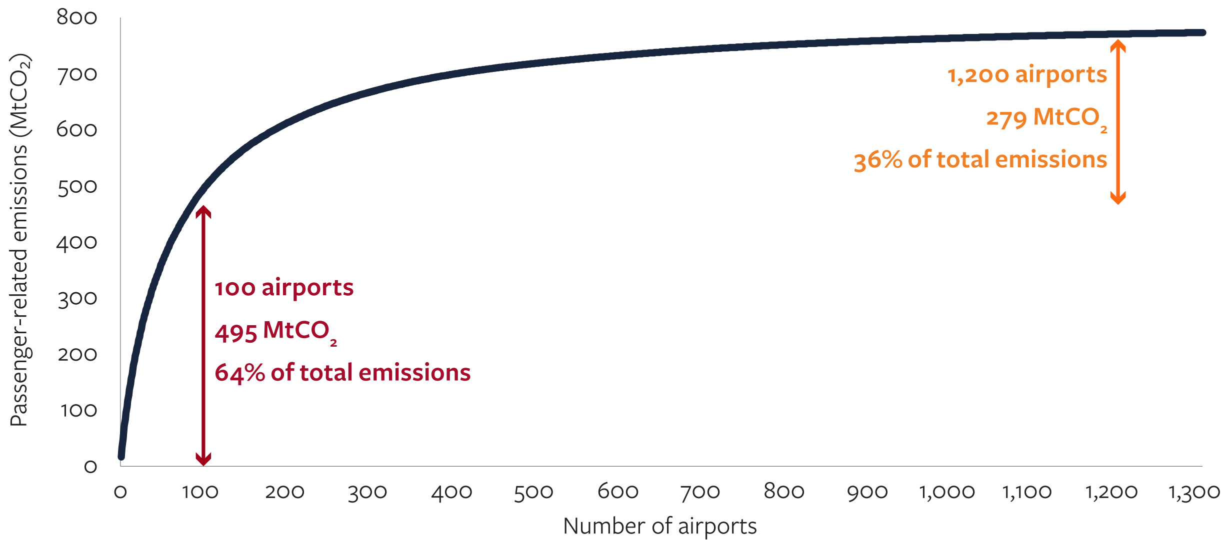
> "There are 44 airports that each created more CO_2 in 2019 than a coal-fired power station"

There is huge variation in airports' climate impact, with a small number of 'big' airports creating a disproportionate climate impact. The 44 largest airports each created more CO_2 in 2019 than a coal-fired power station.

The 100 most polluting airports (8% of the total) combined created 495 $MtCO_2$ in 2019, 64% of all emissions from passenger aviation. They were responsible for 65% of all passenger traffic, and the combined emissions from these 100 airports were nearly double the combined emissions of the 1,200 other commercial airports. Similar inequalities occur within regions: the 10 largest airports in Europe were responsible for 40% of the region's passenger traffic and 42% of its passenger-related emissions, and 4 of these 10 airports are in just two countries: the UK and Germany.

> "The 100 largest airports created 64% of all aviation passenger emissions"

Figure 3 Cumulative emissions from the 100 most polluting airports and the other 1,200 commercial airports



Source: Airport Tracker (www.airporttracker.org)

Eighty-six of the one hundred most polluting airports are located in three regions: the Asia-Pacific (35 airports), North America (28) and Europe (23). The 10 largest airports in these three regions are shown in Table 2. Just one of the 100 (Johannesburg) is in Africa. The same three regions dominate the 20 mega airports – none of which is located in Africa or Latin America, despite these together being home to one-quarter of the global population.

"Airports of 20 cities are responsible for 32% of passenger aviation emissions"

Aggregating emissions by airports' city code allows us to compare the aviation impact of cities with different numbers of airports on a like-for-like basis. Here, the inequality observed at the city level is even more concentrated than that at the airport level. The 20 cities that created the most passenger-related emissions are shown in Table 3, where there is an almost equal split between the Asia-Pacific (seven cities), North America (six) and Europe (six). Dubai is the only city from another region. Passenger-related emissions from airports in these 20 cities totalled 248 $MtCO_2$, 32% of the total global passenger-related emissions and were similar to the annual emissions of Spain (253 $MtCO_2e$).

Table 2 The 10 most polluting airports in the Asia-Pacific, North America and Europe

Rank	Asia-Pacific	Passenger emissions ($MtCO_2$)	North America	Passenger emissions ($MtCO_2$)	Europe	Passenger emissions ($MtCO_2$)
1	Beijing Capital International	11.4	Los Angeles International	15.3	London Heathrow	16.2
2	Hong Kong International	11.3	New York – John F. Kennedy International	12.9	Paris Charles de Gaulle	11.5
3	Singapore Changi	10.8	San Francisco International	10.0	Frankfurt	10.6
4	Seoul – Incheon International	10.4	Chicago – O'Hare International	8.8	Amsterdam Schiphol	8.1
5	Shanghai Pudong International	9.2	Hartsfield-Jackson Atlanta International	8.7	Istanbul	7.1
6	Bangkok – Suvarnabhumi	8.4	Dallas Fort Worth International	7.0	Adolfo Suárez Madrid-Barajas	7.1
7	Tokyo – Narita International	7.8	Toronto Pearson International	6.8	Moscow – Sheremetyevo International	5.8
8	Sydney Kingsford Smith	7.0	Newark Liberty International	6.6	Munich	4.7
9	Tokyo – Haneda	6.5	Miami International	5.4	Rome-Fiumicino International	4.4
10	Guangzhou Baiyun International	6.4	Seattle-Tacoma International	5.4	London Gatwick	4.4

Note: $MtCO_2$ = million tonnes of carbon dioxide.

Table 3 City-scale CO_2 emissions from passenger aviation

	City	Country	Region	Airport city code	Number of airports	Passenger emissions ($MtCO_2$)
1	London	United Kingdom	Europe	LON	6	23.5
2	New York	United States	North America	NYC	4	21.9
3	Dubai	United Arab Emirates	Middle East	DXB	2	16.8
4	Los Angeles	United States	North America	LAX	1	15.3
5	Paris	France	Europe	PAR	3	14.4
6	Tokyo	Japan	Asia-Pacific	TYO	2	14.3
7	Beijing	China	Asia-Pacific	BJS	3	11.9

Table 3 City-scale CO_2 emissions from passenger aviation (continued)

	City	Country	Region	Airport city code	Number of airports	Passenger emissions ($MtCO_2$)
8	Shanghai	China	Asia-Pacific	SHA	2	11.8
9	Hong Kong	China	Asia-Pacific	HKG	1	11.3
10	Seoul	South Korea	Asia-Pacific	SEL	2	11.1
11	Singapore	Singapore	Asia-Pacific	SIN	1	10.8
12	Bangkok	Thailand	Asia-Pacific	BKK	2	10.7
13	Frankfurt	Germany	Europe	FRA	2	10.6
14	Chicago	United States	North America	CHI	2	10.2
15	San Francisco	United States	North America	SFO	1	10.0
16	Moscow	Russia	Europe	MOW	3	9.7
17	Istanbul	Turkey	Europe	IST	2	8.8
18	Atlanta	United States	North America	ATL	1	8.7
19	Amsterdam	Netherlands	Europe	AMS	1	8.1
20	Dallas/Fort Worth	United States	North America	DFW	2	8.0
Total, 20 cities					**43**	**248**
Share of total airport emissions						**32.1%**

Note: $MtCO_2$ = million tonnes of carbon dioxide.

3.2 The carbon inefficiency of some short-haul air travel

The results in Section 3.1 focus on airports that have the largest climate impact overall. These tend to be large international airports that fly lots of passengers over long distances. Separately, we can also investigate the average amount of CO_2 produced to transport a passenger one kilometre. In the Airport Tracker this is called the average carbon intensity and measured in grams of CO_2 per passenger per kilometre.

Although an average long-haul flight creates more CO_2 and has a larger overall climate impact, an average short-haul flight has a higher carbon intensity (Graver et al., 2019).[2] The same is true for flights that carry fewer passengers, either because they operate below full capacity or because they have more first and business class seats, which have a higher carbon footprint than economy

2 Using the data in Figure 3 in Graver et al. (2019): a journey of 500 km has an average carbon intensity of 120 gCO_2/RPK while a journey of 5,000 km has an average carbon intensity of 85 gCO_2/RPK. The longer flight creates more emissions per passenger (85 x 5000 = 425 kg CO_2 compared to 120 x 500 = 60 kg CO_2) and overall because it likely carries more passengers, but the average intensity of the short haul flight is 40% higher.

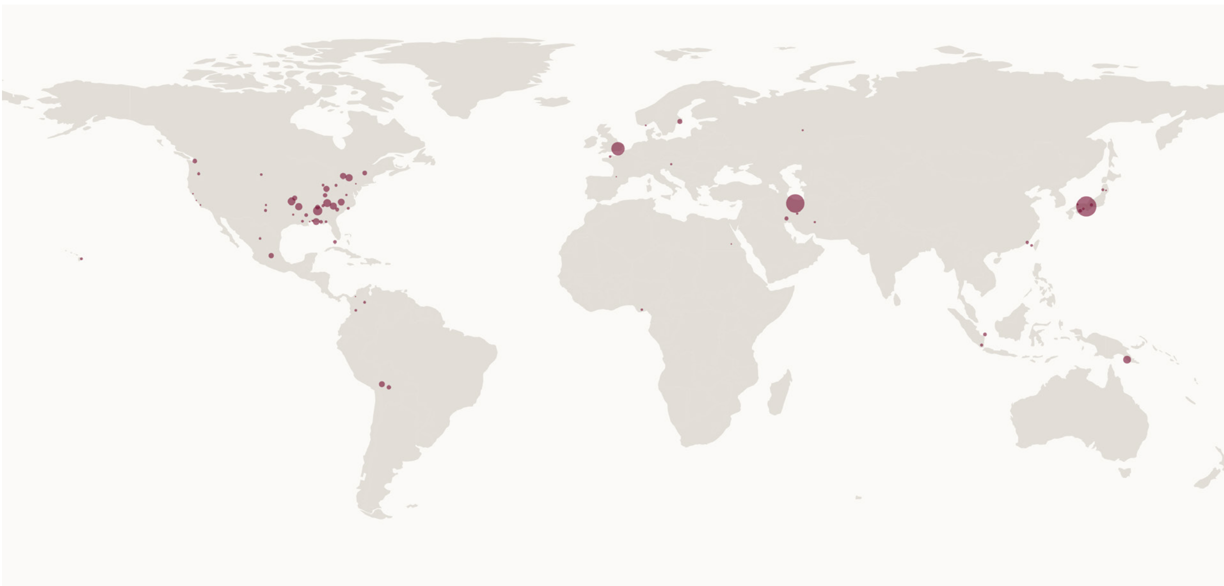
class (Bofinger and Strand, 2013). With this in mind, airports that have much higher average carbon intensities are likely to be dominated by short-haul flights, where other transport options may be available, and those that facilitate low-occupancy routes, where a fair climate future requires we interrogate the social and economic justification for these flights.

> **"Almost all airports create more than five times as much CO_2 as would travelling the same distance by rail"**

Comparing average airport intensities with alternative transport modes shows that flights from almost all airports create more than five times as much CO_2 than travelling the same distance by rail would generate. This should be interpreted as showing how carbon-intensive flying is compared to other types of travel rather than suggesting that rail is a realistic alternative to long-haul flights. We also find that there are 70 airports (5% of the total) where the CO_2 emissions created by flying are at least 10 times those created by travelling the same distance by rail (see Figure 4). Together they created 5.9 million tonnes of CO_2 (equivalent to annual emissions from nearly three million cars). On average across these 70 airports, 92% of emissions were created by short-haul flights. Most of these airports are small, but 15 of them created more than 100,000 tonnes of CO_2 in 2019. Nine of these are in the United States.

The next chapter provides examples of how the Airport Tracker summary and detailed data can advance understanding and advocacy across different aspects of this wide-ranging field.

Figure 4 Airports with very high average carbon intensity



Source: Airport Tracker (www.airporttracker.org)

4 How the Airport Tracker can support research and advocacy

Ensuring the aviation sector fits within a just and fair climate-safe world touches on research and advocacy work across a wide-range of disciplines. The examples in this chapter illustrate how the Airport Tracker can support these efforts, including those related to carbon budgets, climate justice, GHG reporting frameworks and alternative transport modes.

4.1 Challenging airport expansion plans

The Covid-19 pandemic has paused some airport expansion plans, but many – like that of Barcelona (Burgen, 2021) or Dallas-Fort Worth (DFW Airport, 2021) – are still being proposed and accepted by governments around the world. Growth is fastest in the Asia-Pacific region, where 40 of China's busiest airports are slated for expansion alongside 30 entirely new airports being built in the next four years (Chaoyi, 2021). Many of these schemes – in richer and poorer countries alike – are financed by public banks (e.g. KfW IPEX-Bank, 2019; AIIB, 2019; ADB, 2020).

Data from the Airport Tracker can be used to challenge the rationale for new and expanded airports on two levels:

1. Few airport expansion plans provide detailed estimates for increases in GHG emissions, instead focusing on the increased number of passengers. Data presented in the Airport Tracker (i.e. data directly available from the website) can provide useful comparisons for the expected increase in CO_2 emissions – both by scaling up the existing figures for short-/medium-/long-haul flights, and by comparing with existing airports with similar characteristics to those proposed.
2. The Airport Tracker presents a summary of a much richer dataset, extracts of which are available on request. Diving deeper into the data allows interrogation of the supposed 'need' for extra airport capacity. For example, in support of analysis by the Barcelona City Administration, which has published its own reasons for opposing the expansion of the city's airport (Barcelona Regional, 2021), data from the Airport Tracker could show that Madrid and neighbouring Catalan airports already serve very similar destinations.

4.2 Challenging airports' self-reported GHG emissions

As described in the introduction, airport-level GHG reporting is largely detached from the actual GHG emissions airports create because airports ignore most of the emissions created during flight. Until now, airports themselves have often been the only entities with access to the data required to challenge these analyses. By publicly providing airports' passenger-related CO_2 emissions, the Airport Tracker offers the opportunity to comprehensively analyse airports' climate impact.

To highlight this opportunity, we use the example of Glasgow Airport in the UK, which is likely to be the airport used by most of those travelling to the 26th UN Climate Conference (COP26) later this year. Using existing GHG accounting frameworks, Glasgow Airport's total emissions were 136,968 tonnes of carbon dioxide equivalent (tCO_2e) in 2019 (Ricardo Energy and Environment, 2020). Of this, 47% was from non-airplane sources, such as ground transport to and from the airport and gas and electricity used in the terminal buildings. Under the reporting framework, the airport is only deemed responsible for 2,830 tCO_2e,[3] with the rest regarded as beyond its control. The analysis then divides this figure among the 8.85 million passengers who departed and arrived throughout the year to claim emissions per passenger of 300 grams of carbon dioxide equivalent, or the same climate impact as drinking half a pint of beer or eating one egg (OVO Energy, 2021).

This somewhat unlikely equivalence occurs because the reporting framework only counts CO_2 emissions from aircraft movements below a height of 1,000 metres (i.e. airplane ground movements and part of take-off and landing) and then excludes these and other factors, such as the energy used by businesses in the terminals, as beyond the control of the airport (Ricardo Energy and Environment, 2020). By purchasing 2,830 carbon offsets, the airport claimed carbon neutrality for the year (AGS Airports, 2020).

Using the Airport Tracker allows a more accurate estimate of the airport's climate impact. Glasgow Airport's summary page on the Airport Tracker shows it is the eighth most polluting airport in the UK, and that passenger flights created 597,000 tonnes of CO_2 in 2019, equivalent to the emissions from almost 300,000 cars. Totalling the airport's own estimates of non-flight-related emissions, this value from the Airport Tracker, and an additional 105,000 tCO_2 to account for the 15% of fuel-related emissions associated with freight (Graver et al., 2020), gives total emissions of 767,000 tCO_2/tCO_2e.[4]

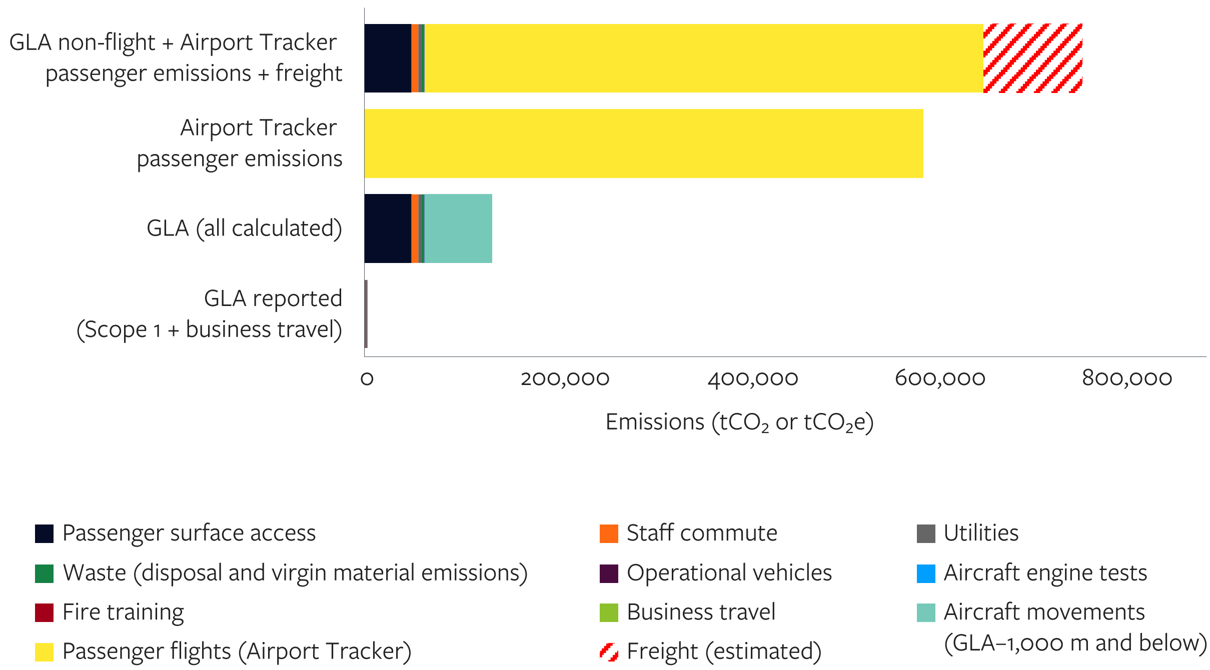
In comparison with the official reported values, we assume that half of the 8.85 million passengers who travelled through the airport in 2019 were departing (to avoid double counting, the Airport Tracker is based on departing passengers). Ignoring freight emissions, total passenger-related emissions were 652,000 tCO_2/tCO_2e.[5] Dividing these among departing passengers means an average passenger created 147 $kgCO_2/kgCO_2e$, nearly 500 times more than the officially reported value.

3 This is termed Scope 1 + Market-based Scope 2 emissions in the report.

4 The Airport Tracker reports CO_2 emissions. Glasgow Airport's own emissions are reported in CO_2e, but do not account for radiative forcing. We use both units here to avoid interpreting Airport Tracker emissions as CO_2e; to do so would require roughly tripling the value to account for the non-CO_2 radiative forcing (Lee et al., 2021).

5 Passenger-related emissions of 652$ktCO_2/ktCO_2e$ calculated by summing Airport Tracker-derived passenger-related flight emissions and 85% of non-flight emissions (assigning the remaining 15% to freight).

Figure 5 Comparison of Glasgow Airport (GLA)'s reported emissions with those calculated using Airport Tracker data



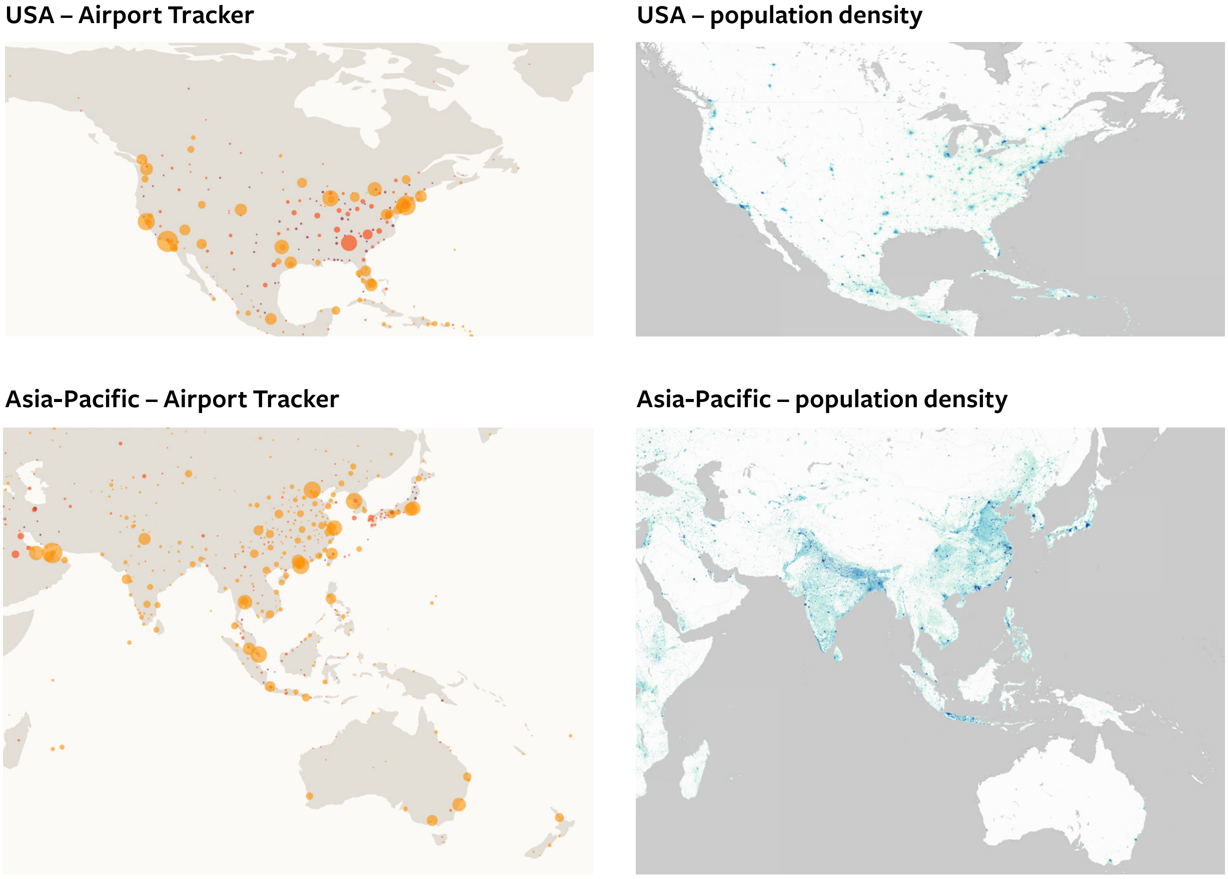
Source: Airport Tracker (www.airporttracker.org); Ricardo Energy and Environment (2020)

4.3 Exploring aviation inequality between geographies

Gössling and Humpe (2020) reviewed research looking at inequality and climate impact in the aviation sector. To date, very little work in this field has considered airport infrastructure. Most comparisons rely on national data for fuel consumption or passenger traffic to illustrate international inequality, such as air traffic in Europe being nearly four times of that in Latin America (ibid.). Work is also beginning to focus on the links between economic inequality and aviation inequality globally. For example, estimates show that less than 1% of the global population is likely responsible for more than half of the CO_2 emissions from passenger air travel (ibid.).

In the face of such stark inequalities, achieving climate justice requires the investigation of the current global allocation of high-carbon infrastructure. The Airport Tracker can support climate justice and sustainable infrastructure advocates by providing easily understandable visualisations of the sector's geographical inequality. One way to strengthen the inequality conclusions in Chapter 3 is to map airports' climate impact against population density. Comparing the Airport Tracker with population density from the Global Human Settlement Layer (Schiavina et al., 2019) visualised in the LuminoCity3D (n.d.) webtool, the maps below show high-polluting airports in areas with relatively few people (e.g. central United States, Singapore, Borneo and Australia) and almost no airport capacity in some areas with very high population densities (e.g. Northern India, Bangladesh, parts of Indonesia). From a climate justice perspective, these maps demonstrate the need to prevent airport expansion in the richer parts of the world.

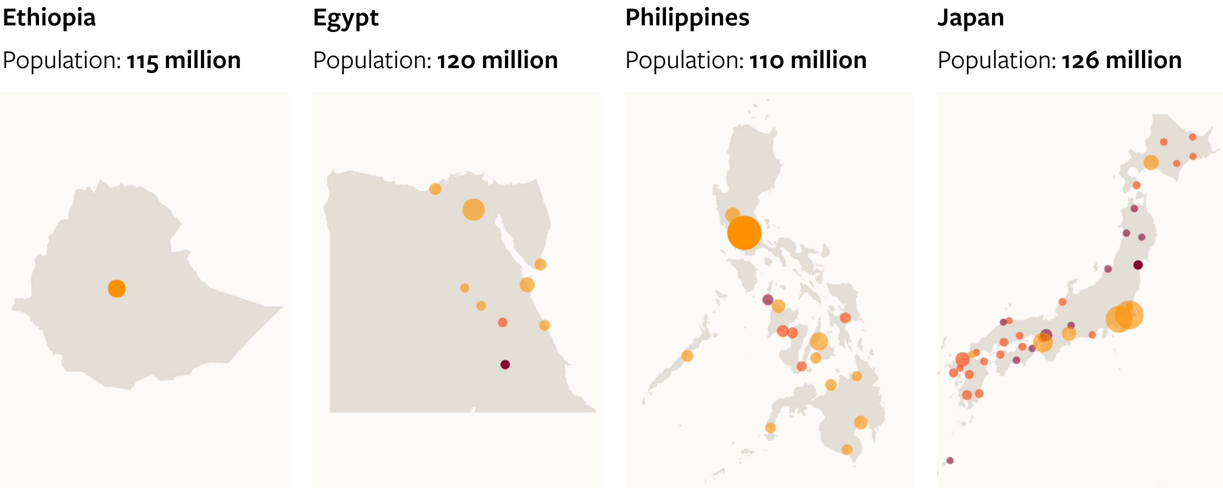
Figure 6 Airport Tracker and population density comparison, USA and Asia-Pacific



Source: Airport Tracker (www.airporttracker.org); LuminoCity3D (www.luminocity3d.org); Schiavina et al. (2019)

The country summary pages of the Airport Tracker also provide a way to visualise the difference between and within nations. We can see that despite having similar populations, the four countries in Figure 7 present very different levels of emissions and spatial equality in terms of airport access.

Figure 7 Selected country summary pages of the Airport Tracker



Source: Airport Tracker (www.airporttracker.org)

4.4 Linking airports to local and national climate plans

Airports and the places where they are based have an asymmetric relationship with regard to taking responsibility for their economic and emissions impacts. The aviation industry cites itself as a key driver of economic activity in countries and cities, yet the sector is largely omitted from national GHG inventories and the emissions that airports create are almost never included in those totalled up by the relevant subnational administrations. This is even more acute for cities with more than one airport (there are six in London, four in New York and three each in Beijing and Moscow), but is another accounting omission that can be corrected using the data behind the Airport Tracker to aggregate passenger-related CO_2 emissions at the city level.

One way to illustrate the importance of accounting for these emissions is to compare them with the GHG emissions cities themselves report (C40, 2021). Table 4 shows cities' self-reported emissions alongside those from the passenger flights their airports create, for 13 of the 20 cities that were responsible for the most aviation emissions (data for the other seven was not available in the C40 database).

Table 4 Cities' self-reported emissions compared to passenger-related emissions from city airports

City	Number of airports	Passenger-transport emissions ($MtCO_2$)	Reporting to C40 database			Passenger aviation as share of reported total (%)*
			Year	Accounting framework	Emissions ($MtCO_2e$)	
London	6	23.5	2018	BASIC+	37.5	63
New York	4	21.9	2016	BASIC	50.1	44
Dubai	2	16.8	2019	BASIC	48.9	34
Los Angeles	1	15.3	2018	BASIC+	53.6	29
Paris	3	14.4	2018	BASIC+	12.0	120
Tokyo	2	14.3	2017	BASIC+	75.9	19
Seoul	2	11.1	2017	BASIC+	47.5	23
Bangkok	2	10.7	2016	BASIC	41.5	26
Chicago	2	10.2	2017	BASIC+	43.9	23
San Francisco	1	10.0	2018	BASIC+	4.8	208
Moscow	3	9.7	2018	BASIC	54.9	18
Istanbul	2	8.8	2015	BASIC+	48.3	18
Amsterdam	1	8.1	2015	BASIC	4.8	169

*The city-reported data in the C40 database varies by year and accounting type (see C40 CCLG et al. (2014) for more detail). This means that the figures in this column are only illustrative of the impact of aviation.

Note: $MtCO_2$ = million tonnes of carbon dioxide equivalent. For more information on BASIC and BASIC+ accounting frameworks, see C40 (2021).

The data in the C40 database covers various years and different accounting frameworks (e.g. BASIC and BASIC+), and airports often serve broader populations than just those within city limits, so the figures in Table 4 are illustrative rather than directly comparable. Even so, in support of findings for the United States (Zheng and Rutherford, 2021), it is clear that cities' airports are major contributors to their climate impact. Emissions from passenger aviation – which cities do not currently report – range from one-fifth of reported emissions in cities where electricity is still mainly generated from fossil fuels (e.g. Moscow, Istanbul, Tokyo) to one or two times reported emissions in cities that rely more on low-carbon electricity (e.g. Paris, San Francisco, Amsterdam) (IEA, n.d.). Similar comparisons can be made for cities more broadly, making a strong case for the need to account for aviation emissions within cities' carbon budgets as well as at national and regional levels (e.g. in NDCs and infrastructure plans).

4.5 Opportunities for replacing short-haul flights with other travel options

One-size-fits-all approaches to limiting the climate impact of passenger flights are unlikely to be successful. Flights over 1,500 km (medium- and long-haul) create approximately two-thirds of the sector's CO_2 emissions (Graver et al., 2019), and require dedicated societal, technological and political changes to curb their climate impact. It is not realistic to argue that longer-haul passengers should simply switch to less carbon-intensive ground or sea transport options. However, this is more feasible for many short-haul flights (under 1,500 km), which create one-third of the sector's climate impact, and serve different mobility demands across different markets to longer-haul flights. Crucially, for many short-haul flights, alternative transport modes that satisfy mobility demand at much lower carbon intensities, such as rail travel, are or could soon be available. The highly granular data that underpins the Airport Tracker allows a detailed analysis of how 'mode-shifting' (i.e. substituting flying with another form of transport) could support high levels of regional mobility in a climate-constrained world, complementing previous work in this area (Transport & Environment, 2020b) and providing the necessary data for further analysis in Europe and beyond.

To illustrate, consider Germany. The country summary page in the Airport Tracker shows that short-haul flights were responsible for 28% of passenger-related CO_2 emissions (6.5 $MtCO_2$). Germany's location suggests that almost all of these flights were within Europe, where there is an extensive high-speed rail network. The route-level emissions data for each airport that underpins the Airport Tracker could be used to comprehensively estimate the carbon, time and monetary impacts associated with shifting these short-haul flights to high-speed rail. Similar analyses could be carried in other regions, e.g. for domestic flights in countries including China, Japan and South Korea, which also have high-speed rail networks.

Figure 8 Short-haul range around Frankfurt, Germany's busiest airport, over a map of European high-speed rail links

Source: Airport Tracker (www.airporttracker.org); High-speed rail in Europe – Wikipedia

5 Conclusion

The aviation sector is a large and growing contributor to GHG emissions, hampering efforts to limit the impacts of climate change. Data reported by the sector is insufficient to understand where emissions come from, creating uncertainties as to who is responsible and what can be done to align aviation with global climate goals. Specifically, very limited data has been available on the emissions created by individual airports.

The Airport Tracker is the first attempt to globally map the passenger-related CO_2 emissions created by individual airports. The interactive online tool presents summary data for the 1,300 largest commercial airports, covering 99% of passenger flights. These summary figures are supported by a vast data series that aggregates route-based emissions for some 35 million flights.

This policy brief presents high-level findings from the Airport Tracker data, exposing the stark global inequality of airport-related CO_2 emissions and the extremely carbon-intensive travel facilitated by some airports. It also shows how the data behind the Airport Tracker can support diverse groups working to address the sector's climate impact.

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Appendix Building and analysing the Airport Tracker (methodology)

Full details of the methodology used to create the data presented in the Airport Tracker are provided in a technical note on the Airport Tracker website (see: www.airporttracker.org/reports/).

In brief, a model developed by the International Council on Clean Transportation (Graver et al., 2019; 2020) estimates the CO_2 emissions associated with passenger transport from the world's 1,300 largest airports. This covers 99% of all passenger traffic. For each airport, we sum estimates of the emissions associated with outbound flights based on the flight distance, the type of aircraft and the number of passengers. This version of the Airport Tracker underestimates the total CO_2 created by individual airports because we only focus on commercial, passenger-related emissions. The totals presented do not include emissions associated with freight (either dedicated flights or carried in the belly of passenger flights), military or general aviation. Emissions associated with freight equate to approximately 15% of total emissions from commercial aviation. Emissions from military and general aviation are considered marginal compared to those from commercial flights. Our data also does not include the non-CO_2 warming effects of aviation fuel, emissions related to airport ground operations or terminal buildings, or emissions created by passengers before or after their flights (e.g. travelling to/from the airport).

We present data for each airport overall in terms of the total CO_2 emissions created in $MtCO_2$. To make these figures more relatable, we also equate the values to a number of coal-fired power stations or cars. Using globally relevant figures, one coal-fired power station is assumed to produce four $MtCO_2$/year (US EPA, n.d.), and one car is assumed to produce two tCO_2/year (IEA, 2019; ICCT, n.d.).

We also show a breakdown of how an airport's emissions are distributed between short-haul (<1,500 km), medium-haul (1,500–4,000 km) and long-haul (>4,000 km) flights. For the airport as a whole, and for each of these distance segments, we divide the total emissions by the total distance passengers travelled to provide the average CO_2 emissions per passenger per kilometre, measured in grams of CO_2 per revenue passenger kilometre (gCO_2/RPK).

These calculations form the basis for the results presented in this policy brief, which we compare with emissions from other areas of society, using the following sources:

- National territorial emissions are from the data in the Global Carbon Atlas (Freidlingstein et al., 2020).
- Emissions intensity of different modes of transport is from the IEA's passenger emissions from non-urban transport (IEA, 2020b).
- City-scale emissions are from C40's greenhouse gas emissions interactive dashboard (C40, 2021).
- Population data is taken from *World population prospects* (UN, n.d.).

Other assumptions:

- Regions are defined following those used by EUROCONTROL; see Graver et al. (2020).
- Unless stated otherwise, all data relates to 2019 figures.