UK Aviation Environmental Review 2025

CAP 3198

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Contents

Executive Summary

Aviation is an important part of our society, bringing benefits to people, businesses and our national economy. Like other fossil-fuel powered transport, aviation also has impacts on the environment, including on noise, air quality and climate change. The UK Aviation Environmental Review 2025 (AER 2025) sets these out at a high level for the period 2019 to 2024 (2023 for air quality). 2019 represented peak numbers of flights and emissions before the COVID pandemic drastically curtailed air traffic, making that year a good point of comparison. Over this period, passenger demand for air travel continued to increase following the COVID pandemic and the aviation sector has responded to that by providing capacity and adjusting routes and aircraft types to match that demand.

The UK's aviation industry continues to take steps to improve its environmental performance – such as alternative fuels, introducing quieter and more fuel efficient aircraft, or airspace modernisation to improve flight procedures. These are designed to improve the environmental efficiency of aviation on a per flight basis. The sector's total environmental performance benefits from these measures, but growth in flight numbers increases aviation's impact. Although most of these improvements are captured in our results, our analysis does not distinguish the potential carbon savings / impacts from each of these measures. We intend to explore this more in the future.

Our reporting this year builds on our first AER published in 2023 but provides a greater level of detail and contextualises aviation's progress against other transport modes, fulfilling our intentions expressed in the AER Roadmap published in September 2025. Recommendations from the original AER were not updated.

AER 2025 relies on newly developed as well as existing data sources. The CAA's new emissions database estimates the greenhouse gas emissions generated by civil aviation flights departing the UK based on the actual time spent in flight by each aircraft, providing more representative results compared to typical distance-based estimations. The air quality analysis relied on information provided by Defra, which was last reported in 2023.

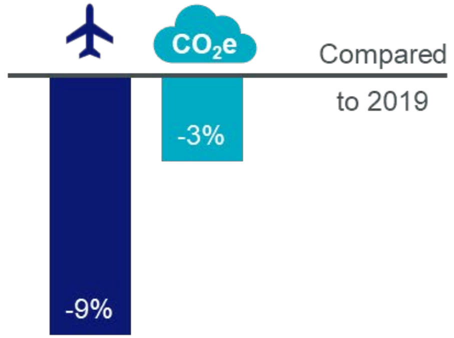
The data provided in this report represents our understanding of the environmental impact of UK aviation at the time of writing. We will aim to update our analysis in the future should additional information become available.

The key findings from AER 2025 are provided in the remainder of this section.

In 2024, emissions generated by flights from the UK grew faster than the number of flights

In 2024, civil aviation flights departing from UK airports generated 36.2 $MtCO_2e$

Emissions outpaced the growth in air traffic. The number of departing flights decreased by **9%** but emissions only reduced by **3%** compared to 2019



2019 is considered the **peak** year for UK aviation CO_2e emissions and serves as a benchmark that should not be exceeded in order to meet Net Zero by 2050

For flights where both the departure and arrival are within the UK (i.e. **domestic** flights), this trend is even more pronounced. Domestic traffic decreased by **22%** compared to 2019 but emissions only reduced by **14%**, reflecting the fact airlines used larger aircraft.

Long-haul flights produced the majority of CO_2e emissions

11% of flights… … generated **63%** of emissions

There were more medium-haul (13%) and long-haul flights (2%) departing the UK in 2024 compared to 2019

Flights from the 10 busiest UK airports generated 95% of all aviation emissions

Flights departing from Heathrow produced the most CO_2e emissions, **4.5x** that of Gatwick, the airport with the second most flights

***Methodology**: Greenhouse Gas emissions, expressed in CO_2 equivalent (CO_2e), produced by civil aviation flights departing the UK in 2024. Data generated from the CAA's emissions database which estimates emissions based on actual flight times and aircraft types, with assumptions including on taxi times and cruise level.*

In 2024, people significantly affected by aviation noise in the UK rose slower than the number of flights

Approximately 1.2 million people in the UK were exposed to noise from departing and arriving flights in 2024

This is **fewer** people than in 2019

Daytime

1.21 million people were exposed to aviation noise in 2024
That was **87%** of the population exposed in 2019, while air traffic was **94%** that of 2019

Night-time

1.26 million people were exposed to aviation noise in 2024
That was **93%** of the population exposed in 2019, while air traffic recovered beyond pre-COVID-19 pandemic levels to **104%** that of 2019

Night-time flights affect **more** people than daytime flights

On average, the noise generated by a flight in 2024 exposed fewer people compared to 2019

Dividing the number of people exposed to aviation noise by the number of flights departing or arriving each year gives a measure of aviation noise performance

In 2024, a **daytime** flight exposed on average **8%** less people compared to 2019

In 2024, a **night-time** flight exposed on average **11%** less people compared to 2019

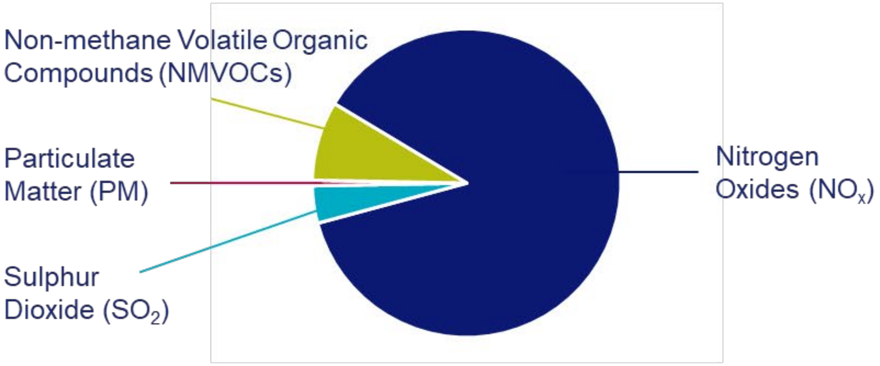
This trend is likely to be primarily driven by airlines retiring older, noisier aircraft and introducing new generation, quieter aircraft. It is unclear if this trend will continue as air traffic grows and the delivery a new aircraft slow down due to supply chain issues

For context, based on data from 2016, flights to and from Heathrow generated **73%** of the noise exposure.

Methodology: *Based on modelling 8 UK airports handling 70% of flights departing and arriving in the UK.*
There is no one threshold at which all individuals are considered to be significantly adversely affected by [aircraft] noise. It is possible to set a Lowest Observed Adverse Effect Level (LOAEL) that is regarded as the point at which adverse effects begin to be seen on a community basis. Our analysis uses the LOAEL thresholds set for the purpose of assessing airspace changes, i.e. 51 dB $L_{Aeq,16h}$ *for daytime and 45 dB* $L_{Aeq,8h}$ *for night-time respectively.*

In 2023, most air pollutants from aviation produced on the ground up to 3,000ft were below 2019 levels

Nitrogen oxides emissions make up the largest share of air pollutants generated by aviation in terms of mass



NO_x can cause **inflammation** of the airways and increase susceptibility to **respiratory infections** and to **allergens**. It exacerbates symptoms of those who are already suffering from **lung** or **heart conditions**

Growing evidence indicates that **ultra-fine particles** (UFP), with a diameter smaller than 100 nanometres, should also be considered. Understanding UFP concentrations is important but challenging - due to their extremely small size, the measurement and characterisation of UFP are subject to significant uncertainty

NO_x emissions from flight departing and arriving in the UK grew relative to air traffic as the number of flights in 2023 was 13% below 2019

SO_2 (-67%), $PM_{2.5}$ (-22%) and NMVOCs (-34%) all increased more slowly

Flights departing and arriving from the 10 busiest UK airports generated 87% of all aircraft NO_x emitted in the UK in 2023

In 2023, flights to and from Heathrow produced more NO_x than any other UK airport, **3x** as much as flights to and from Gatwick

Methodology: *Air pollutants from aircraft engines only, modelled for flights departing and arriving at UK airports, on the ground up to 3,000 ft (i.e. Landing and Take-Off cycle), provided by the National Atmospheric Emissions Inventory (NAEI)). At the time of writing, the latest year the NAEI had published emissions data for was 2023. Air pollutants were modelled based on aircraft types and traffic data; they do not show measured concentrations of air pollutants.*

Climate Change: Data and Analysis

Dependence upon fossil fuels has resulted in UK surface temperatures for the most recent decade (2015-2024) rising by 1.24˚C above those recorded on average between 1961 and 1990. These temperature rises, caused principally by the release of greenhouse gas emissions from human activities, have resulted in more weather and climate extremes leading to widespread impacts upon ecosystems and populations across the globe.

Aviation is contributing to climate change through its ongoing dependence on fossil fuels, accounting for 2.5% of global energy-related CO_2 emissions. This dependence, coupled with an upward trend in demand for air travel, continues to increase the industry's contribution to global temperature rise. Aviation is set to become one of the highest-emitting sectors in the UK relative to others who are decarbonising more quickly. In addition, some research is also suggesting aviation contributes to non-CO_2 warming impacts, for example through contrail formation. Explore UK AER: Climate Change for more information on environmental protection measures in place to manage the impact of civil aviation on climate change.

Our analysis provides an overview of the greenhouse gas emissions generated by civil aviation in the UK from 2019 to 2024. It covers domestic[1] and international flights departing from UK airports (excluding military operations), and calculates the emissions generated during the entire duration of each flight.

The greenhouse gas emissions accounted for within this analysis are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), all reported as CO_2 equivalent (CO_2e). CO_2e is an internationally recognised metric used to compare various greenhouse gas emissions based on their global warming potential.

Emissions calculations focus on the operation of aircraft and excludes other emission sources such as ground support vehicles or from the aviation supply chain. Our analysis assumes no impact (positive or negative) from the contrails. Research work is underway to consider these. Sustainable Aviation Fuel (SAF) usage was not modelled. Considering the relatively low volumes of SAF usage prior to the entry into force of the UK SAF Mandate in 2025, this analysis assumes for now no impact of SAF on carbon emissions in these historical numbers. Our intention is to include SAF usage in future iterations of the AER.

Our analysis utilises actual flight times rather than predicated flight distances. This is more reflective of actual operations, for example catering for emissions generated

[1] All flights where both the departure and arrival take place within the UK (including Channel Islands and Isle of Man).

through flight inefficiencies such as holding patterns before landing. Some assumptions were made where necessary, such as standard ICAO landing and take-off times or default cruise level. While we recognise these limitations and will endeavour to address them in the future, we are confident our analysis is robust. Due to differences in aviation emissions methodologies, the results presented here should not be directly compared with other sources. Instead, they should be interpreted in the context of the trends and insights provided within this analysis.

Emissions data has been calculated using the CAA's Emissions Database. The AER Climate Change Technical Note provides more information on the methodology used to estimate the emissions outlined in this analysis.

UK Aviation CO_2e Emissions

The total amount of emissions produced by aviation in the UK is modelled by calculating the contributions from departing flights to both domestic and international destinations.

2019 is considered the peak year for UK aviation CO_2e emissions and serves as a benchmark that should not be exceeded in order to meet Net Zero by 2050. Compared to 2019, emissions decreased by approximately 62% in 2020 and 2021 as a result of reduced aviation activity due to the COVID-19 pandemic. Since 2022, emissions have increased by over 8% year-on-year on average to 2024 reflecting strong increases in passenger demand for flying.

In 2024, flights departing from the UK[2] emitted 36.2 $MtCO_2e$. This is 3% lower than the 2019 peak, however 2024 air traffic movements were 9% below 2019 levels. This shows that overall, emissions grew faster than air traffic, reflecting the increased use of larger aircraft as airlines responded to passenger demand both in total and across different routes [3].

[2] Reporting emissions from domestic flights within the UK, and international flights departing the UK, aligns with international reporting practices on the allocation of aviation greenhouse gas emissions. This practice avoids double-counting emissions between reporting States.

[3] This analysis does not capture potential efficiency gains made on a per passenger basis, for example from airlines investing in newer aircraft or higher load factors.

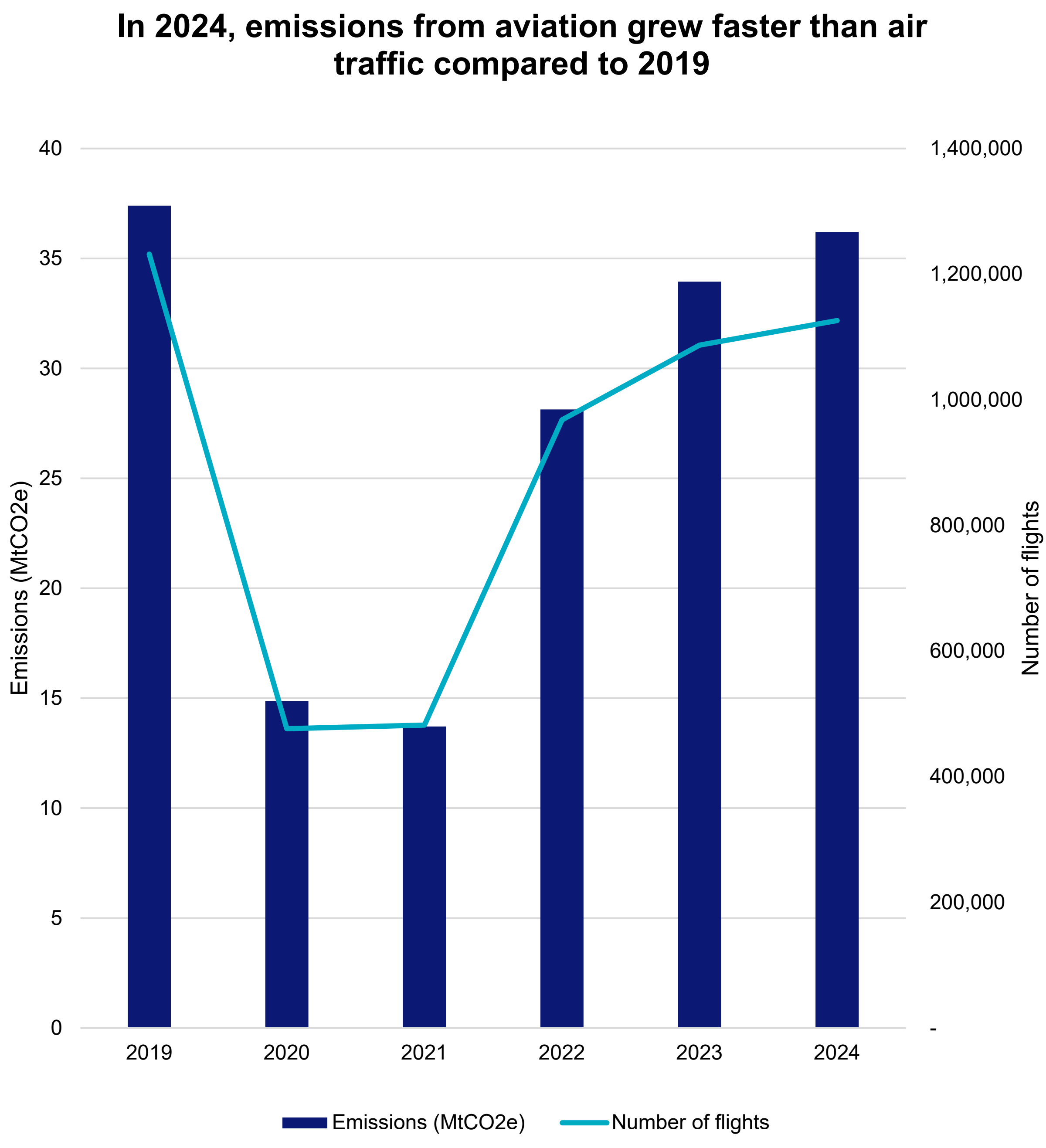


Figure 1: UK aviation emissions (2019 to 2024)

CO_2e Emissions from International and Domestic Flights

The number of international flights departing from the UK in 2024 was 3.1% less than 2019. The emissions produced reduced relatively proportionately, by 2.7%.

A different trend was observed at domestic level. The number of domestic flights reduced by 22% in the same period, reflecting changes in the market, such as the collapse of Flybe in March 2020. Emissions however only reduced by 14%. This change was mainly driven by airlines using larger aircraft to serve domestic destinations.

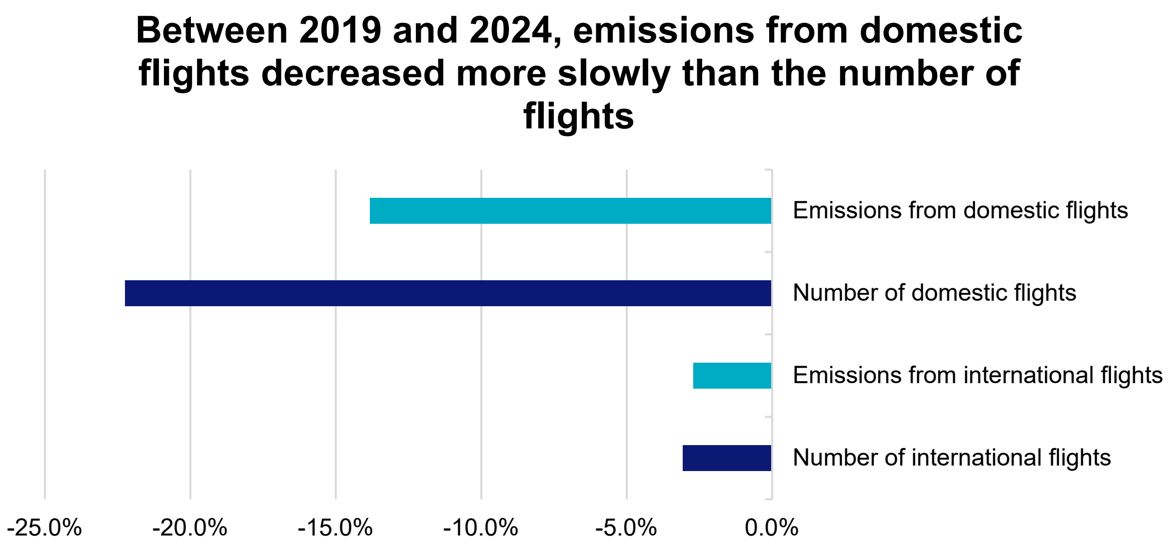


Figure 2: Percentage reductions in flight numbers and emissions for domestic and international air traffic (2019 compared to 2024)

To provide some context, data from the Department for Energy Security and Net Zero was used to compare greenhouse gas (GHG) emissions between several UK transport modes: domestic civil aviation, passenger cars, heavy goods vehicles (HGVs), light duty vehicles (LDVs), buses and rail.

In 2023, domestic aviation emitted about 1% of all GHG emissions produced by these transport modes.

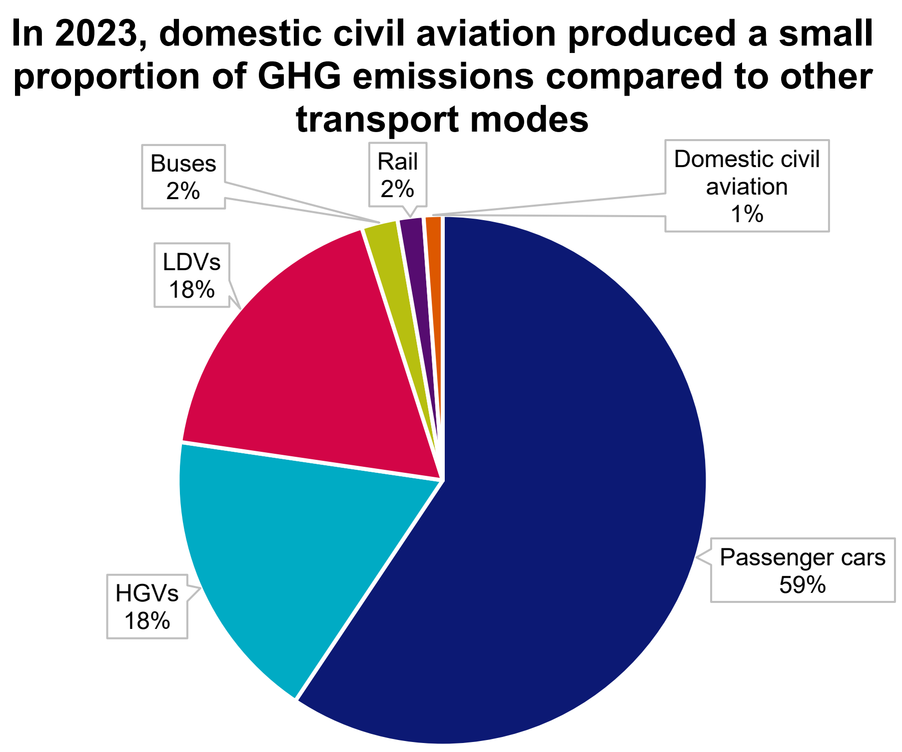


Figure 3: Proportion of GHG emissions for selected transport modes in the UK (2023)

Most UK domestic transport modes have, over the last two decades, seen significant reductions in the amount of emissions they generated. For example, from 2005 to 2023, emissions from passenger cars reduced by 23% despite the number of miles travelled increasing. Over the same period, emissions from HGVs reduced by 16%. LDVs emissions, however, grew by 21%.

Emissions from buses reduced by over 51% in that timeframe. Emissions from rail grew until 2014 but have reduced since, despite the number of passenger journeys increasing. Emissions from domestic aviation decreased significantly until the COVID-pandemic, then grew again from 2020 onwards. In 2023, emissions from rail were 27% higher than emissions from domestic aviation, while emissions from buses were 47% higher.

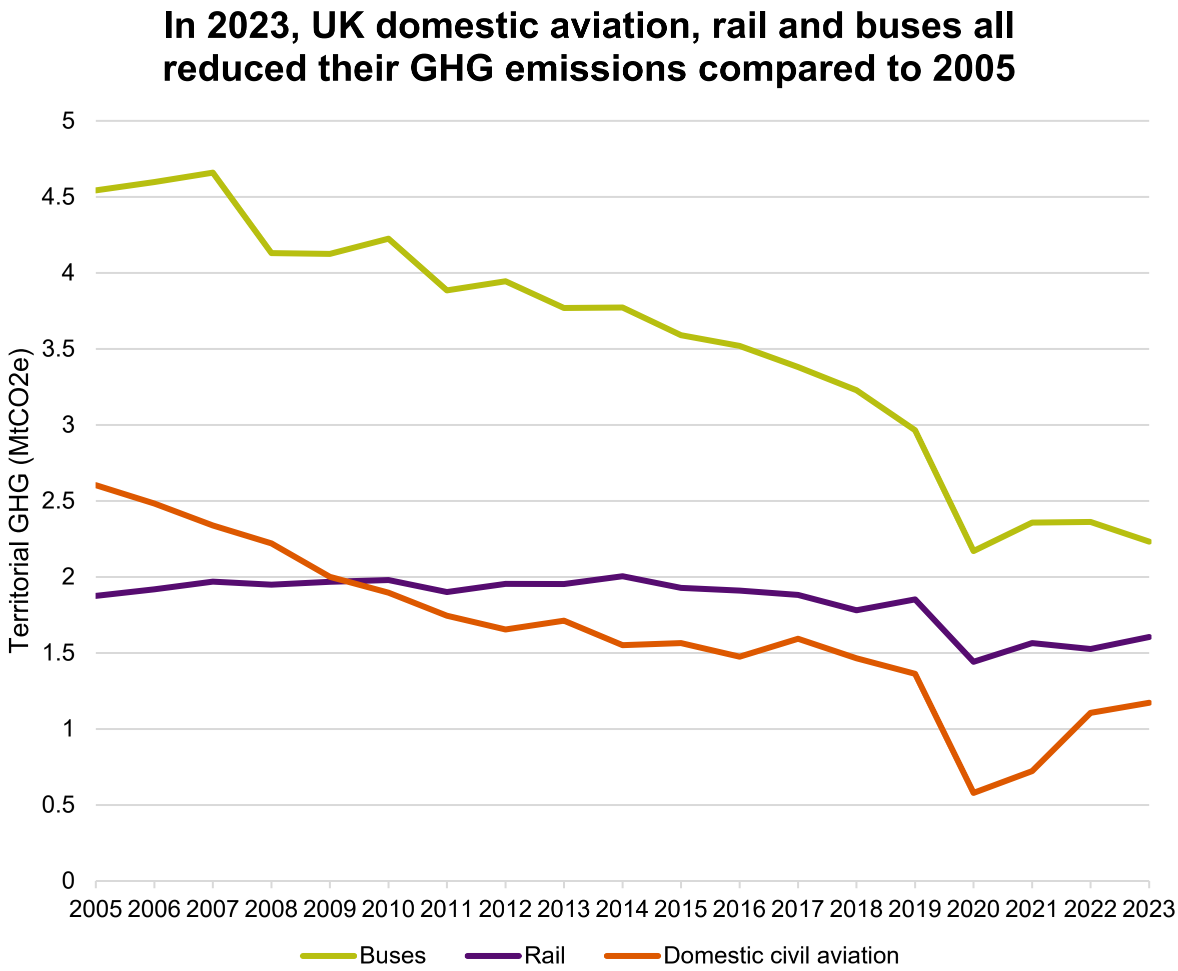


Figure 4: Trends in UK domestic GHG emissions between buses, rail and domestic aviation (2005 to 2023)

CO_2e Emissions by Flight Distance

Domestic operations accounted for 24% of all flights in the UK, however they only generated 4% of emissions. Changes in the environmental performance of domestic operations therefore have a limited impact on the overall emissions trends.

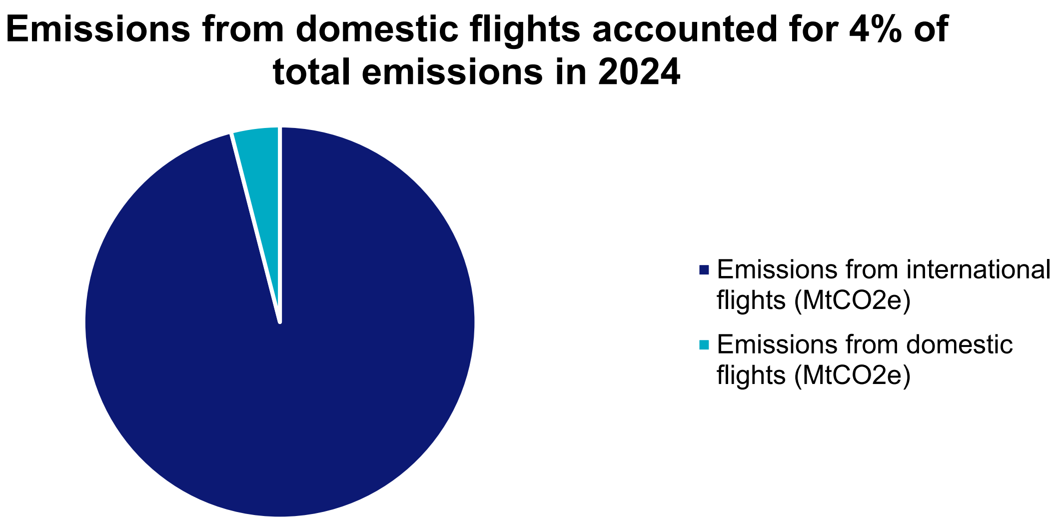


Figure 5: Proportion of domestic and international emissions (2024)

In 2024, long-haul operations generated the largest share (63%) of all emissions despite accounting for the smallest share of flights departing from the UK (11%). These flights, being longer than 4,000 km, fly for prolonged periods of time and utilise larger, wide-body aircraft, resulting in higher levels of emissions.

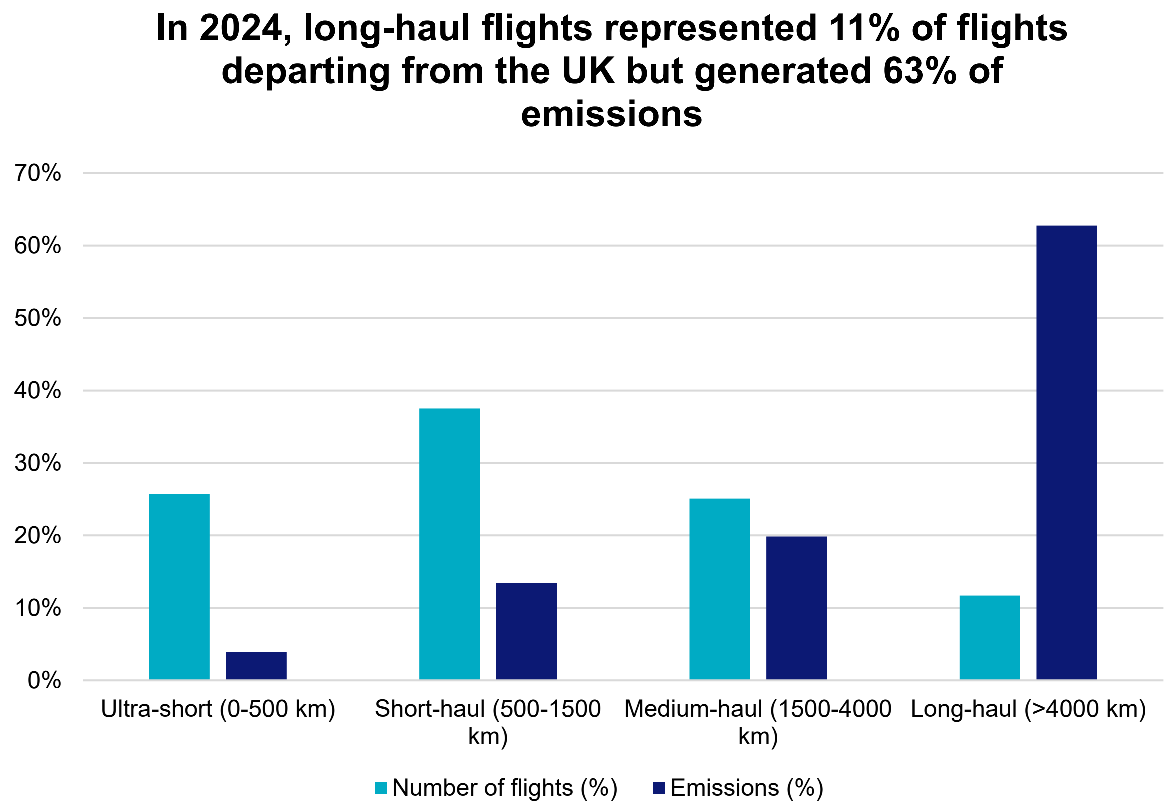


Figure 6: Comparison between ultra-short, short, medium and long-haul operations from the UK (2024)

By contrast, ultra-short and short-haul flights (i.e. all flights under 1,500 km) accounted for a combined 63% of flights in 2024, but only 17% of total emissions.

Between 2019 and 2024, the number of medium and long-haul flights increased while ultra-short and short-haul flights decreased.

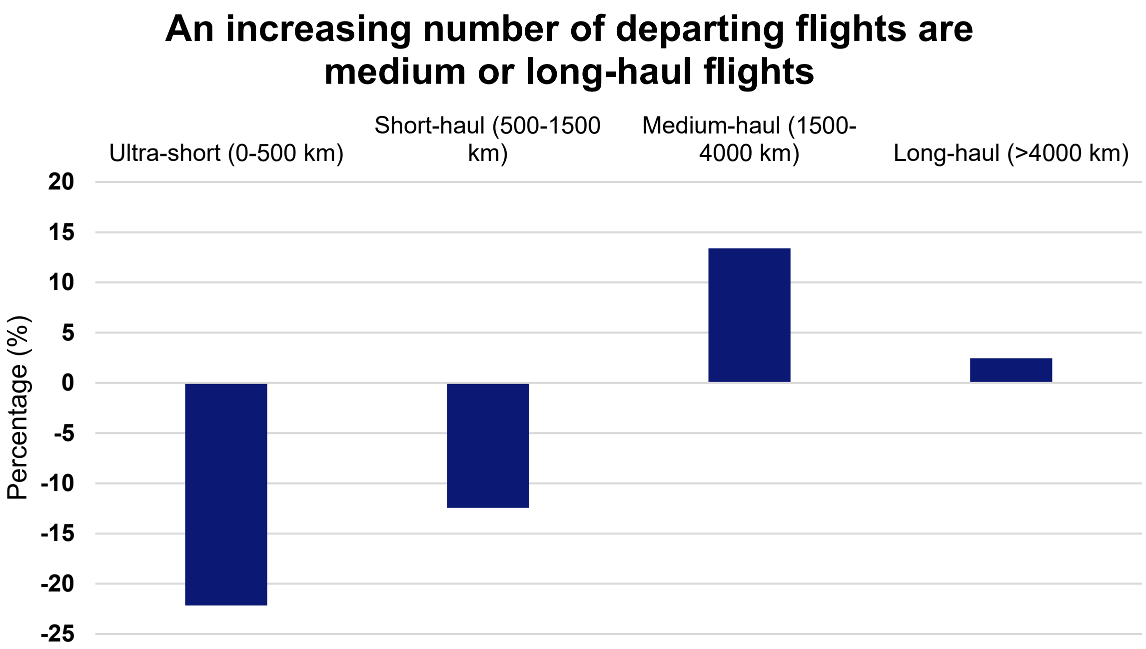


Figure 7: Percentage change in the number of flights by distance (2019 compared to 2024)

CO_2e Emissions by Airport

In 2024, flights departing from the 10 busiest UK airports in terms of passengers handled generated 95% of all civil aviation emissions in the UK.

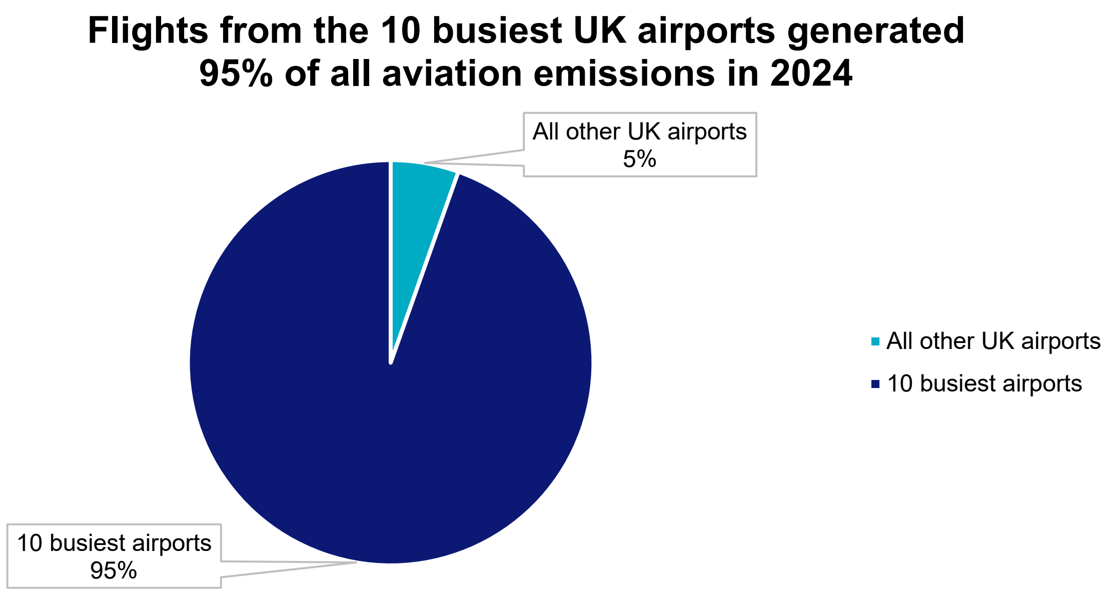


Figure 8: Proportion of emissions from the 10 busiest airports and all other UK airports (2024)

Because long-haul flights produce the most emissions, they largely determine how emissions are distributed among UK airports.

Heathrow, the airport with the most flights (including the most long-haul flights), generated 4.5x more emissions than Gatwick.

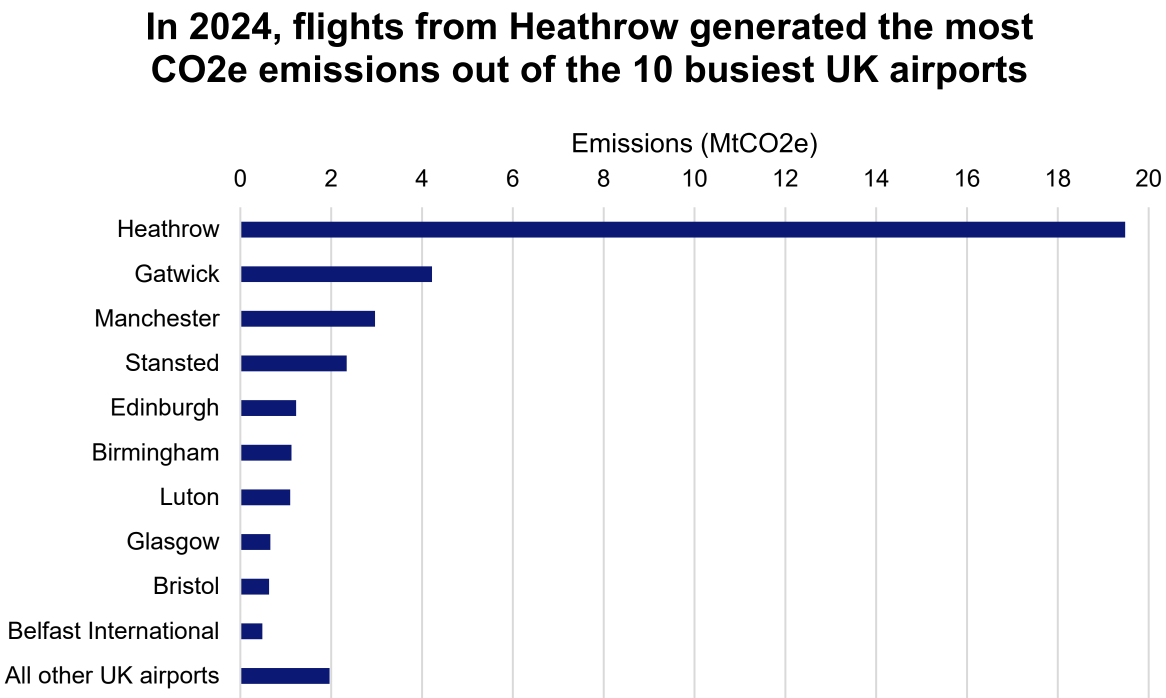


Figure 9: CO_2e emissions (Mt) amongst the top 10 busiest airports (2024)

Aviation Noise: Data and Analysis

Aircraft noise is mainly generated from two sources: the engine, and air moving over the airframe. This noise is louder during critical phases of flight, such as take-off when greater thrust is required from the engines, or during landing when flaps and gears are extended resulting in increased air resistance. Explore UK AER: Noise for more information on environmental protection measures in place to manage the impact of civil aviation noise on local communities near airports.

Our analysis models the noise exposure of eight large UK airports to provide a picture at national level. These airports were selected based on CAP 1731 which was commissioned by the Department for Transport (DfT) in 2018. Together, these airports handled 70% of all civil aviation flights in the UK in 2024 and are the eight largest contributors by size of population exposed to aviation noise. The eight airports utilised in this analysis are:

- Birmingham;
- Edinburgh;
- Gatwick;
- Glasgow;
- Heathrow;
- Luton;
- Manchester; and
- Stansted.

Our analysis is based on modelled assumptions, giving an estimate of the number of people exposed to aviation noise in the UK. Population information was sourced from census data, with estimates on population distribution made to account for inter-census years. Changes in aviation noise reflect a range of factors including the noise generated by individual aircraft, the mix of aircraft flying, the number of aircraft flown, as well as changes in size and geographic distribution of population. Our analysis does not necessarily allow to distinguish between these factors.

The AER Noise Technical Note provides more information on the methodology used to model the noise exposure outlined in this analysis.Further information regarding the noise modelling methodology is outlined in the AER technical annex.

Aviation Noise in the Wider Context

Historic data produced by the European Environmental Agency in 2016[4] indicates that road transport is the largest contributor to transport noise. Importantly, this data cannot be compared to the results from our analysis. It is from a year not included in our modelling, uses a different noise metric, and different noise exposure bands. This is purely to contextualise the scale of aviation noise in the UK.

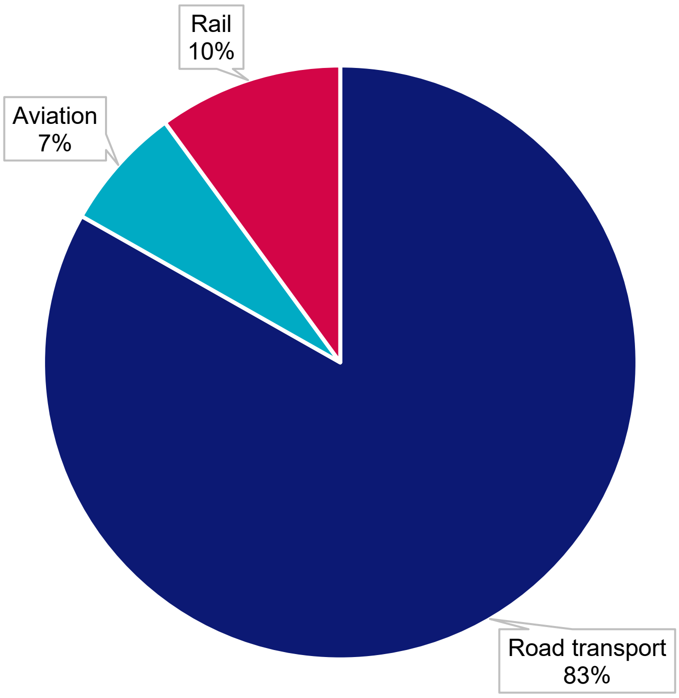


Figure 10: Proportion of people affected by aviation, rail, and road transport noise in the UK (2016)

Population Exposed to Aircraft Noise

The equivalent continuous noise level (L_{Aeq}) is a metric used to describe the average sound level over a specific period. To establish this noise level, aircraft noise is modelled across a daytime 16-hour period from 07:00 to 23:00 ($L_{Aeq,16h}$), and a night-time 8-hour period from 23:00 to 07:00 ($L_{Aeq,8h}$) for an average summer day or night.[5] Once these noise levels are established, it is possible to determine the number of people exposed to certain noise levels around airports.

[4] Noise exposure information under the END Directive (2002/49/EC) — European Environment Agency, providing people noise exposure according to the data reported by EU Member States under the frame of the Environmental Noise Directive.

[5] In the UK, airports are likely to be busier in the summer. Residents are more likely to be outside or with windows open in the summer than in the winter, and so will be more affected by any aviation noise. Summer is defined here as the 92-day period between 16 June and 15 September inclusive.

For the purpose of assessing airspace changes,[6] the Lowest Observed Adverse Effect Level (LOAEL), which is the point at which negative effects of sound begin to be seen on communities is set at 51 dB $L_{Aeq,16h}$ for day and 45 dB $L_{Aeq,8h}$ for night respectively. Our analysis provides an estimate of the number of people in the UK exposed to noise levels from civil aviation above these two thresholds, from 2019 to 2024.[7]

Daytime Noise Exposure

In 2024, approximately 1.21 million people were exposed to aircraft noise in the UK during the daytime period. This is a cumulative total, accounting for all people exposed to noise levels greater than or equal to 51 dB $L_{Aeq,16h}$. Higher bands represent higher levels of noise exposure.

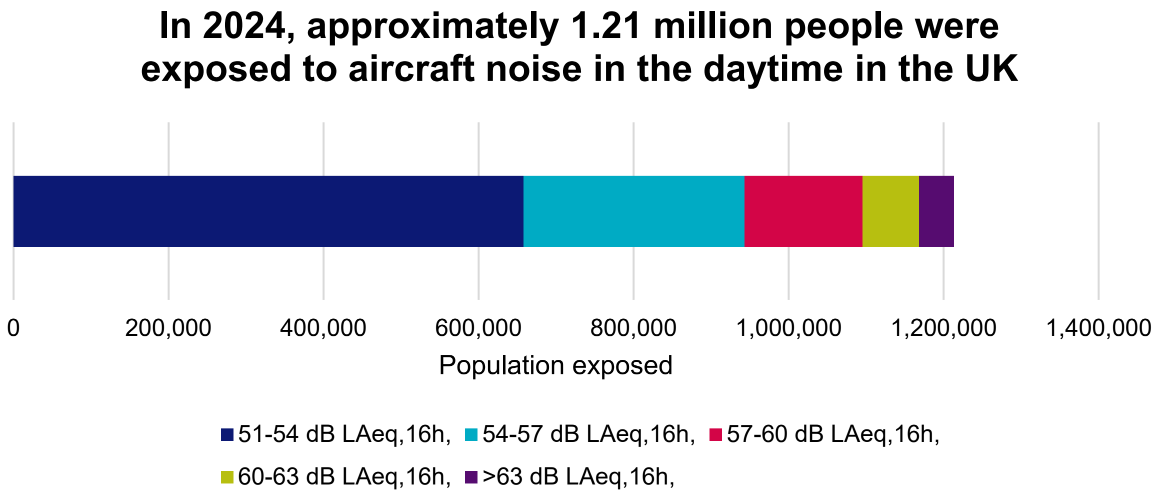


Figure 11: Population exposed to daytime aviation noise in the UK (2024)

Daytime noise exposure across the eight airports was highest in 2019, reflecting pre-COVID-19 pandemic air traffic levels. Population exposure to noise levels above 51 dB $L_{Aeq,16h}$ reduced by 78% in 2020 when flight operations declined due to the COVID-19 pandemic. Population exposure to noise above this level has increased steadily since the pandemic as air traffic levels recovered. By 2024, the number of people exposed to noise levels above 51 dB $L_{Aeq,16h}$ was 87% that of 2019, so not back to pre-pandemic levels, while air traffic was 94% that of 2019. This shows that whilst air traffic has decreased, the number of people exposed to noise levels above 51 dB $L_{Aeq,16h}$ has decreased at a faster rate, indicating that fewer people were

[6] As described in paragraph 3.5 of the Air Navigation Guidance 2017, "*there is no one threshold at which all individuals are considered to be significantly adversely affected by [aircraft] noise. It is possible to set a Lowest Observed Adverse Effect Level (LOAEL) that is regarded as the point at which adverse effects begin to be seen on a community basis*".

[7] Modelling was undertaken from 2019 as this was the year with the most flights prior to COVID-19 pandemic (Latest quarterly statistics | UK Civil Aviation Authority)

exposed to daytime noise in 2024 compared to 2019. The proportion of people in each band has remained stable between 2019 and 2024.

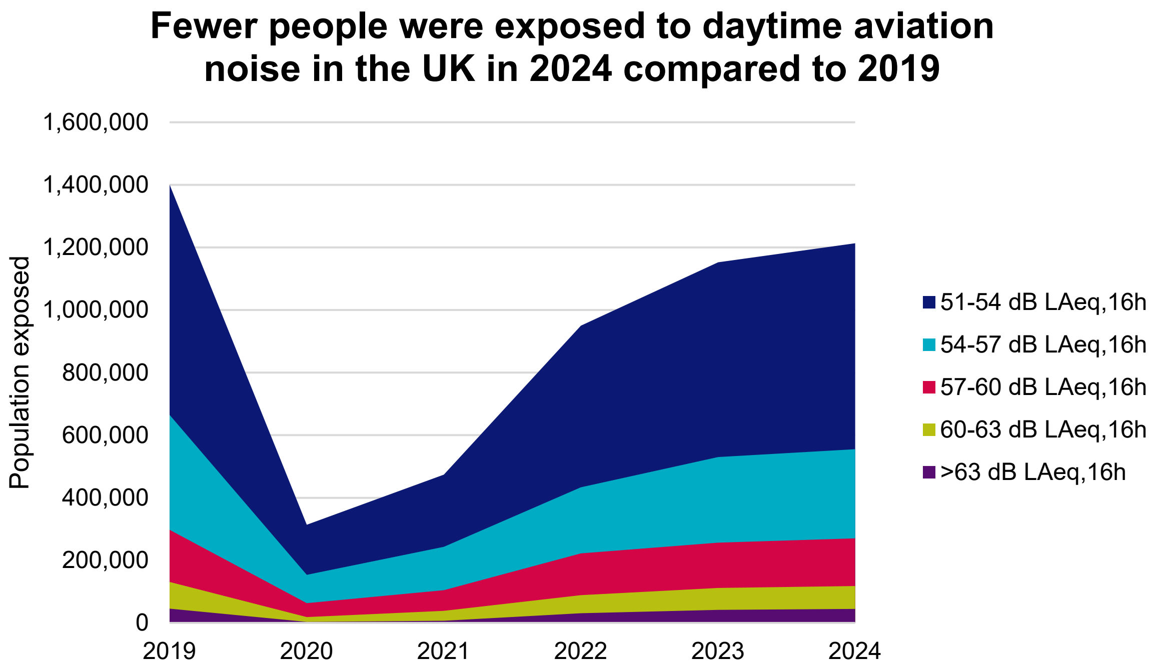


Figure 12: Population exposed to daytime aviation noise in the UK (2019 to 2024)

Night-time Noise Exposure

In 2024, approximately 1.26 million people were exposed to night-time noise in the UK. This is a cumulative total, accounting for all people exposed to noise levels greater than or equal to 45 dB $L_{Aeq,8h}$.

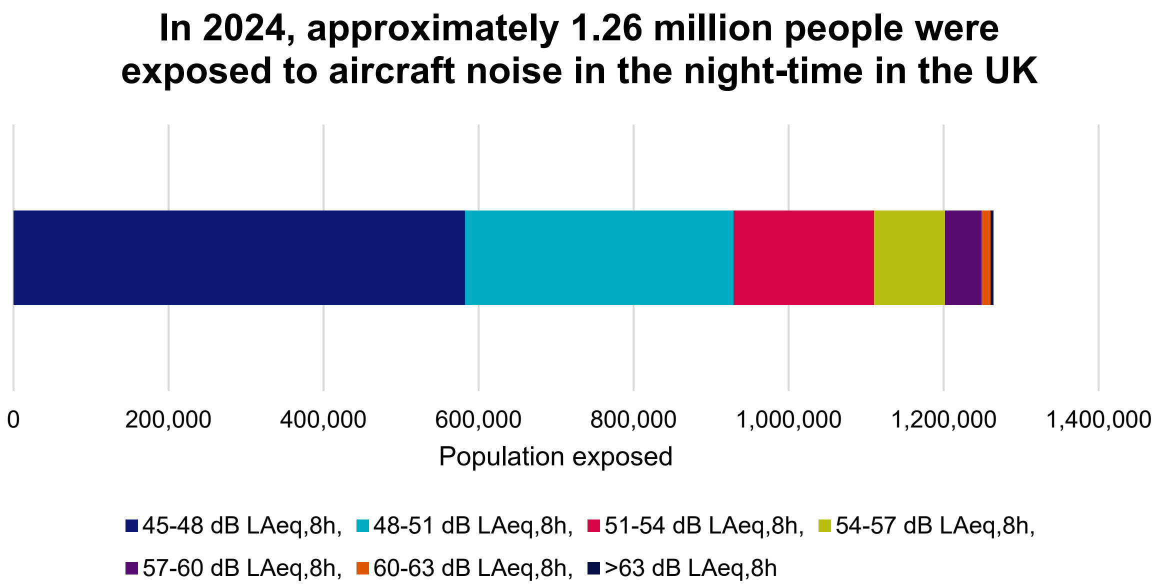


Figure 13: Population exposed to night-time aviation noise in the UK (2024)

Night-time noise exposure followed a similar trend compared to daytime noise exposure. The population exposed to noise levels above 45 dB $L_{Aeq,8h}$ decreased by 75% in 2020 compared to pre-pandemic levels. By 2024, the number of people exposed was 93% that of 2019, while air traffic had recovered beyond pre-COVID-19 pandemic levels to 104% that of 2019. Fewer people were exposed to night-time noise in 2024 compared to 2019. Similar to daytime, the proportion of people in each band has remained stable between 2019 and 2024.

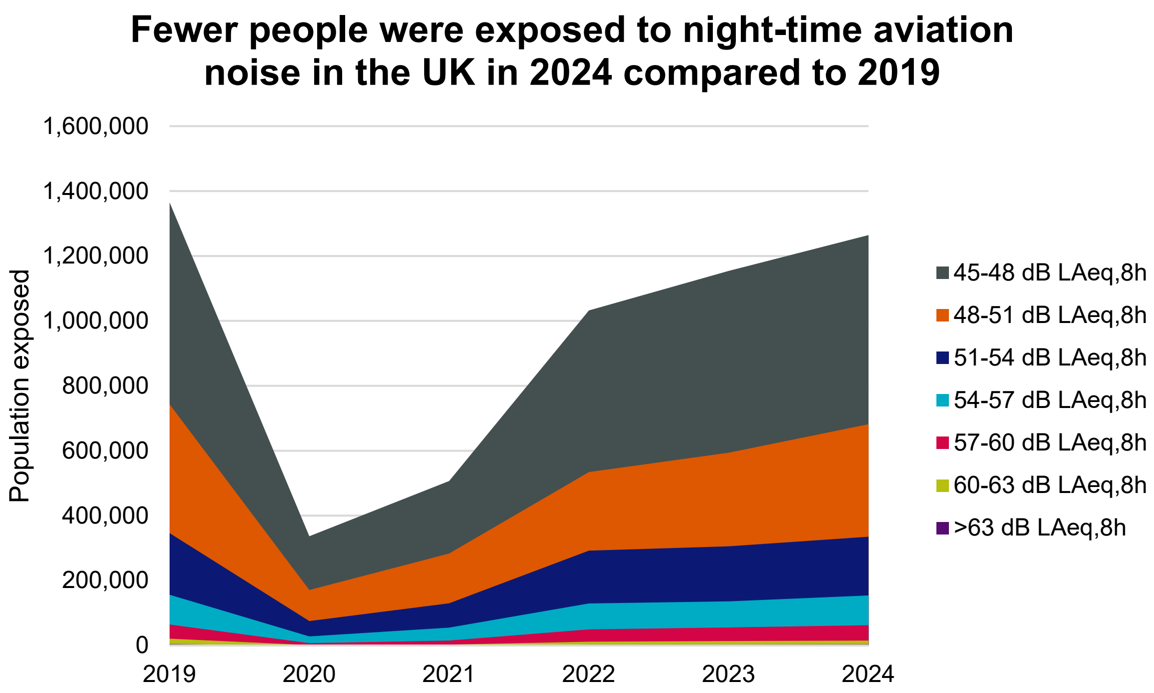


Figure 14: Population exposed to night-time aviation noise in the UK (2019 to 2024)

Contributions from Designated Airports

Section 80 of the Civil Aviation Act 1982 gives the Department for Transport (DfT) power to designate airports for the control of aircraft noise. These ‘controls’ are defined in Section 78 and 79 of the Act. There are currently three airports designated for the control of aircraft noise: Heathrow, Gatwick, and Stansted.

For context, based on data from CAP1731 published in 2016, the three airports combined accounted for 76% of the overall population exposed to daytime noise across the 8 airports studied. Heathrow alone accounted for 73% of population exposed to daytime noise, meaning that changes in its noise levels largely determine national trends. Although the data is historic, and therefore the number of people exposed have changed, these ratios remain valid in 2024.

Population Exposure: Long-Term Trends

The area and shape of the daytime (51 dB $L_{Aeq,16h}$) and night-time (45 dB $L_{Aeq,8h}$)

noise contours[8] around an airport can change annually, which directly influences the number of people exposed to aviation noise. These can be influenced by several factors, such as:

- Changes to how and where aircraft fly;
- An increase or decrease in the volume of air traffic; and
- The introduction of different aircraft types e.g. newer, quieter aircraft.

Population growth and changes in distribution around airports can also influence noise exposure trends. By freezing population data for a given year, we can isolate the effect of any population growth from other factors such as changes in flight volumes or aircraft types. Therefore, alongside calculating the actual population exposed each year, we also calculated noise exposure using a 2019 population dataset which was frozen across the reporting years 2019 to 2024.

Daytime Population Exposure Trends

Between 2019 and 2024, the total area exposed to daytime noise reduced by 15% on average across all bands. This translated into a 10% reduction in the number of people exposed cumulatively. In the hypothetical case where population had remained constant since 2019, this figure decreases further to 13%. For context, air traffic levels in 2024 were 6% below 2019 levels.

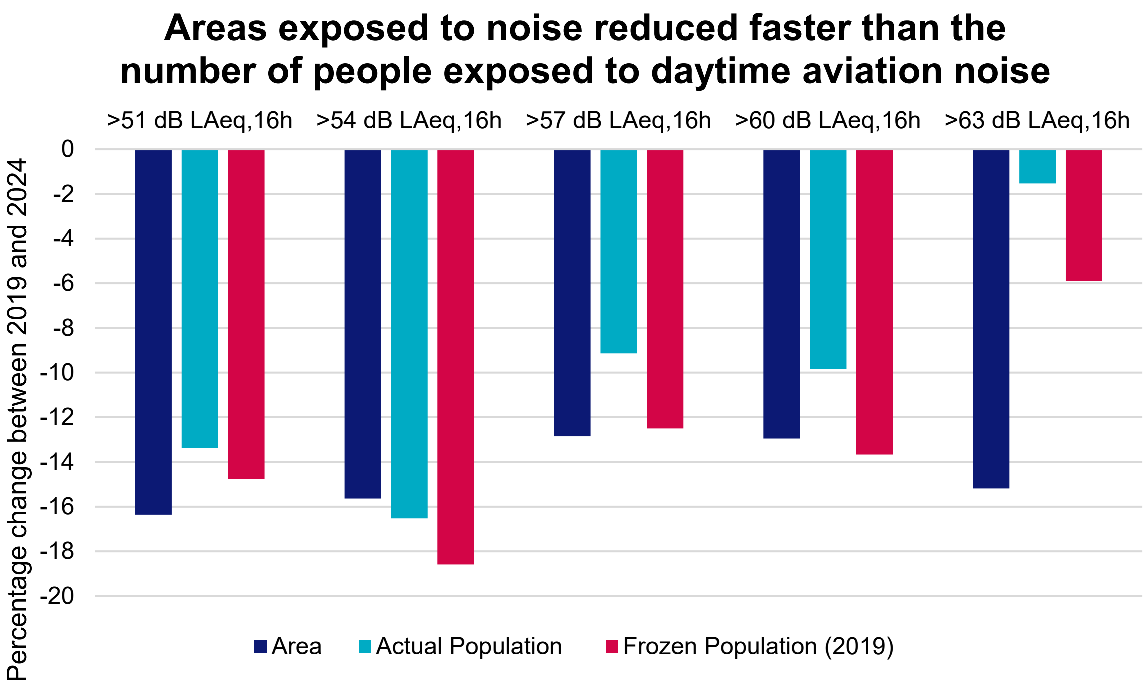


Figure 15: Changes in daytime noise contours area, people exposed assuming actual (2024) population data, and people exposed assuming 2019 population data (%)

[8] All areas on the ground where the average noise level equals or exceeds the specified threshold. Larger contours indicate greater geographical spread of noise or higher traffic volumes.

Night-time Population Exposure Trends

Similar trends are observed for night-time operations. Between 2019 and 2024, the total area exposed to night-time noise reduced by 13% on average across all bands. This translated into a 9% reduction in the number of people exposed. In the hypothetical case where population had remained constant since 2019, this figure decreases further to 12%.

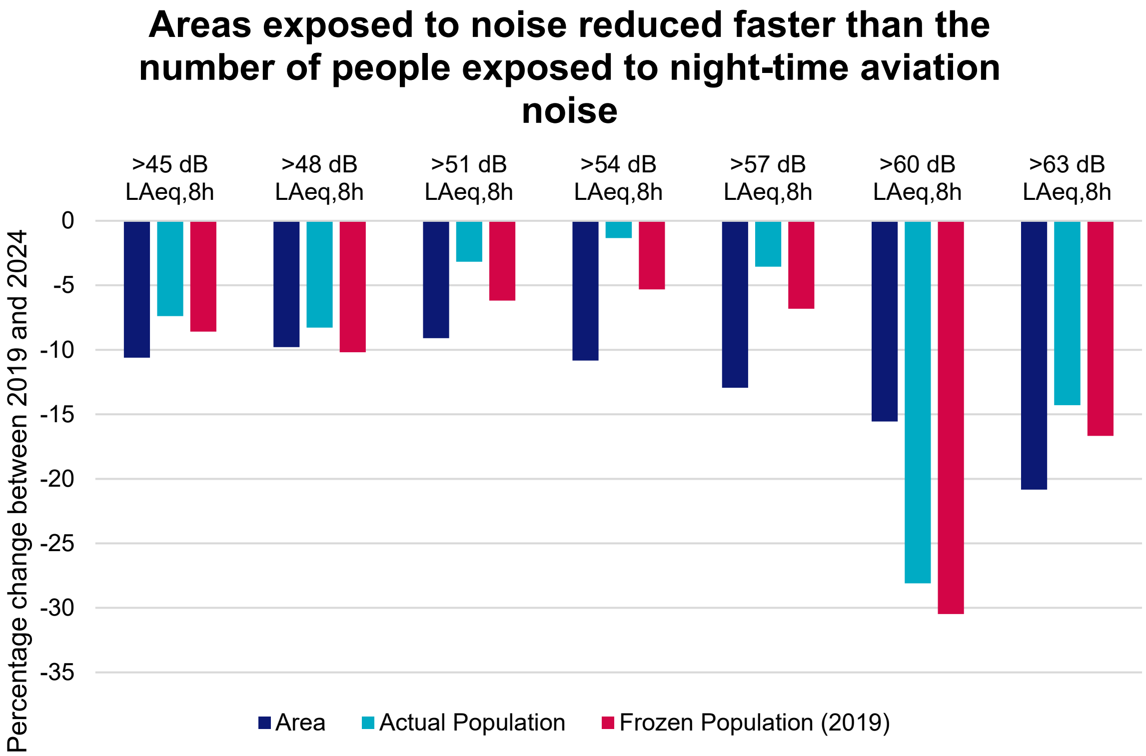


Figure 16: Changes in night-time noise contours area, people exposed assuming actual (2024) population data, and people exposed assuming 2019 population data (%)

Noise Exposure Per Flight

A measure of aviation noise performance can be calculated by dividing the number of people exposed to the daytime and night-time LOAEL (Lowest Observed Adverse Effect Level) by the number of flights for each year. [9] Noise exposure per flight gives an indication, on a per flight basis, on whether the number of people exposed to aviation noise above the LOAEL, the point at which negative effects of sound starts to impact communities, is increasing or decreasing.

There are limitations to this metric. Noise exposure does not grow linearly based on the number of flights, meaning that one additional flight might not in practice expose more people proportionally. Figures might also vary significantly between airports, due to population density and traffic numbers. In addition, yearly results are

[9] Annual aircraft movements for the 8 airports modelled, split by day and night, were divided by the total number of people exposed to daytime and night-time noise.

influenced by changes in the distribution of flightpaths, and therefore population exposed.

Nevertheless, noise exposure can highlight trends with regards to the number of people affected by each flight.

The COVID-19 pandemic led to a reduction in traffic numbers, changes in operational patterns, and different aircraft types being used by airlines compared to before and after the pandemic. As a result, the noise exposure per flight varies widely for 2020 and 2021, and is not deemed to be representative of normal operations.

Daytime Noise Exposure Per Flight

In 2019, on average 1.03 people for every daytime flight were exposed to noise levels above the daytime LOAEL (51 dB $L_{Aeq,16h}$). By 2024, the number of people exposed to noise above these levels, on a per flight basis, decreased by 8%.

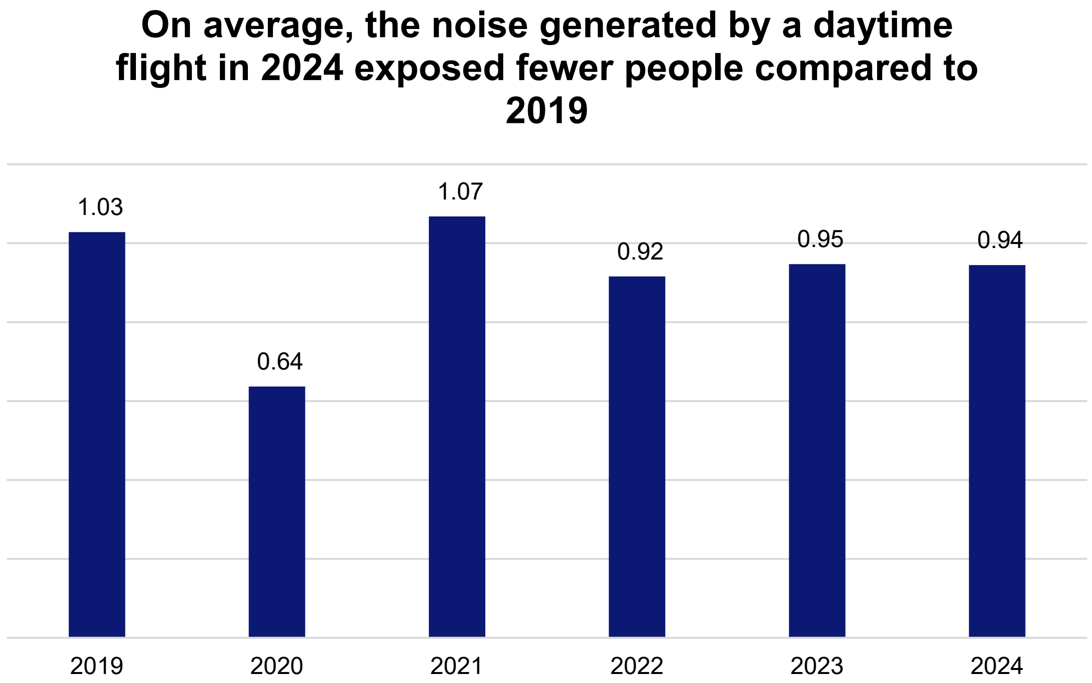


Figure 17: Average number of people in the UK exposed to noise per flight in the daytime (2019 to 2024)

Night-time Noise Exposure Per Flight

In 2019, on average 7.19 people for every night-time flight were exposed to noise levels above the night-time LOAEL (45 dB $L_{Aeq,8h}$). By 2024, the number of people exposed to noise above these levels on a per flight basis decreased by 11%.

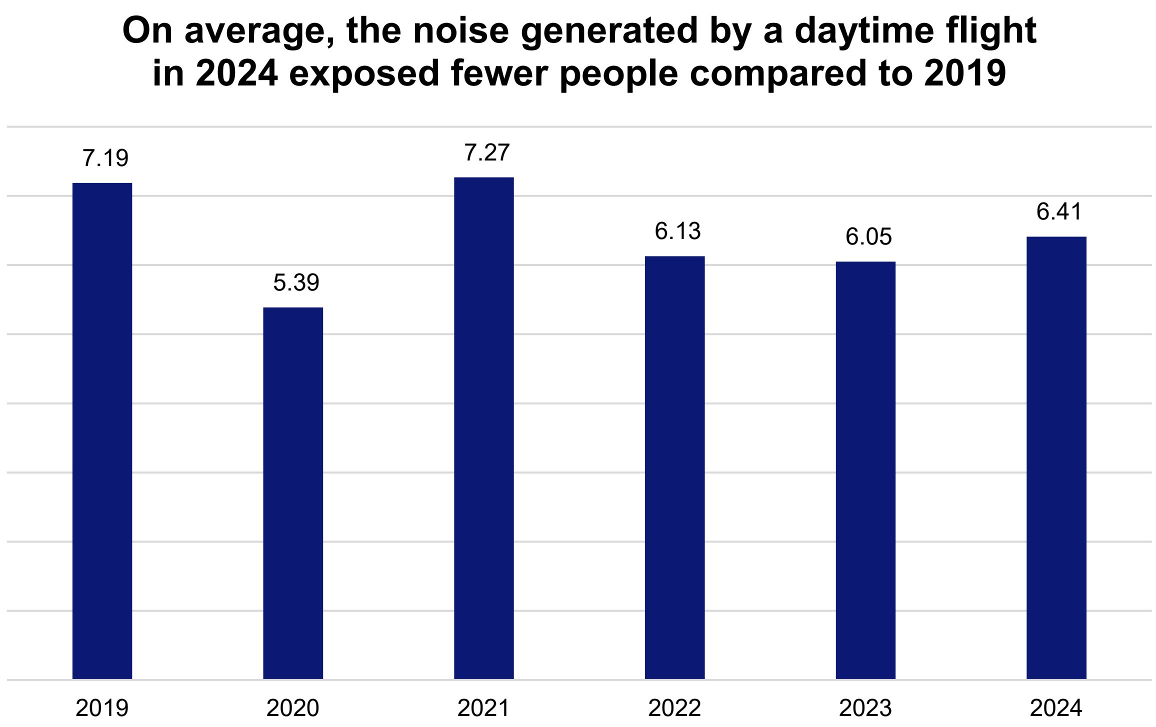


Figure 18: Average number of people in the UK exposed to noise per flight in the night-time (2019 to 2024)

The reduction in noise exposure per movement since 2019 demonstrates the continuing effectiveness of measures addressing noise at source, one of the key pillars of the ICAO Balanced Approach. The retirement, in the UK, of noisier aircraft types such as the older Boeing 747 fleet during the COVID-19 pandemic, together with a growing number of quieter Chapter 14[10] aircraft entering into service, contributed to this reduction in noise intensity per aircraft movement. The wider adoption of more optimised operational procedures also played a supporting role. These operational procedures, such as low power, low drag (LP/LD) procedures, have the ability to provide environmental benefits including reducing noise impacts.

[10] Aircraft noise certification chapters refer to the standards set out in ICAO Annex 16, Volume I, which define maximum allowable noise levels for aircraft during certification tests. Chapter 14, the latest and strictest, applies to new aircraft types from 2017.

Air Quality: Data and Analysis

Around airports, air quality is influenced by a range of emission sources including aircraft engines, ground support equipment, terminal generators, and surface transport to get people and goods to and from an airport. These emissions contribute to the concentration of harmful pollutants in the atmosphere, which can affect human health, ecosystems, and biodiversity. Explore UK AER: Air Quality for more information on environmental protection measures in place to manage the impact of civil aviation on air quality.

Our analysis focuses on air pollutants emitted by aircraft engines only, during the landing and take-off (LTO) phase, which include operations on the ground and up to 3,000 feet above ground level.[11] Air pollutants emitted during other flight phases, like the cruise phase, were excluded from our analysis.

Emissions data was sourced from the latest[12] aircraft-specific landing and take-off emissions reported by the National Atmospheric Emissions Inventory (NAEI).[13] It reports calculated mass estimates, expressed in kilo tonnes, for the following four damaging air pollutants outlined by the Clean Air Strategy 2019:

- nitrogen oxides (NO_x);
- sulphur dioxide (SO_2);
- non-methane volatile organic compounds (NMVOCs); and
- fine particulate matter ($PM_{2.5}$ i.e. particulate matter smaller than 2.5μm).

Our analysis defines aviation emissions as air pollutants emitted during aircraft engine operation. It excludes other sources of air pollutants from airport ground support vehicles or surface transport.

Actual, measured concentrations of air pollutants were not considered for this AER.

The AER Air Quality Technical Note provides more information on the methodology used to estimate the emissions inventories outlined in this analysis document.

[11] 3,000 feet (approximately 914 m) is considered the mixing height or inversion layer. While the mixing height can vary from location to location, on average pollutants emitted below this altitude can potentially have an effect on air quality concentrations, with those emitted closer to the ground having possibly greater effects on ground level concentrations.

[12] At the time of writing, the latest year the NAEI had published emissions data for was 2023.

[13] The NAEI is maintained under contract to the Science and Innovation for Climate and Energy (SICE) Division at the Department for Energy Security and Net Zero (DESNZ) and the Air Quality and Industrial Emissions Evidence Team of the Department for Environment, Food and Rural Affairs (Defra).

Aircraft Air Pollutant Emissions Trends

In 2023, NO_x emissions was the largest air pollutant (in terms of mass) generated by flights departing and arriving at UK airports (up to 3,000 ft).

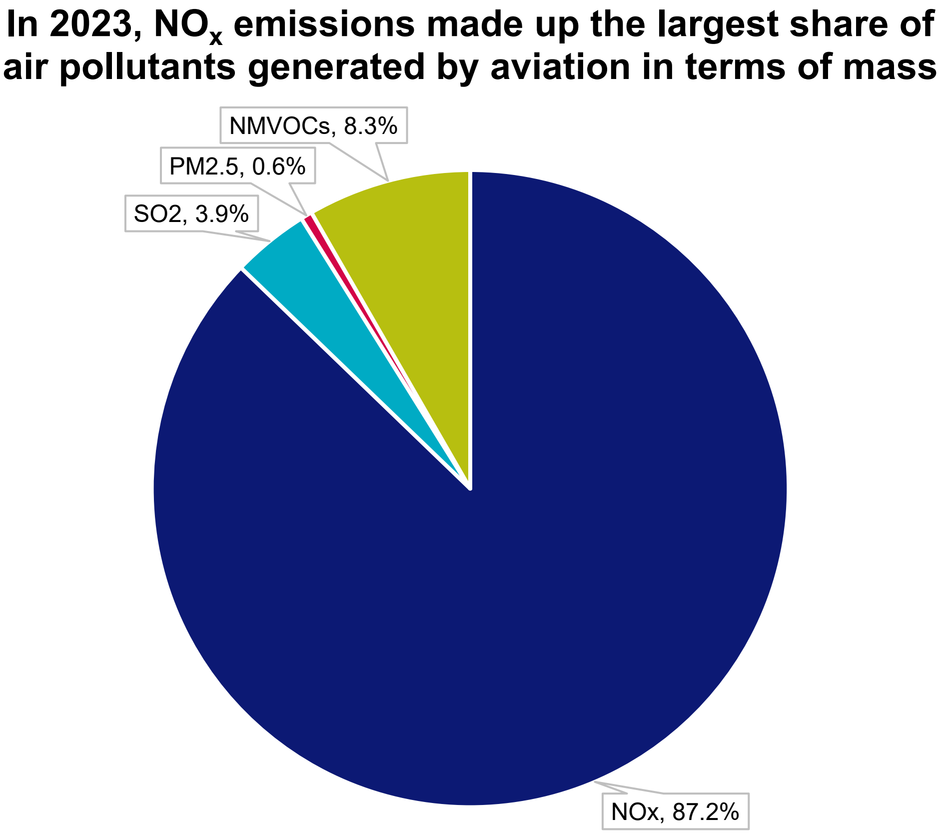


Figure 19: Proportion of air pollutants emitted by aircraft during LTO cycle in the UK (2023)

NO_x emissions amounted to 11.6 kt in 2023, accounting for 87.2% of all pollutants considered in our analysis. NMVOCs and SO_2 accounted for 1.11 kt (8.3%) and 0.52 kt (3.9%) respectively. Fine particulate matter ($PM_{2.5}$) accounted for approximately 0.08 kt (0.6%) of emissions.

It is important to note that each pollutant has differing impacts on human health, productivity, wellbeing, and the environment.

A growing body of evidence indicates that $PM_{2.5}$ may not represent the full impact of particulate matter produced by aircraft engines. Alongside $PM_{2.5}$ and PM_{10}, aircraft engines release ultra-fine particles (UFP). These are particles with a diameter smaller than 100 nanometres. Understanding UFP concentrations is important but challenging - due to their extremely small size, the measurement and characterisation of UFP are subject to significant uncertainty.

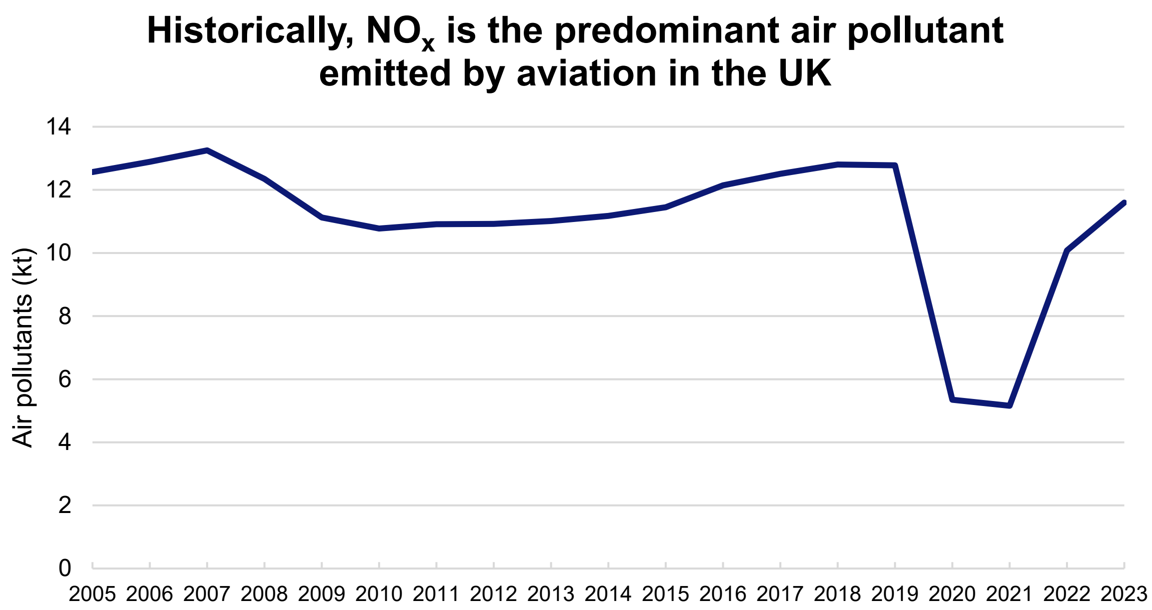


Figure 20: Trends in NO_x emissions by aircraft during LTO cycle in the UK (2005 to 2023)

The results observed in 2023 align with historical, pre-COVID pandemic trends. NO_x emissions produced by departing and arriving flights consistently was the largest air pollutant in terms of mass since 2005.[14]

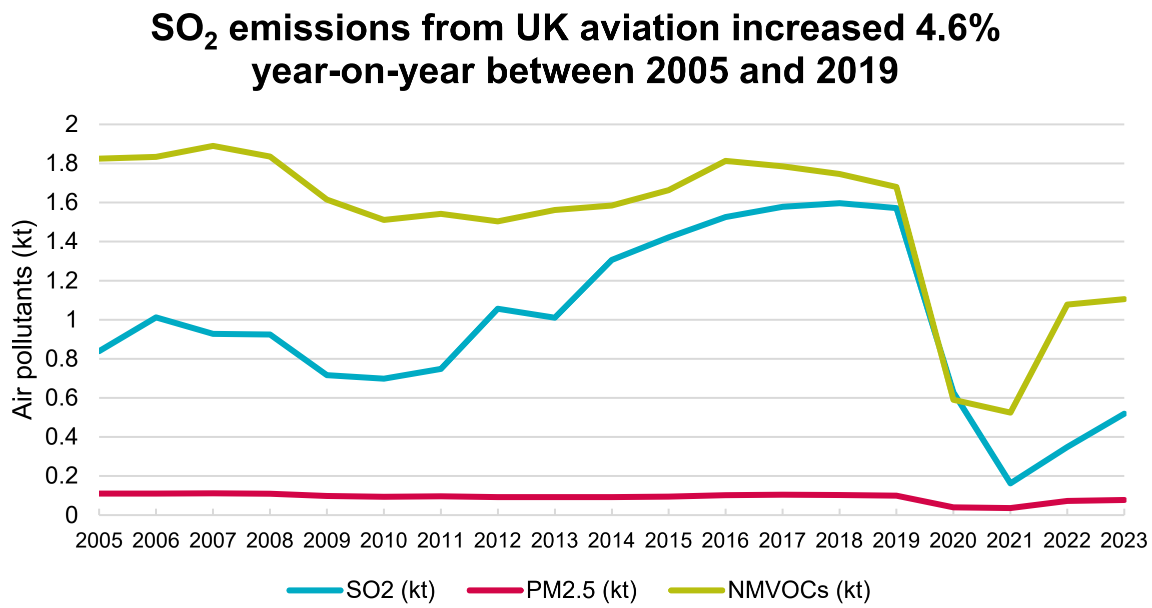


Figure 21: Trends in SO_2, $PM_{2.5}$ and NMVOCs emissions by aircraft during LTO cycle in the UK (2005 to 2023)

[14] The Convention on Long Range Transboundary Air Pollution (CLRTAP)'s amended Gothenburg Protocol and National Emission Ceilings Regulations (NECR) (2018) requires the UK to reduce emissions of NO_x by 55% compared to emissions in 2005 by 2020 and in each subsequent year, up to and including 2029. The NECR also requires the UK to reduce emissions of NO_x by 73% compared to emissions in 2005 by 2030.

NMVOCs and $PM_{2.5}$ emissions fluctuated but followed a similar trend to NO_x emissions. On the contrary, SO_2 emissions increased at a rate of 4.6% per year in that period.

In 2023, emissions of all four pollutants did not reach pre-pandemic levels.

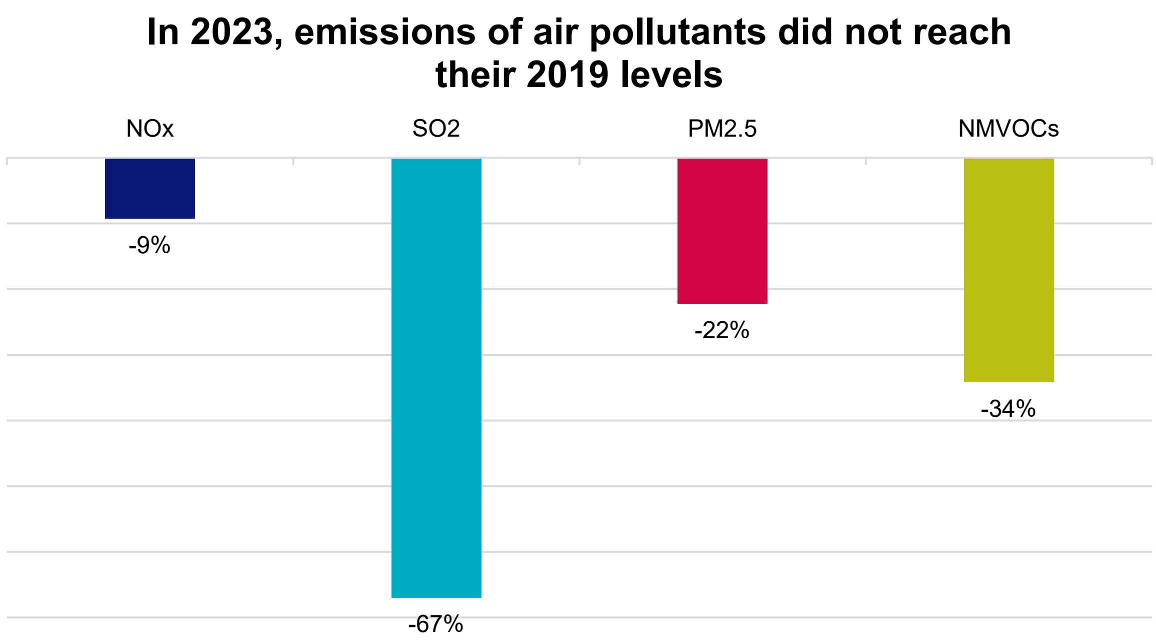


Figure 22: Difference between air pollutants emitted by aircraft during LTO cycle in the UK (2023 compared to 2019)

In 2023, the number of flights was 13% below 2019. NO_x emissions were 9% below their level in 2019 and therefore grew relative to air traffic. $PM_{2.5}$ and NMVOCs increased more slowly, at 22% and 34% below their 2019 levels. Contrary to historical trends, SO_2 emissions were well below pre-pandemic levels in 2023, 67% lower compared to 2019.

NO_x Emissions Per UK Transport Modes

2023 UK Transport Modes Comparison

Drawing on NAEI datasets enables direct comparisons between transport modes. In 2023, passenger cars emitted the most NO_x emissions compared to Light Goods Vehicles[15] (LGVs), Heavy Goods Vehicles (HGVs), aviation, rail, and buses and coaches. NO_x emissions from aviation were 8.7x lower than emissions generated by passenger cars. Rail, on the other hand, produced 7% less NO_x emissions than aviation.

[15] Vehicles designed to primarily transport goods with a maximum weight exceeding 3.5t are classed as HGVs (e.g. trucks), with lighter goods vehicles classed as LGVs (e.g. vans).

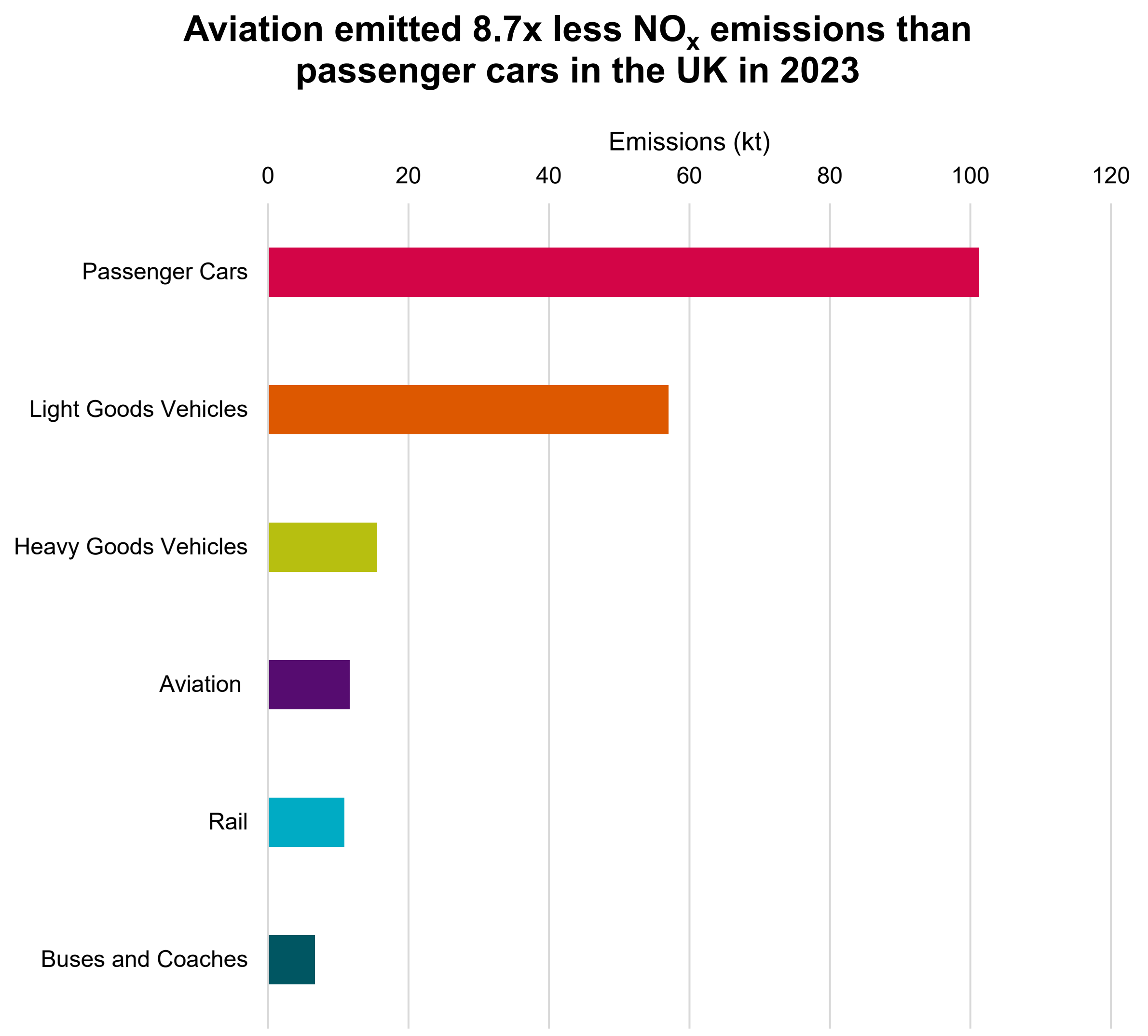


Figure 23: Comparison between UK aviation LTO cycle NO_x emissions and other UK transport sectors (2023)

Long-Term Comparison between UK Transport Modes

Historical data shows significant changes in NO_x emissions levels for several transport modes.

Between 2005 and 2019, aviation's NO_x emissions were lower than other sectors.

Passenger cars, HGVs, and LGVs all drastically reduced their NO_x emissions in that timeframe, despite increases in traffic. HGV NO_x emissions decreased at the fastest rate compared to other sectors. In 2005, it was approximately 16.4x greater than aviation however, by 2023, HGV emissions had decreased to 1.3x that of aviation. This is due to several reasons such as the entry into force of stricter emission standards and advances in engine and exhaust technologies.

These trends contrast sharply with the direction of travel of NO_x emissions from aircraft. 2023 was the first time aviation produced more NO_x emissions than rail.

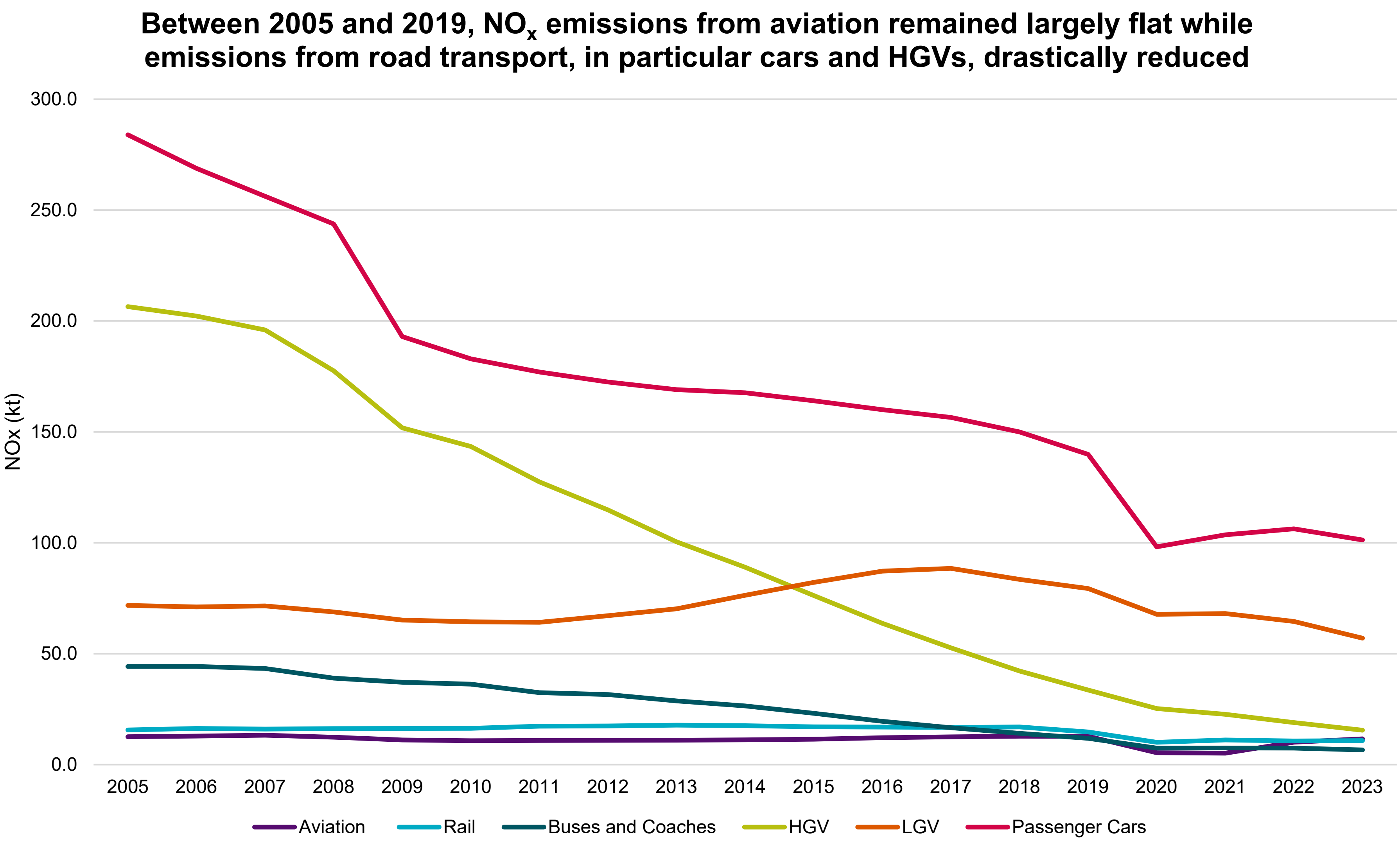


Figure 24: Historical trends in NO_x emissions from several UK transport modes (2005 to 2023)

In 2023, NO_x emissions from all sectors remained below 2019 levels. However, aviation's NO_x emissions increased the fastest, sitting 10% lower in 2023 compared to 2019. By contrast, HGV emissions were down 54% in the same timeframe.

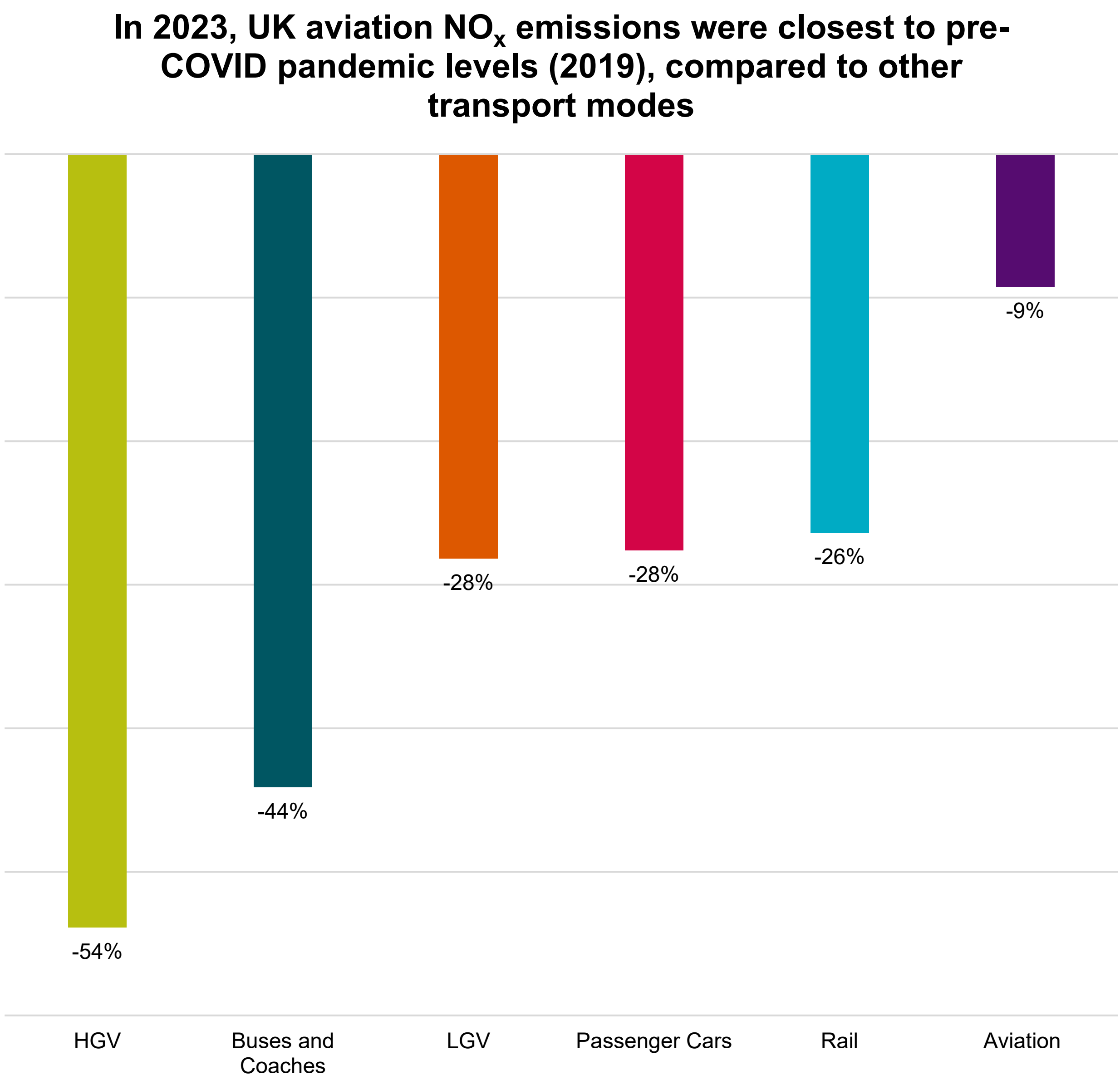


Figure 25: Difference between NO_x emitted by different UK transport sectors (2023 compared to 2019)

Aviation NO_x Emissions Per Regions

The change in NO_x emissions from aviation at regional levels was broadly stable from 2005 to 2019. Over that period, the North East saw the largest year-on-year reduction (3%), while the South West and East of England recorded the largest increase (2%).

Aviation NO_x emissions are not distributed evenly across the UK. Regions with a greater proportion of large airports register higher level of NO_x emissions. In 2023, London accounted for 41% of total NO_x emissions generated by aviation, while the three largest regions combined (London, the East of England, and the South East) accounted for 68%.

Figure 26: Proportion of NO_x emissions by aircraft during LTO cycle per UK region (2023)

Large airports drive trends at regional level. A breakdown of the 10 busiest UK airports and their grouping by region is given below.

Airports	Region
Luton	East of England
Stansted	East of England
Heathrow	London
Manchester	North West
Belfast International	Northern Ireland
Edinburgh	Scotland
Glasgow	Scotland
Gatwick	South East
Bristol	South West
Birmingham	West Midlands

Table 1: Breakdown of regions hosting the 10 busiest UK airports (number of passengers in 2023)

Aviation NO_x Emissions Per Airport

Flights departing and arriving at the 10 busiest UK airports (Heathrow, Gatwick, Manchester, Stansted, Luton, Birmingham, Edinburgh, Glasgow, Bristol, and Belfast International) made up the majority of LTO aircraft NO_x emitted in the UK in 2023. Together, they accounted for 87% of all emissions, with the rest of UK airports generating the remaining 13%.

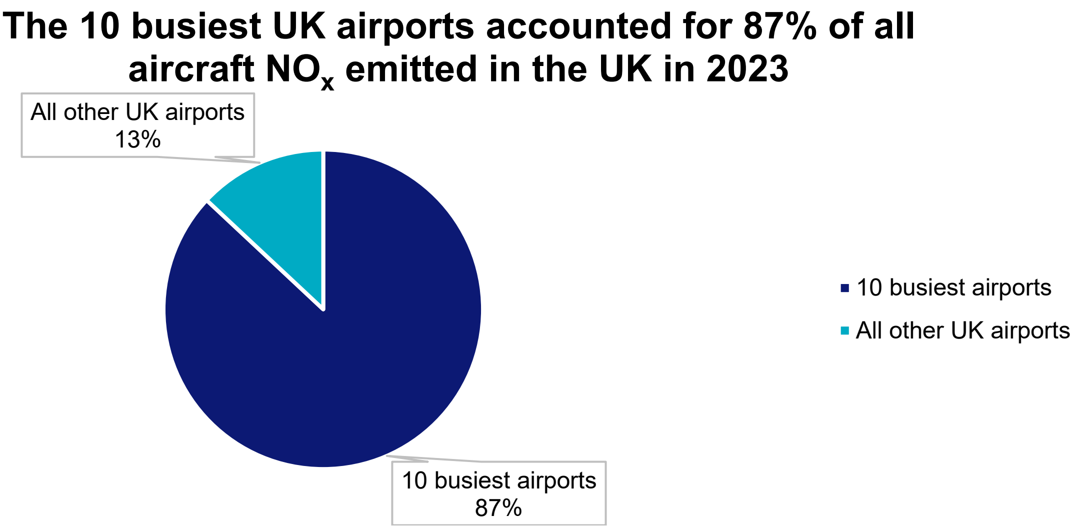


Figure 27: Proportion of NO_x emissions by aircraft during LTO cycle between 10 busiest and all other UK airports (2023)

Amongst the 10 busiest airports, flights to and from Heathrow accounted for 45% of the emissions generated in 2023. This was equivalent to 3x the emissions from flights to and from Gatwick, the second busiest airport in the UK.

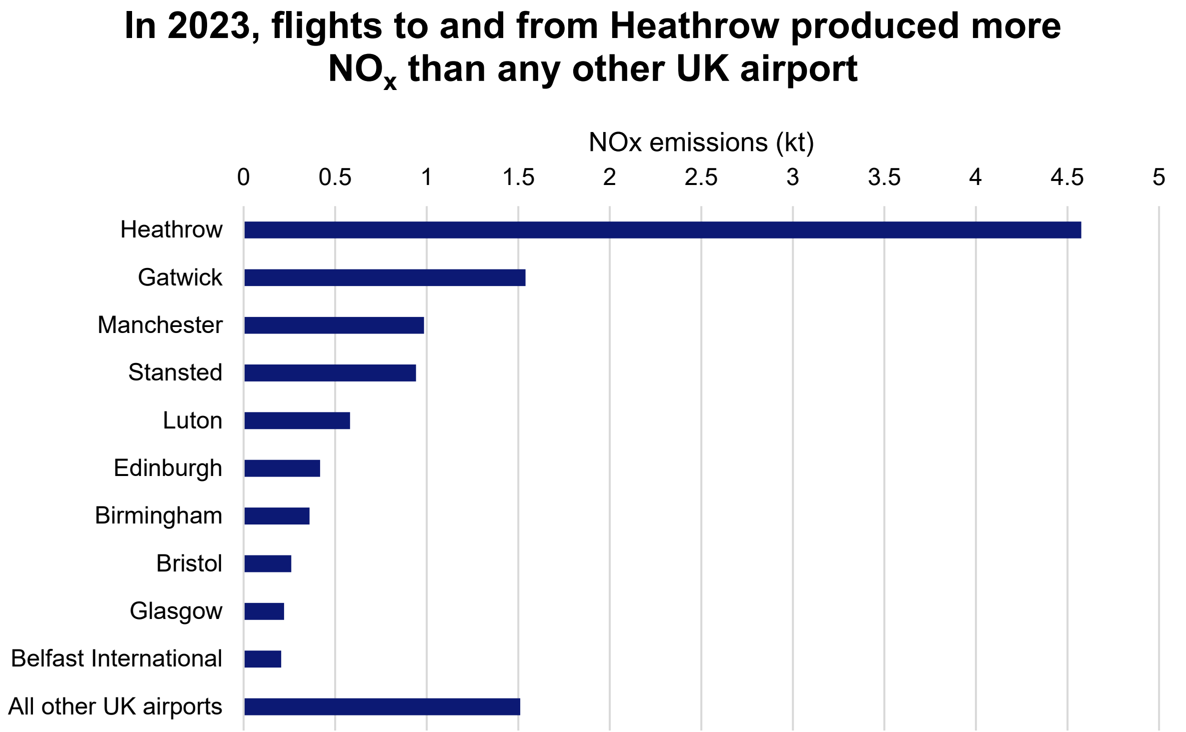


Figure 28: NO_x emissions from aircraft during LTO cycle for the 10 busiest UK airports (2023)

This trend was reflected for the other three air pollutants, SO_2, $PM_{2.5}$ and NMVOCs.

Due to the number of flights and the types of aircraft operated at Heathrow (wide-body aircraft with larger engines, typically serving long-haul destinations), the airport's environmental performance with regards to air pollutants has a determinant impact at national level.