MODULE 4 | 4.9 | IN-DEPTH VERSION

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Aviation

KEY FINDINGS

Demand, use and access

- The air passenger market has demonstrated resilience and recent growth. Global revenue passenger-kilometres, a standard measure of passenger traffic, increased 10.4% in 2024 and pushed total traffic 3.8% above the pre-pandemic levels of 2019, indicating a full recovery across all regions.

- Evidence of strong aviation demand was also reflected in record passenger load factors, as airlines used their capacity more efficiently than ever before to reach new highs both in December 2024 (84.0%) and for the full year (83.5%). Although high load factors are positive from an operational efficiency perspective, efficiency improvements risk being overshadowed by the scale of rising demand, highlighting the core challenge of reducing absolute emissions in a growing market.

- International passenger traffic was a major driver of aviation's 2024 recovery, climbing 13.6% despite ongoing geopolitical tensions and airspace restrictions that necessitated adjustments to global networks. Domestic markets also contributed to the growth, expanding 5.7% globally in 2024.

- Aviation has played a minor role in global freight transport, representing only 1% of the global trade volume and just 0.1% of global freight tonne-kilometres in 2021. Even so, cargo flights remain a key revenue stream for the airline industry, with commercial airlines making around 5-10% of their total revenue from hauling freight.

- Freight aviation volumes experienced strong performance in 2024, with industry-wide cargo tonne-kilometres increasing 11.3%, setting a new record above 2021's volumes and above the pre-pandemic levels of 2019. Contributing factors included booming e-commerce demand and continued disruptions in maritime shipping.

- Available cargo capacity (in tonne-kilometres) hit a record high in the third quarter of 2024, supporting a rise in cargo load factors.

- Global aviation's recovery masks significant regional differences in demand growth, with particular dynamism in developing economies. The Asia Pacific region experienced a 16.9% increase in passenger traffic in 2024, driven by strong domestic markets in China and India, but

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international travel in the region remained below 2019 levels. Africa ranked second with a 13.2% increase in passenger traffic and notable growth on the Africa-Asia route.

- Strong passenger growth in Asia Pacific and Africa suggests a potential long-term shift in aviation expansion towards developing and emerging economies. China and India (and Asia Pacific as a whole) are projected to account for nearly half (46%) of the 42,430 new passenger and freighter deliveries in the 2024-2043 period. This has implications for future global emission trajectories, as these regions generally have lower historical emissions but higher growth potential. It underscores the critical need for globally inclusive and equitable decarbonisation strategies that support sustainable development alongside climate action.
- In addition to economic and demographic factors, geopolitical events have influenced regional aviation patterns, posing threats to the stability needed for long-term investments in decarbonisation. Both demand forecasts and effective decarbonisation planning must account for this volatility. Direct risks to airline operations and demand can stem from policy instability following major elections, potential trade disputes (e.g., US tariffs), a shifting global power balance (potentially leading to more conflict), and even reduced political commitment to climate action.
- Behavioural factors and consumer preferences are increasingly influencing travel choices, including a potential shift from air travel to high-speed rail for shorter journeys.
- The cost of air travel is a significant factor influencing demand, and decarbonisation efforts are widely expected to exert upward pressure on prices. The deployment of Sustainable Aviation Fuels (SAF), which currently costs 2-8 times more than conventional fuel, is a primary driver of anticipated cost increases.

Sustainability and climate trends

- The global transition towards net zero aviation will inevitably have consequences; it is not solely a technical and economic challenge but also carries significant social and equity implications. These must be carefully managed to ensure fairness and to minimise negative impacts on connectivity, equity in access, and economic growth related to jobs and tourism.
- In 2024, aviation supported an estimated 11.6 million direct jobs and 20.4 million indirect jobs globally and contributed USD 4.1 trillion (3.9%) to the global gross domestic product (GDP) – reflecting the strong link between economic prosperity and air travel growth.
- Aviation's role in facilitating global connectivity supports economic growth, enables trade and tourism, fosters international collaboration, and provides access to essential services and humanitarian aid. Overall, the sector supports many of the 17 United Nations Sustainable Development Goals (SDGs), including SDG 8 (Decent Work and Economic Growth) and SDG 17 (Partnerships). Maintaining these positive contributions while mitigating the sector's emissions and supporting climate action (SDG 13) is a key aspect of a sustainable and just transition.
- As both air passenger and air cargo demand recovered in 2023, aviation-related greenhouse gas emissions rose to reach 90% of their 2019 (pre-pandemic) peak level. Aviation emissions grew in nearly all regions to just over 900 million tonnes of carbon dioxide (CO_2) equivalent, of which around 10% was from cargo planes. International aviation emitted 498 million tonnes of CO_2 equivalent, while domestic aviation contributed 406 million tonnes. Aviation's CO_2 equivalent emissions were expected to surpass their 2019 level in 2025.
- Aviation contributed only around 2.2% of the total global CO_2 emissions from human activities in 2023; however, the sector's absolute volume of emissions was still substantial. Between 1990 and 2023, air traffic grew 5% annually on average, while CO_2 emissions from aviation grew 2%, indicating some efficiency gains but still resulting in a net increase in emissions over the period. The sector's demand growth rate has outpaced overall emission reductions in many economies.
- Around 80% of the CO_2 emissions from aviation originate from flights of more than 1,500 kilometres, distances that generally cannot be substituted by rail. This has profound implications for decarbonisation strategies and underscores the importance of developing and

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deploying scalable solutions that can effectively reduce emissions from medium- and long-haul flights; the leading solution is SAF, and potentially also future fuel-efficient aircraft and propulsion technologies.

- The International Civil Aviation Organization (ICAO) has adopted a Long-term Global Aspirational Goal (LTAG) for the international aviation sector of achieving net zero carbon emissions by 2050. To meet this goal, the ICAO and its Member States strive to reduce CO_2 emissions in international aviation 5% by 2030 through the use of cleaner fuels such as SAF, without specific obligations or commitments in the form of emission reduction goals attributed to individual members.

- The aviation sector would need to adhere to stringent carbon budgets to align with the goals of the Paris Agreement to keep global temperature rise below 1.5 degrees Celsius (°C) and well below 2°C. As of 2023, the global commercial aviation fleet already in service was set to emit around 9 gigatonnes of CO_2 over its lifetime, or nearly half the indicative carbon budget of 18.4 gigatonnes of CO_2 that is required for the sector to align with a net zero emission pathway. New aircraft delivered from 2024 onwards might exhaust the sector's 1.5°C carbon budget by 2032.

- Aviation's carbon budget constraints underscore that relying solely on incremental efficiency gains and SAF deployment in conventional aircraft may be insufficient, particularly to achieve the ambitious 1.5°C target. This points to an urgent need either for much sooner and larger-scale deployment of genuinely zero-emission aircraft (powered by hydrogen or electricity), or for the delivery of aircraft from the mid-2030s onwards that operate exclusively on 100% SAF, with extremely low life-cycle emissions.

- The risk of remaining dependent on the current (high-carbon) pathway is significant. The continued production and delivery of new aircraft designed primarily for fossil fuels, even if they incorporate efficiency improvements, locks in emissions for decades due to the long operational lifespan of aircraft (20-30 years).

- Models of future CO_2 emission trajectories for the aviation sector illustrate the critical levers for decarbonisation, based on varying assumptions about technology, policy and demand. If current growth trends continue without significant intervention, aviation's CO_2 emissions could potentially triple by 2050. The stark contrast between potential net zero pathways and the possibility of emissions tripling highlight the transformative nature of the changes required and the high stakes involved in failing to implement effective mitigation measures.

- Operational improvements such as enhancing the efficiency of air traffic management and aircraft operations can yield immediate fuel savings and emission reductions. Collectively, operational efficiencies offer a maximum emission reduction potential of 10%.

- Fleet renewal remains a cornerstone of aviation's decarbonisation strategy. New-generation aircraft

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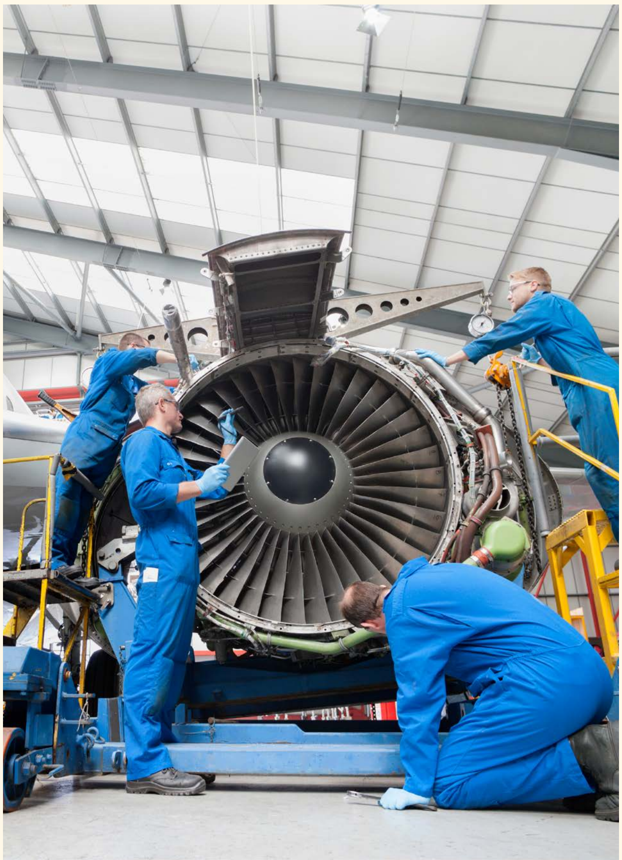
delivered by major manufacturers such as Airbus, Boeing, COMAC and Embraer are a reported 20-30% more efficient than the older models they replace. However, the rate of fuel efficiency improvement (around 1% per year) has stagnated since 2020. If all cost-effective technologies are adopted, annual fuel burn reductions of up to 2.2% are technically possible through 2034, although current trends are slower.

- Airlines have invested heavily in new aircraft, with more than 19,360 new planes delivered since 2009 and a production backlog of around 15,700 new-technology aircraft set to enter the fleet from 2023 onwards. The combination of new technology, operational efficiencies and infrastructure improvements avoided an estimated 14.6 billion tonnes of CO_2 between 1990 and 2023.
- Research and development continue to target further incremental improvements. Disruptive technologies such as battery electric and hydrogen propulsion hold promise for zero-emission flight but face large hurdles to widespread adoption by 2050, with commercial deployment not expected before the late 2030s. Their contribution to overall aviation fuel consumption and emission reduction by 2050 is projected to be limited in most scenarios.
- In a critical timing gap, incremental efficiency improvements in conventional aircraft appear insufficient on their own to meet stringent climate budgets, especially given recent stagnation. Yet the transformative technologies (hydrogen/electric) needed for deeper cuts face substantial barriers to deployment by 2050, according to most projections.
- Global SAF production more than doubled in 2024 to 1 million tonnes (1.3 billion litres) – up from around 0.5 million tonnes (600 million litres) in 2023 – and is projected to double again to 2.1 million tonnes (2.7 billion litres) in 2025 (albeit starting from a very low base).
- Despite this rapid growth rate, SAF's share of total global aviation fuel consumption was only around 0.15% in 2023, rising to 0.3% in 2024 and a projected 0.7% in 2025.
- Globally, the pipeline of SAF projects is expanding. However, projections for actual global SAF production capacity by 2030 vary considerably, reflecting significant uncertainty.
- Scaling SAF production from less than 1% of current fuel use to the levels required by targets for 2050 represents a monumental undertaking fraught with challenges.
- Demand signals for SAF have arisen from policy mandates in the European Union (EU) and the United Kingdom, goals in the United States, and growing voluntary commitments from airlines. Yet securing the necessary long-term off-take agreements remains a hurdle.
- Beyond CO_2 emissions, aviation impacts the climate greatly through non-CO_2 effects, including the release of nitrogen oxide (NO_x) emissions at altitude and the formation of persistent condensation trails (contrails) and contrail-induced cirrus clouds. These effects could equal or exceed the total climate warming impact of aviation's CO_2 emissions alone.
- Despite the growing recognition of non-CO_2 effects and the initiation of monitoring requirements, the implementation of large-scale trials and mitigation strategies to address these effects appears less advanced compared to measures targeting CO_2. Translating this into effective, globally co-ordinated mitigation action remains a key challenge and opportunity for the coming years.
- In addition to mitigating its own climate impact, the aviation sector must adapt to the unavoidable consequences of climate change already under way, including increasing disruptions from more frequent and intense extreme weather events. Initiatives are emerging to study these impacts and to develop adaptation strategies.



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Policy and investment developments

- In 2022, the ICAO Assembly adopted its Long-Term Aspirational Goal (LTAG) for international aviation to achieve net zero carbon emissions by 2050. This global goal signals a collective ambition to align the sector with the global warming targets of the Paris Agreement, although it is not binding on individual member states.

- To support the LTAG, in November 2023 the third ICAO Conference on Aviation and Alternative Fuels adopted the "ICAO Global Framework for Sustainable Aviation Fuels (SAF), Lower Carbon Aviation Fuels (LCAF) and other Aviation Cleaner Energies". The Framework includes a collective global aspirational vision to reduce CO_2 emissions in international aviation 5% by 2030 through the use of cleaner energy sources, compared to a baseline that assumes zero use of cleaner energy.

- Although the ICAO framework represents important progress in building global consensus and providing guidance, its effectiveness relies heavily on voluntary implementation by member states, and its aspirational nature and 5% vision for 2030 contrast with legally binding mandates adopted at the regional or national levels. This highlights the inherent challenge of achieving globally harmonised and sufficiently ambitious action through international agreements alone.

- The EU has taken a leading role in translating international goals into binding regional legislation with its landmark ReFuelEU Aviation regulation, in effect since January 2025 and part of the "Fit for 55" climate package. The regulation sets legally binding minimum shares of SAF that must be blended into aviation fuel supplied at EU airports, starting at 2% in 2025 and rising to 6% in 2030, 20% in 2035 and 70% by 2050. ReFuelEU creates the world's largest mandated market for SAF and provides a strong, long-term demand signal intended to drive investment in production, particularly within the EU; however, implementation challenges remain due to the high costs.

- As of early 2025, the United States was pursuing its 2050 net zero goal for aviation primarily through incentives, research, and public-private partnerships, as outlined in the updated 2024 US Aviation Climate Action Plan. The centrepiece of the US SAF strategy is the SAF Grand Challenge, setting ambitious production goals of 3 billion gallons (11.4 billion litres) by 2030 and 35 billion gallons (132.5 billion litres) by 2050, intended to meet 100% of domestic demand.

- In January 2025, the incoming Trump administration issued an executive order halting the disbursement of funds for implementing the 2024 US Aviation Climate Action Plan. In July 2025, the so-called One Big Beautiful Bill Act reduced SAF production incentives from USD 1.75 per gallon to USD 1 per gallon.

- The 2024 US Aviation Climate Action Plan also includes significant investment in R&D of aircraft and engine technology – such as NASA's Sustainable Flight National Partnership and the Federal Aviation Administration's Continuous Lower Energy, Emissions and Noise (CLEEN) Program – as well as operational improvements through air traffic management modernisation (NextGen, Trajectory-Based Operations). In addition, the Plan highlights US international leadership within the ICAO, airport emission reduction initiatives, and research into non-CO_2 impacts and carbon removals.

- Increasingly, policy focus globally has expanded to include the impacts of non-CO_2 emissions. Starting in January 2025, aircraft operators under the EU Emissions Trading Scheme will be required to monitor and report the non-CO_2 climate impacts of their flights (initially those within the European Economic Area, Switzerland and the United Kingdom).

- Some European countries have implemented or considered demand-side measures that restrict short-haul flights where viable transport alternatives exist. In France, a 2022 law prohibits domestic flights on routes where a direct train journey of less than 2 hours and 30 minutes is available. Policy analysis has explored extending this ban to routes with train alternatives under five hours, which could greatly increase the number of affected routes and potential emission savings. However, critics argue that airlines may simply reallocate the freed-up slots to longer, potentially more carbon-intensive international flights; thus, short-haul bans should be implemented alongside broader measures that address potential rebound effects or emission leakage.

- Although the adoption of SAF and other decarbonisation technologies is expected to increase the cost of flying, it can also serve as a key means to moderate the growth in aviation demand. As of 2018, the demand for aviation from 1% of the world's population produced 50% of the sector's emissions, while around 80% of people had never set foot on a plane.

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- Research from 2022 found that, globally, the wealthiest 5% of people accounted for 55% of aviation activity and emissions. However, the impact of higher flying costs will vary across regions and socio-economic groups. Addressing these distributional effects is crucial to maintain public support and ensure that the transition is perceived as fair.

- Policies aimed at mitigating these impacts could include targeted subsidies for essential routes, progressive taxation schemes that shield infrequent flyers, and using the revenue from aviation taxes to support lower-income groups or invest in alternative transport infrastructure.

- Some countries are applying the "polluter pays" principle more directly to aviation, including through aviation fuel taxes, national ticket taxes, frequent flyer levies and international solidarity levies to internalise the environmental costs of flying, moderate demand and generate revenue to fund climate mitigation or cleaner technologies such as SAF.

- With a small percentage of the population accounting for a large share of flights and emissions, frequent flyer levies are seen as an equitable tool targeting those who fly most frequently and often farthest (typically, higher-income individuals). This contrasts with the potentially regressive impact of flat taxes or general price increases resulting from SAF adoption, which could disproportionately affect those who rely on flying for essential connectivity.

- Despite the substantial revenue potential of taxes and levies, which could be channelled towards climate finance or subsidising SAF, significant implementation hurdles remain. These include persistent legal complexities surrounding fuel tax exemptions and the challenge of international co-ordination for global levies.

- As of December 2023, within the broad "transport services" sector, 337 companies globally had validated targets for emission reductions under the Science Based Targets initiative (SBTi), which provides a framework for companies to set emission reduction targets aligned with climate science.

- In July 2024, Air New Zealand, only the second carrier globally to have its targets validated under the SBTi aviation framework, abandoned its SBTi-validated goal to reduce its carbon intensity 28.9% below 2019 levels by 2030 (including a 16.3% cut in absolute emissions). Although the carrier reaffirmed its long-term goal of net zero emissions by 2050, its decision to abandon the 2030 goal underscores the practical difficulties the industry faces in delivering deep emissions cuts in the near term, given the state of technology deployment, fuel supply chains and enabling policies.

- Major aircraft manufacturers play a pivotal role in decarbonisation through the development and delivery of more efficient aircraft and enabling the use of future fuels.

- A clear convergence exists among major aircraft manufacturers on the core technological levers for decarbonising aviation, which provides a degree of confidence for technological development. These levers

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are: enhancing conventional aircraft efficiency, enabling universal SAF use in the near term, and investing in R&D for potentially transformative hydrogen and/or electric propulsion for the longer term.

- Ensuring that all manufacturers accept their life-cycle responsibility and set ambitious targets covering the in-use emissions of the aircraft they sell is critical for driving progress. Airbus' adoption of a specific Scope 3 intensity reduction target reflects an important signal.
- There are two main carbon market schemes in the aviation sector: the EU Emissions Trading System (ETS) and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). To avoid double-claiming benefits under the different schemes, airlines must carefully account for SAF use.
- This fragmentation of carbon reduction efforts for aviation, lacking a single, globally consistent carbon price signal, potentially leads to compliance complexities and competitive distortions.
- Financial support mechanisms are crucial enablers of the SAF transition, given the high cost of the fuels and the significant investment risks associated with developing new technologies and production facilities.
- The policy landscape appears to be evolving beyond traditional R&D support towards more sophisticated financial instruments designed specifically to de-risk commercial-scale investment.
- Although the primary focus of aviation decarbonisation is on avoiding and reducing emissions at the source, there is growing recognition of the potential role of carbon dioxide removal (CDR) in addressing the residual emissions that remain after maximising reduction efforts.
- The decarbonisation of aviation is not an isolated challenge but is deeply intertwined with broader energy systems and requires unprecedented levels of collaboration across multiple stakeholder groups.
- This need for collaboration stems from the sheer complexity of the transition.
- Collaboration also faces challenges, as different stakeholders have varying, sometimes conflicting, interests.
- Building aviation's resilience requires a collaborative effort across the interconnected aviation network to ensure operational continuity and safety in a changing climate. There is a need for aviation stakeholders (airports, airlines, air navigation service providers) to conduct systematic climate risk assessments and develop adaptation plans. This involves understanding local climate projections, assessing vulnerabilities, prioritising risks and identifying adaptation measures.
- National adaptation plans are also beginning to incorporate transport sector strategies.

Context, challenges and opportunities

Measurable progress has been made since 2023 in addressing the climate impacts of aviation. However, achieving the sector's ambitions for net zero carbon emissions by 2050 remains a monumental challenge. Demand from both air passengers and air cargo has rebounded strongly, surpassing pre-COVID-19 pandemic levels of 2020, driven in particular by growth in developing economies. Although operational efficiencies are being pursued and fleet renewals continue to deliver incremental gains, these efforts alone will not be enough to counteract the emissions generated by rising traffic volumes in the coming decades, especially in low- and middle-income countries.

Sustainable aviation fuel (SAF) has emerged as the central pillar of the industry's decarbonisation strategy in the near to medium term. Production volumes have grown rapidly, with SAF supplies doubling to 1 million tonnes in 2024, but they remain a tiny fraction (less than 1%) of aviation's total fuel consumption.[1] Scaling SAF production to meet ambitious policy targets (e.g., 5-10% by 2030) requires overcoming hurdles related to high costs, securing sustainable feedstocks (beyond constrained waste oil supplies), attracting massive investment and accelerating the deployment of advanced conversion technologies such as power-to-liquids (e-fuels). Ensuring the environmental integrity of SAF through robust life-cycle analysis and certification remains critical.

Policy frameworks have advanced since 2023. The International Civil Aviation Organization's (ICAO) Global Framework provides high-level guidance and aspirational vision, and several regions have created greater market pull for SAF, including the European Union (EU) (through ReFuelEU), the United Kingdom (through legally binding mandates for SAF) and the United States.[2] The diversity of national policy approaches underscores the need for greater international harmonisation. Carbon market mechanisms such as the EU Emissions Trading System (ETS) are being strengthened, and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) provides a global framework for carbon offsetting. Financial mechanisms are evolving beyond support for research and development (R&D) and towards de-risking commercial investment through instruments such as revenue guarantees.

Major manufacturers are developing disruptive technologies such as hydrogen and electric propulsion, but widespread deployment faces substantial technical and economic barriers within the 2050 time frame. Analysis of the emissions already committed from existing and planned conventional aircraft underscores the urgency of accelerating this transition, as current trajectories risk exceeding climate budgets as early as the mid-2030s.[3] In addition, impacts on global warming from sources other than carbon dioxide (CO_2) – such as nitrogen oxide (NO_x) emissions at altitude and the formation of persistent condensation trails (contrails) – have gained policy attention, with monitoring requirements commencing, but large-scale mitigation strategies appear less developed.

Decarbonising the aviation sector carries significant socio-economic consequences. Rising ticket prices, while potentially progressive in cost distribution, necessitate careful consideration of the equity impacts on people's connectivity and access. Managing the transition in the aviation labour market and ensuring environmental justice in fuel production are crucial components of an equitable shift. Finally, the sector must pro-actively adapt its activities, such as airport infrastructure and aircraft operations, to the increasing physical risks posed by climate change (flooding, extreme heat, turbulence, etc.).

So far, the scale and pace of change required to align aviation with a pathway to keep the average global temperature rise within 1.5 degrees Celsius (°C), or even to align it with a net zero emission pathway by 2050, remain immense. Bridging the gap requires sustained and intensified efforts across all fronts:

accelerating the scale-up of SAF with robust sustainability safeguards, pushing the boundaries of technological innovation for both conventional and future aircraft, implementing effective and globally co-ordinated policies that include carbon pricing and demand management, mobilising substantial and well-directed finance, and ensuring that the transition is environmentally sound and socially equitable. Continued collaboration among governments, industry, finance and research institutions is paramount to navigating this critical transformation.

Demand, use and access

The air passenger market has demonstrated resilience and recent growth. Global revenue passenger-kilometres, a standard measure of passenger traffic, increased 10.4% in 2024 and pushed total traffic 3.8% above the pre-pandemic levels of 2019, indicating a full recovery across all regions (Figure 1)**.**[4]

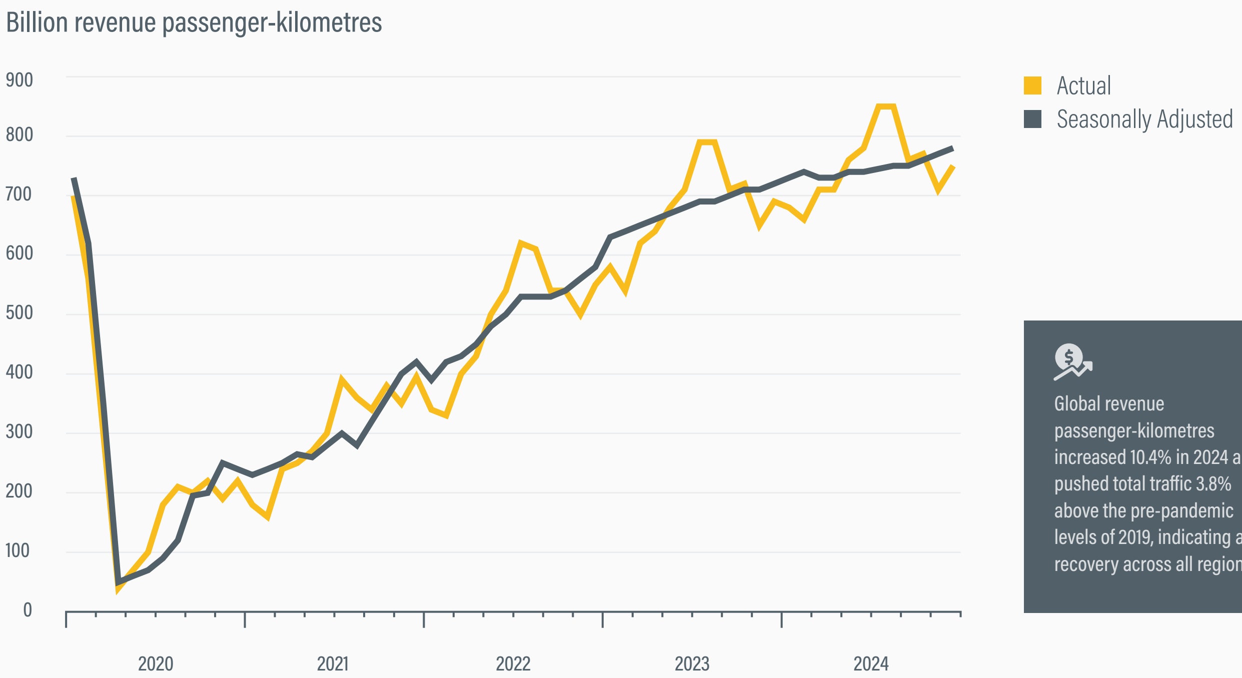
Evidence of strong aviation demand was also reflected in record passenger load factors, as airlines used their capacity more efficiently than ever before to reach new highs both in December 2024 (84.0%) and for the full year (83.5%).[5]

While high load factors are positive from an operational efficiency perspective, efficiency improvements risk being overshadowed by the scale of rising demand, highlighting the core challenge of reducing absolute emissions in a growing market.

International passenger traffic was a major driver of aviation's 2024 recovery, climbing 13.6% despite ongoing geopolitical tensions and airspace restrictions that necessitated adjustments to global networks.[6] **Domestic markets also contributed to the growth, expanding 5.7% globally in 2024.**[7] In the United States, domestic aviation grew 9% in 2023 to a record high of 1.25 billion passenger-kilometres.[8] However, the strong global growth trajectory showed signs of deceleration in 2024 compared to the initial sharp recovery in 2023, settling into rates more aligned with pre-pandemic long-term trends.[9]

Aviation has played a minor role in global freight transport, representing only 1% of the global trade volume and just 0.1% of global freight tonne-kilometres in 2021.[10] **Even so, cargo flights remain a key revenue stream for the airline industry, with commercial airlines making around 5-10% of their total revenue from hauling freight.**[11]

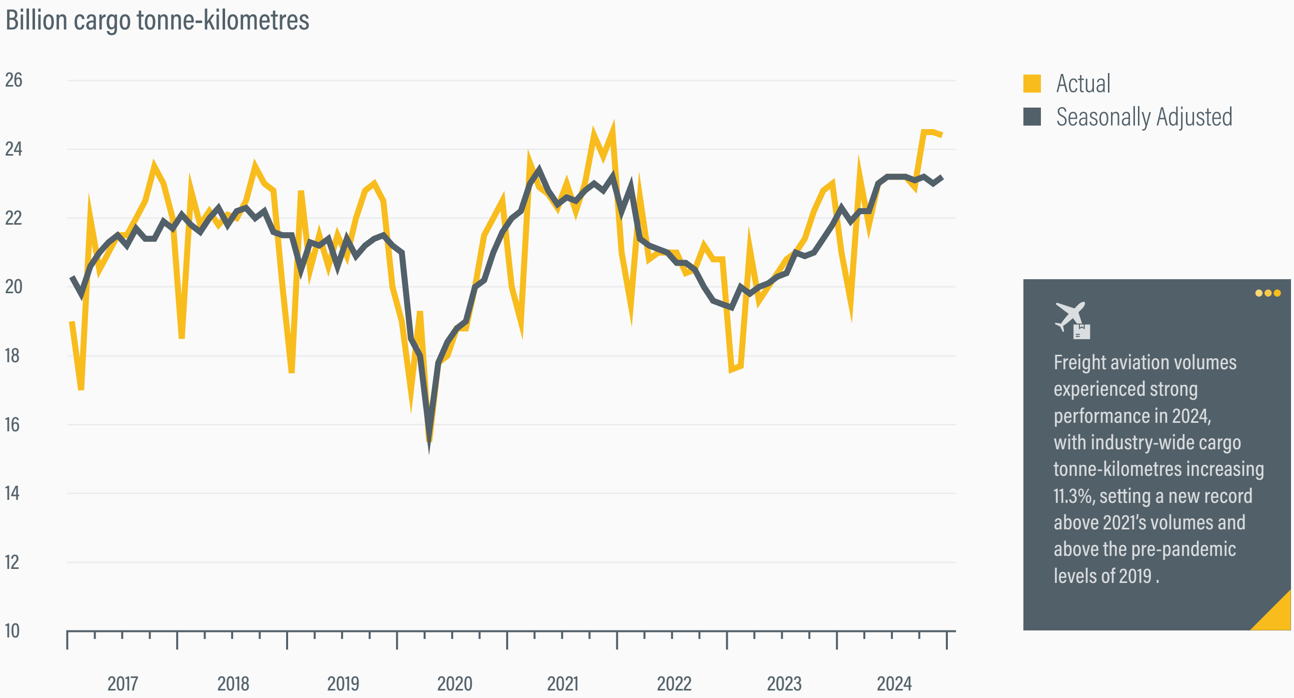
FIGURE 1. Aviation passenger volumes (in billion revenue passenger-kilometres), 2020-2024



Global revenue passenger-kilometres increased 10.4% in 2024 and pushed total traffic 3.8% above the pre-pandemic levels of 2019, indicating a full recovery across all regions.

Source: See endnote 4 for this section.

FIGURE 2. Freight aviation volumes (in billion cargo tonne-kilometres), 2017-2024



Source: See endnote 12 for this section.

Freight aviation volumes experienced strong performance in 2024, with industry-wide cargo tonne-kilometres increasing 11.3%, setting a new record above 2021's volumes and above the pre-pandemic levels of 2019 (Figure 2).[12] **Contributing factors included booming e-commerce demand and continued disruptions in maritime shipping**. However, as with passenger traffic, the momentum in air cargo appeared to slow by the end of 2024.[13]

Available cargo capacity (in tonne-kilometres) also hit a record high in the third quarter of 2024, supporting a rise in cargo load factors.[14] This capacity growth was due mainly to the increased availability of belly-hold space on recovering passenger flights.[15] Global air cargo yields saw their first annual increase since late 2022.[16]

Global aviation's recovery masks significant regional differences in demand growth, with particular dynamism in developing economies. The Asia Pacific region experienced a 16.9% increase in passenger traffic in 2024, driven by strong domestic markets in China and India, but international travel in the region remained below 2019 levels.[17] **Africa ranked second with a 13.2% increase in passenger traffic and notable growth on the Africa-Asia route.**[18]

- Air traffic in the Middle East benefited from airspace restrictions elsewhere in the world (provoked by conflicts), leading to greater traffic on Europe-Asia routes and substantial cargo growth in the region.[19]
- Europe experienced steady passenger growth and strong cargo volumes, while Latin America had moderate passenger growth but significant cargo growth.[20]
- North America had the slowest passenger growth in 2024 but experienced a late-year surge in domestic demand and moderate cargo growth.[21]

Strong passenger growth in Asia Pacific and Africa suggests a potential long-term shift in aviation expansion towards developing and emerging economies. China and India (and Asia Pacific as a whole) are projected to account for nearly half (46%) of the 42,430 new passenger and freighter deliveries in the 2024-2043 period.[22] **This has implications for future global emission trajectories, as these regions generally have lower historical emissions but higher growth potential. It underscores the critical need for globally inclusive and equitable decarbonisation strategies that support sustainable development alongside climate action.**

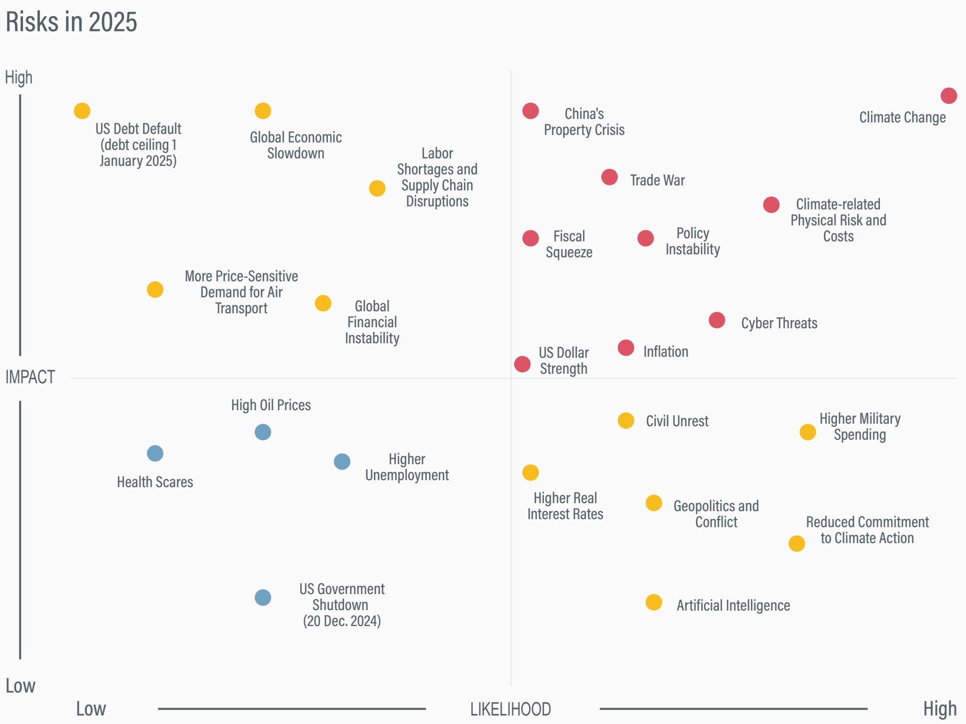
In addition to economic and demographic factors, geopolitical events have influenced regional aviation patterns, posing threats to the stability needed for long-term investments in decarbonisation. Both demand forecasts and effective decarbonisation planning must account for this volatility.[23] **Direct risks to airline operations and demand can stem from policy instability following major elections, potential trade disputes (e.g., US tariffs), a shifting global power balance (potentially leading to more conflict), and even reduced political commitment to climate action** (Figure 3).[24] These factors pose indirect risks to sustainability initiatives by fostering economic (and investment) uncertainty, shifting policy priorities away from climate action and potentially disrupting supply chains for new technologies, critical minerals and sustainable fuels.

- Conflicts leading to airspace restrictions – such as the curtailment of international flights over the Russian Federation following its invasion of Ukraine in 2022 – have directly altered global air traffic patterns, while disrupting others.[25]
- Political tensions, such as between the United States and China, have limited airline capacity on certain routes and impacted the recovery of international travel in regions such as Asia Pacific.[26]

Behavioural factors and consumer preferences are increasingly influencing travel choices, including a potential shift from air travel to high-speed rail for shorter journeys. The resurgence in international travel, particularly from the Asia Pacific region, reflects pent-up demand as travel restrictions related to the COVID-19 pandemic eased. Record-breaking load factors also point to a strong underlying desire to travel. For high-speed rail, evidence of a shift exists on specific routes: in Spain, the decision of airline Vueling to terminate its Madrid-Barcelona flights explicitly cited the growing market share of high-speed rail, which reduced the journey to as little as 2 hours and 30 minutes.[27]

The cost of air travel is a significant factor influencing demand, and decarbonisation efforts are widely expected to exert upward pressure on prices. The deployment of SAF, which currently costs 2-8 times more than conventional fuel, is a primary driver of anticipated cost increases.[28] Modelling of a decarbonisation scenario suggests that higher ticket prices will likely moderate the rise in demand, with passenger growth in Europe expected to fall from a baseline of 2.0% per year to 1.4% per year due to cost impacts.[29]

FIGURE 3. Assessment of potential risks to the global economy that can affect aviation, as of 2025



In addition to economic and demographic factors, geopolitical events have influenced regional aviation patterns, posing threats to the stability needed for long-term investments in decarbonisation. Both demand forecasts and effective decarbonisation planning must account for this volatility. Direct risks to airline operations and demand can stem from policy instability following major elections, potential trade disputes (e.g., US tariffs), a shifting global power balance (potentially leading to more conflict), and even reduced political commitment to climate action.

Source: See endnote 24 for this section.

Sustainability and climate trends

The global transition towards net zero aviation will inevitably have consequences; it is not solely a technical and economic challenge, but also carries significant social and equity implications. These must be carefully managed to ensure fairness and to minimise negative impacts on connectivity (particularly for remote regions or island states), equity in access, and economic growth related to jobs and tourism (Box 1).[30]

In 2024, aviation supported an estimated 11.6 million direct jobs and 20.4 million indirect jobs globally and contributed USD 4.1 trillion (3.9%) to the global gross domestic product (GDP) – reflecting the strong link between economic prosperity and air travel growth.[31] A further 17.2 million jobs were induced by the spending of aviation employees in the wider economy, and aviation also supported 37.3 million jobs through tourism.[32] The sector's extensive supply chain amplifies its impact on job creation worldwide.

- Regional estimates for the Asia Pacific region, based on other methodologies, found that air transport (domestic, regional and international) employed 42 million people in 2023 and contributed USD 890 billion to the region's GDP.[33]
- Air transport in Asia – and related job opportunities – have expanded rapidly driven by rising middle-class demand, low-cost carrier networks and international tourism. (See 3.2 Asia Regional Overview.)

Aviation's role in facilitating global connectivity supports economic growth, enables trade and tourism, fosters international collaboration, and provides access to essential services and humanitarian aid. Overall, the sector supports many of the 17 United Nations Sustainable Development Goals (SDGs), including SDG 8 (Decent Work and Economic Growth) and SDG 17 (Partnerships). Maintaining these positive contributions while mitigating the sector's emissions and supporting climate action (SDG 13) is a key aspect of a sustainable and just transition.

Aircraft manufacturer Airbus explicitly maps its activities to the SDGs, highlighting the contributions of its core business and corporate practices to SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action) and SDG 16 (Peace, Justice and Strong Institutions).[34] The company also supports SDG 4 (Quality Education) and potentially SDG 5 (Gender Equality) through workforce development and outreach programmes.[35]

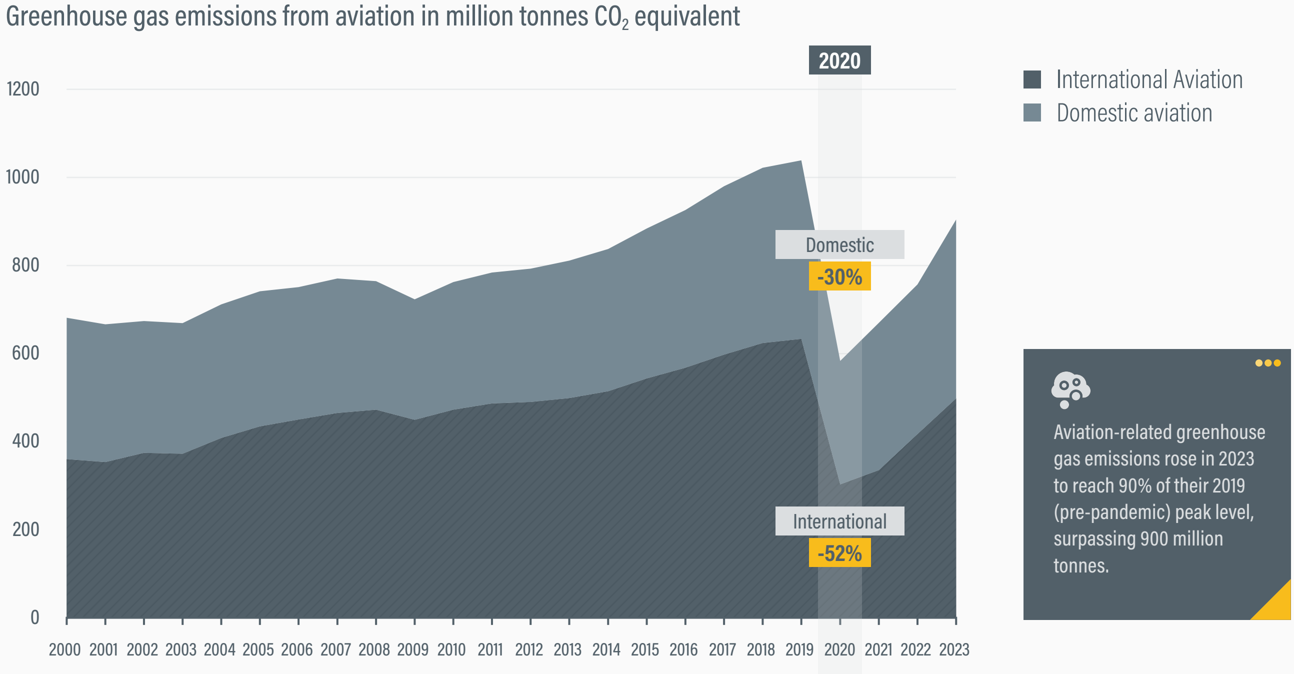
Box 1.
Consequences of the transition to net zero aviation

The transition to net zero aviation will inevitably have consequences, which must be carefully managed to ensure fairness and to minimise negative impacts on connectivity, equity in access and economic growth.

- **Connectivity:** The increased cost associated with decarbonisation measures (especially SAF) may dampen overall growth in aviation demand. However, essential connectivity will need to be preserved, particularly for remote regions or small island developing states (SIDS) that are heavily reliant on air travel. Policies must be designed to support SAF adoption and potentially alternative means of propulsion on essential routes to avoid disproportionately impacting vulnerable communities.
- **Tourism:** Rising air ticket prices could shift tourism patterns, potentially favouring shorter-distance travel or destinations accessible by cleaner modes of transport. This could particularly affect tourism-dependent economies, including SIDS. Potential mitigation strategies include promoting sustainable tourism practices (e.g., longer stays) and accelerating the deployment of clean aviation solutions in these regions.
- **Access (Equity):** The costs of decarbonisation will likely be borne mainly by higher-income frequent flyers who account for most emissions; however, an overall rise in ticket prices could still marginally increase inequality in access to air travel. Policy design, such as progressive taxes (frequent flier levies) rather than flat levies, can help mitigate regressive impacts. The concentration of emissions among a small global elite also raises ethical questions about prioritising decarbonisation pathways.
- **Labour market:** The transition to net zero aviation will likely reshape employment in the sector. Although overall growth in passenger-kilometres might continue, the effects of suppressed demand could lead to fewer direct jobs in traditional airline and airport roles, compared to a baseline scenario. However, the massive scale-up required for SAF production (feedstock sourcing, refining, logistics) is expected to create many new employment opportunities globally, potentially offsetting losses elsewhere. A "just transition" for the workforce is critical and will require pro-active planning, stakeholder collaboration (governments, industry, unions, education providers), investment in reskilling and upskilling programmes, and ensuring decent work standards in emerging green aviation industries. The transition also presents an opportunity to improve gender balance and diversity within the sector.

Source: See endnote 30 for this section.

FIGURE 4. Global aviation emissions (domestic and international), 2000-2023



Source: See endnote 36 for this section.

As both air passenger and air cargo demand recovered in 2023, aviation-related greenhouse gas emissions rose to reach 90% of their 2019 (pre-pandemic) peak level (Figure 4).[36] **Aviation emissions grew in nearly all regions to just over 900 million tonnes of CO_2 equivalent, of which around 10% was from cargo planes.**[37] **International aviation emitted 498 million tonnes of CO_2 equivalent, while domestic aviation contributed 406 million tonnes.**[38] **Aviation's CO_2 equivalent emissions were expected to surpass their 2019 level in 2025.**[39] Historically, the sector's emissions grew 2.2% annually on average between 2000 and 2019, then dropped from more than 1,000 million tonnes in 2019 to less than 600 million tonnes in 2020, in the context of the COVID-19 pandemic.[40]

Aviation contributed only around 2.2% of the total global CO_2 emissions from human activities in 2023; however, the sector's absolute volume of emissions was still substantial.[41] **Between 1990 and 2023, air traffic grew 5% annually on average, while CO_2 emissions from aviation grew 2%, indicating some efficiency gains but still resulting in a net increase in emissions over the period.**[42] **The sector's demand growth rate has outpaced overall emission reductions in many economies.**[43]

- In 2024, rising energy demand, particularly aviation fuel consumption, contributed to an increase in global oil-related CO_2 emissions, even as the overall growth in energy-related CO_2 emissions slowed compared to 2023.[44]

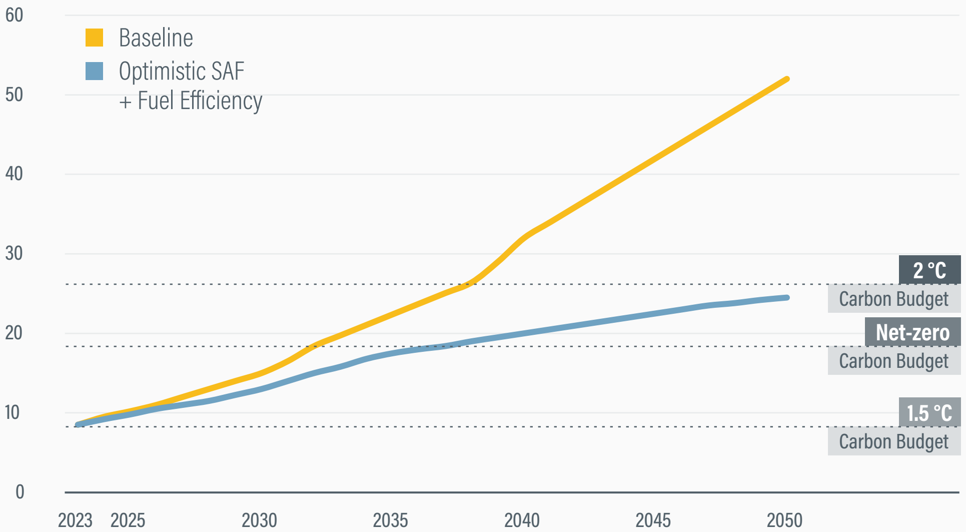
- In the EU, aviation has experienced the fastest emission growth among transport modes in recent decades, contributing 13.9% of the region's transport greenhouse gas emissions in 2022 (the second largest source after road transport).[45] (See 3.3 Europe Regional Overview.)

Around 80% of the CO_2 emissions from aviation originate from flights of more than 1,500 kilometres, distances that generally cannot be substituted by rail.[46] **This has profound implications for decarbonisation strategies and underscores the importance of developing and deploying scalable solutions that can effectively reduce emissions from medium- and long-haul flights; these include primarily SAF, and potentially also future fuel-efficient aircraft and propulsion technologies.** The impact on global aviation emissions of a modal shift from air to high-speed rail appears limited, based on the available information.

The International Civil Aviation Organization (ICAO) has adopted a Long-term Global Aspirational Goal (LTAG) for the international aviation sector of achieving net zero carbon emissions by 2050.[47] **To achieve this goal, the ICAO and its Member States strive to reduce CO_2 emissions in international aviation 5% by 2030 through the use of cleaner fuels such as SAF, without specific obligations or commitments in the form of emission reduction goals attributed to individual members.**[48] Analysis of cumulative emissions reveals the immense scale of the challenge.

FIGURE 5. Consumption of aviation carbon budget from cumulative lifetime emissions of projected fleet

Cumulative lifetime CO_2 emissions in gigatonnes



The aviation sector would need to adhere to stringent carbon budgets to align with the goals of the Paris Agreement to keep global temperature rise below 1.5°C and well below 2°C. As of 2023, the global commercial aviation fleet already in service was set to emit around 9 gigatonnes of CO_2 over its lifetime, or nearly half the indicative carbon budget of 18.4 gigatonnes of CO_2 that is required for the sector to align with a net zero emission pathway. New aircraft delivered from 2024 onwards might exhaust the sector's 1.5°C carbon budget by 2032.

Source: See endnote 50 for this section

The aviation sector would need to adhere to stringent carbon budgets to align with the goals of the Paris Agreement to keep global temperature rise below 1.5°C and well below 2°C.[49] **As of 2023, the global commercial aviation fleet already in service was set to emit around 9 gigatonnes of CO_2 over its lifetime, or nearly half the indicative carbon budget of 18.4 gigatonnes of CO_2 that is required for the sector to align with a net zero emission pathway** (Figure 5).[50] **New aircraft delivered from 2024 onwards might exhaust the sector's 1.5°C carbon budget by 2032.**[51]

- For flights within and departing the EU-27, the United Kingdom, and the European Free Trade Association region, cumulative net aviation CO_2 emissions between 2020 and 2050 would total around 3.3 gigatonnes under the region's proposed net zero pathway.[52] This is 52% below the 6.9 gigatonnes of emissions that would result in a reference scenario without climate action.[53]

Aviation's carbon budget constraints underscore that relying solely on incremental efficiency gains and SAF deployment in conventional aircraft may be insufficient, particularly to achieve the ambitious 1.5°C target. This points to an urgent need either for much sooner and larger-scale deployment of genuinely zero-emission aircraft (powered by hydrogen or electricity), or for the delivery of aircraft from the mid-2030s onwards that operate exclusively on 100% SAF, with extremely low life-cycle emissions.[54]

The risk of remaining dependent on the current (high-carbon) pathway is significant. The continued production and delivery of new aircraft designed primarily for fossil fuels, even if they incorporate efficiency improvements, locks in emissions for decades due to the long operational lifespan of aircraft (20-30 years).[55] This inertia makes the transition progressively harder and increases the likelihood that the sector will need to rely on large-scale, potentially costly, and technologically nascent carbon dioxide removal (CDR) technologies towards 2050 to balance the residual emission budget.[56]

Models of future CO_2 emission trajectories for the aviation sector illustrate the critical levers for decarbonisation, based on varying assumptions about technology, policy and demand.[57] **If current growth trends continue without significant intervention, aviation's CO_2 emissions could potentially triple by 2050.**[58] **The stark contrast between potential net zero pathways and the possibility of emissions tripling highlights the transformative nature of the changes required and the high stakes involved in failing to implement effective mitigation measures.** The divergence across scenarios underscores the high degree of uncertainty about the sector's future emission trajectory.

- The ICAO estimates that in 2050, the residual CO_2 emissions from aviation (i.e., the emissions that remain unabated, even after maximising reduction efforts) could total around 200 million tonnes, a third of the 2019 level

and 87% below the baseline scenario; the reductions are achieved 11% from operations, 21% from aircraft technologies and 55% from fuels.[59]

- The International Energy Agency's (IEA) Net Zero Emissions (NZE) Scenario projects that global aviation CO_2 emissions will peak around 2025 at around 950 million tonnes before falling to 210 million tonnes by 2050.[60] Alongside ongoing efficiency improvements, this large drop relies on factors including constrained demand growth (through policies favouring high-speed rail and curbing business travel), a substantial increase in SAF use (reaching 15% of fuel consumption by 2030) and the introduction of hydrogen-based synthetic fuels (meeting around 30% of fuel demand by 2050).[61]
- The European industry roadmap Destination 2050 (EU+ Focus) outlines a pathway to net zero CO_2 emissions by 2050 for flights within and departing the EU, United Kingdom and European Free Trade Association region. It projects a continuous decline from the emission peak in 2019 (excluding impacts from the COVID-19 pandemic).[62] By 2050, net CO_2 emissions from aviation would fall 90-91%, with the largest contribution (35%) coming from SAF (an 80% fuel share by 2050), followed by aircraft and engine technology (27%), optimised operations (6%) and demand reduction from higher prices; the remaining 10% reduction (around 29 million tonnes) is through carbon removals outside the sector.[63]
- The Air Transport Action Group (ATAG) draws out several scenarios to reach net zero by 2050. Aviation might record around 10 billion passengers per year, flying 22 trillion revenue passenger-kilometres.[64] Aviation emissions would stay at the same levels from 2024 to 2035 and then start declining. [65] Depending on the scenario, technology improvements contribute 12-34% of emission reductions, operational improvements 7-10%, SAF 53-71% and market-based measures 6-8% by 2050.[66]

- The International Council on Clean Transportation's (ICCT) Budget-Based Scenarios, focused on carbon budget alignment, suggest that even optimistic scenarios combining aggressive SAF uptake and efficiency gains struggle to keep the aviation sector within its net zero budget without exhausting it by 2037.[67] To avoid overshooting budgets, this work emphasises the critical need for zero-emission aircraft or 100% low-emission SAF for new deliveries by the mid-2030s.[68]

Operational improvements such as enhancing the efficiency of air traffic management and aircraft operations can yield immediate fuel savings and emission reductions. Collectively, operational efficiencies offer a maximum emission reduction potential of 10%.[69] Initiatives to modernise airspace management include the US Next Generation Air Transportation System (NextGen) and Europe's Single European Sky ATM Research (SESAR).[70] Improving data quality, automation and weather information systems can further enable flight path optimisation and more fuel-efficient routing.

Fleet renewal remains a cornerstone of aviation's decarbonisation strategy. New-generation aircraft delivered by major manufacturers such as Airbus, Boeing, COMAC and Embraer are a reported 20-30% more efficient than the older models they replace.[71] **However, the rate of fuel efficiency improvement (around 1% per year) has stagnated since 2020.**[72] **If all cost-effective technologies are adopted, annual fuel burn reductions of up to 2.2% are technically possible through 2034, although current trends are slower.**[73] The efficiency lull exists in part because manufacturers have focused on refining existing models rather than launching new "clean sheet" designs, which limits incorporation of the latest technologies.[74]

Airlines have invested heavily in new aircraft, with more than 19,360 new planes delivered since 2009 and a production backlog of around 15,700 new-technology aircraft set to enter the fleet from 2023 onwards.[75] **The combination of new technology, operational efficiencies and infrastructure improvements avoided an estimated 14.6 billion tonnes of CO_2 between 1990 and 2023, according to industry sources.**[76]

Research and development continue to target further incremental improvements. Disruptive technologies such as battery electric and hydrogen propulsion hold promise for zero-emission flight but face large hurdles to widespread adoption by 2050, with commercial deployment not expected before the late 2030s.[77] **Their contribution to overall aviation fuel consumption and emission reduction**

TABLE 1. Estimates of future sustainable aviation fuel capacity

Source	Description	SAF production estimate
ICAO	SAF capacity from 67 facilities already operational or under construction	13.9 million tonnes
SkyNRG	SAF-specific capacity	17.3 million tonnes by 2030
ATAG	Realistic SAF production	17-20 million tonnes by 2030
IATA	Identified SAF capability from 158 projects across 37 countries that aim to be operational by 2030	51 million tonnes of *renewable fuel* capacity by 2030 (implying that not all will produce SAF)

Source: See endnote 92 for this section.

by 2050 is projected to be limited in most scenarios.[78] This is because of challenges related to energy density, range, payload capacity, infrastructure requirements, and the long timelines for aircraft development, certification and fleet turnover.

- The IEA's NZE scenario projects that these disruptive technologies would reduce fuel consumption less than 2% by 2050, while the EU's Destination 2050 roadmap models show hydrogen resulting in a 4% CO_2 reduction.[79]
- Airbus is pursuing its ZEROe hydrogen aircraft concept and is advancing key technologies for next-generation single-aisle aircraft.[80]
- Embraer is developing its Energia family of aircraft exploring electric/hybrid options.[81]
- The US space agency NASA and the Federal Aviation Administration are supporting exploratory research, and the International Air Transport Association (IATA) tracks numerous innovative concepts.[82]

In a critical timing gap, incremental efficiency improvements in conventional aircraft appear insufficient on their own to meet stringent climate budgets, especially given recent stagnation. Yet the transformative technologies (hydrogen/electric) needed for deeper cuts face substantial barriers to deployment by 2050, according to most projections.[83] This reinforces the importance of SAF, which is widely regarded as the most significant near- to medium-term solution for decarbonising aviation, offering a "drop-in" replacement for conventional jet fuel with substantially lower life-cycle emissions (see 5.1 Transport Energy Sources).

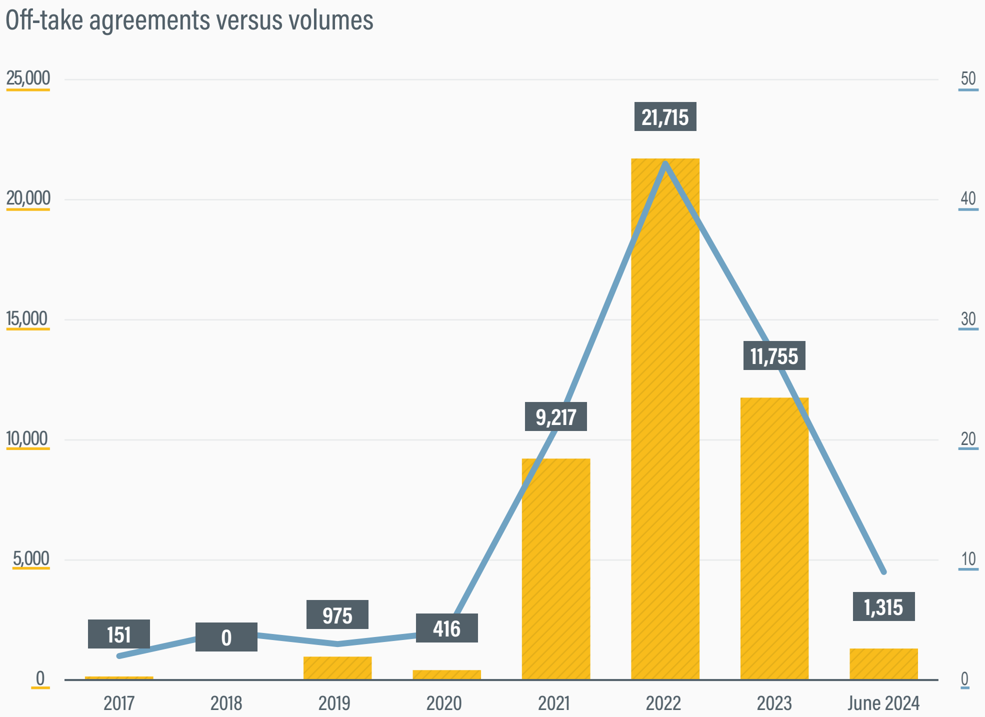
Global SAF production more than doubled in 2024 to 1 million tonnes (1.3 billion litres) – up from around 0.5 million tonnes (600 million litres) in 2023 – and is projected to double again to 2.1 million tonnes (2.7 billion litres) in 2025 (albeit starting from a very low base).[84] SAF is widely regarded as the most significant near- to medium-term solution for decarbonising aviation, offering a "drop-in" replacement for conventional jet fuel with substantially lower life-cycle emissions (see 5.1 Transport Energy Sources). Tracking its production is key to assessing progress (e.g., through ICAO's Cleaner Energy Tracker Tools).[85]

Despite this rapid growth, SAF's share of total aviation fuel consumption was only around 0.15% in 2023, rising to 0.3% in 2024 and a projected 0.7% in 2025.[86] The industry needs to bridge a vast gap to meet agreed targets such as the ICAO's collective aspirational vision of a 5% reduction in CO_2 emissions through cleaner energy by 2030, the EU's mandated 6% SAF share by 2030, and the United Kingdom's 10% SAF mandate by 2030.[87] Tracking SAF production is key to assessing progress (for example, through the ICAO's Cleaner Energy Tracker Tools).[88]

- In the United States, domestic SAF consumption grew from 5 million gallons in 2021 to 26 million gallons in 2023, with 93 million gallons produced or imported through September 2024.[89]
- In the EU, the market in 2023 was dominated by SAF produced via the hydrotreated esters and fatty acids (HEFA) pathway.[90]
- Announced EU SAF production capacity could reach 3.2 million tonnes by 2030 (realistic scenario), sufficient to meet the overall 6% mandate in ReFuelEU, although significant progress is needed on e-SAF (synthetic fuel) projects to meet the specific sub-mandate.[91]

Globally, the pipeline of SAF projects is expanding. However, projections for actual global SAF production capacity by 2030 vary considerably (Table 1), reflecting significant uncertainty.[92] Estimates of future SAF supply are influenced by factors such as policy realisation, final investment decisions, feedstock availability, technological progress, and competition with other sectors such as road transport or shipping for similar

FIGURE 6. Off-take agreements for sustainable aviation fuel, 2017-2024



Globally, the pipeline of SAF projects is expanding. However, off-takers (such as airlines) often prefer shorter-term contracts due to price and volume uncertainties. This mismatch contributed to a slowdown in off-take agreement announcements in 2023/2024 after a peak in 2022.

(See 5.1 Transport Energy Sources for more on SAF, covering life-cycle assessments, greenhouse gas emission thresholds and costs.)

Source: See endnote 95 for this section.

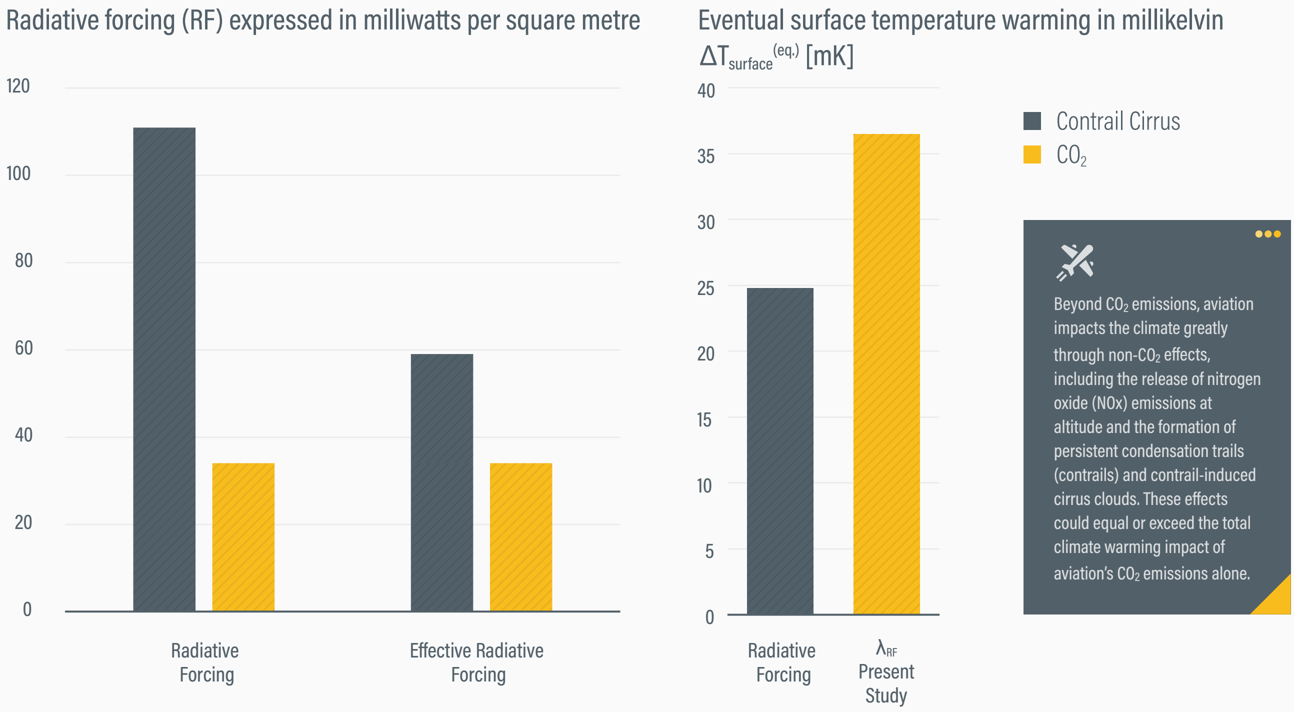
feedstocks and production capacity.

Scaling SAF production from less than 1% of current fuel use to the levels required by targets for 2050 represents a monumental undertaking fraught with challenges. Bridging the gap requires mobilising an estimated USD 1.5 trillion in capital investment over 30 years.[93] For perspective, overall industry revenue in 2023 was an estimated USD 908 billion, with a net post-tax profit of USD 27.4 billion.[94]

Demand signals for SAF have arisen from policy mandates in the EU and the United Kingdom, goals in the United States, and growing voluntary commitments from airlines. Yet securing the necessary long-term off-take agreements remains a hurdle. SAF producers typically require bankable contracts of 10 or more years to secure financing for new plants. However, off-takers (such as airlines) often prefer shorter-term contracts due to price and volume uncertainties. This mismatch contributed to a slowdown in off-take agreement announcements in 2023/2024 after a peak in 2022 (Figure 6).[95]

Beyond CO_2 emissions, aviation impacts the climate greatly through non-CO_2 effects, including the release of nitrogen oxide (NO_x) emissions at altitude and the formation of persistent condensation trails (contrails) and

FIGURE 7. Estimation of the contrail cirrus climate impact on global surface temperature



Source: See endnote 96 for this section.

contrail-induced cirrus clouds. These effects could equal or exceed the total climate warming impact of aviation's CO_2 emissions alone (Figure 7).[96] Research efforts are under way to better understand and mitigate non-CO_2 effects.

- Airbus is involved in projects such as CICONIA, GEESE, and VOLCAN, partly funded by the EU, to study and address non-CO_2 emissions from aviation.[97]
- The US Aviation Climate Action Plan includes specific actions to improve the scientific understanding of non-CO_2 impacts (particularly aviation-induced cloudiness, or AIC) and to develop decision support tools and a research roadmap for mitigation.[98]

Despite the growing recognition of non-CO_2 effects and the initiation of monitoring requirements, the implementation of large-scale trials and mitigation strategies to address these effects appears less advanced compared to measures targeting CO_2.[99] Translating this into effective, globally co-ordinated mitigation action remains a key challenge and opportunity for the coming years, provided uncertainties related to ice super-saturated regions to avoid are properly quantified.[100] Data are lacking on the widespread implementation or regulatory status of operational measures such as flight rerouting to avoid contrail-prone atmospheric regions, and on changes in fuel composition (potentially a co-benefit of certain SAF with lower aromatic content).[101]

In addition to mitigating its own climate impact, the aviation sector must adapt to the unavoidable consequences of climate change already under way, including increasing disruptions from more frequent and intense extreme weather events. Initiatives are emerging to study these impacts and to develop adaptation strategies.[102] In Europe, the physical risks facing aviation infrastructure and operations include increased temperatures (leading to reduced aircraft performance, heat damage to pavements, increased demand for cooling, and heat stress for personnel/passengers); changes in storms and precipitation (causing operational disruptions such as delays, cancellations and diversions); flooding of airfields and infrastructure; damage from wind and lightning; disruption to ground access; and sea-level rise (threatening coastal airports with inundation and loss of capacity).[103] Additional impacts include changes in wind patterns (affecting routes and turbulence), shifts in biodiversity (such as increased risk of bird strikes), changes in icing conditions and potential desertification effects.[104]

Policy and investment developments

In 2022, the ICAO Assembly adopted its Long-Term Aspirational Goal (LTAG) for international aviation to achieve net zero carbon emissions by 2050.[105] This global goal signals a collective ambition to align the sector with the global warming targets of the Paris Agreement, although it is not binding on individual member states. The ICAO provides the primary platform for co-ordinating global action on the aviation sector's efforts to address climate change. Although the LTAG has global application, initial participation is explicitly non-binding on individual ICAO members (whereas the net-zero regulations recently adopted by the International Maritime Organization also apply worldwide but are mandatory across the industry sector from October 2025).[106]

To support the LTAG, in November 2023 the third ICAO Conference on Aviation and Alternative Fuels adopted the "ICAO Global Framework for Sustainable Aviation Fuels (SAF), Lower Carbon Aviation Fuels (LCAF) and other Aviation Cleaner Energies".[107] The Framework includes a collective global aspirational vision to reduce CO_2 emissions in international aviation 5% by 2030 through the use of cleaner energy sources, compared to a baseline that assumes zero use of cleaner energy.[108] This framework outlines a comprehensive strategy, emphasising that cleaner energy sources such as SAF are expected to make the largest contribution to CO_2 reductions by 2050. It's four building blocks are: policy and planning, regulatory framework, implementation support and financing.[109]

- *Policy and planning:* Encouraging member states to develop supportive national policies and roadmaps (reflected in State Action Plans), guided by principles such as flexibility, feasibility and avoiding market distortions.
- *Regulatory framework:* Recognising the use of the CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) sustainability criteria and methodologies as the basis for SAF/LCAF eligibility, enhancing certification schemes, accelerating fuel standards development and ensuring robust accounting to avoid double counting.
- *Implementation support:* Establishing a substantial capacity building programme, particularly for developing countries (aligned with the "No Country Left Behind" initiative), facilitating technology transfer and co-ordinating support efforts.
- *Financing:* Recognising the massive investment required (up to an estimated USD 3.2 trillion for cleaner fuel production alone by 2050), facilitating access to public and private finance (especially for low-and-middle income countries), establishing the ICAO Finvest Hub and exploring a dedicated climate finance initiative or funding mechanism under the ICAO.[110]

Although the ICAO framework represents important progress in building global consensus and providing guidance, its effectiveness relies heavily on voluntary implementation by member states, and its aspirational nature and 5% vision for 2030 contrast with legally binding mandates adopted at the regional or national levels. This highlights the inherent challenge of achieving globally harmonised and sufficiently ambitious action

through international agreements alone. Nonetheless, the framework's strong emphasis on facilitating finance, particularly for developing countries, signals a crucial recognition that addressing the investment gap is a core pillar of the global strategy. Positive developments since the LTAG include the ICAO Cleaner Energy Tracker Tools' announcement of prospects for increased SAF production capacity (see earlier section on Sustainability and climate trends).

The EU has taken a leading role in translating international goals into binding regional legislation with its landmark ReFuelEU Aviation regulation, in effect since January 2025 and part of the "Fit for 55" climate package. The regulation sets legally binding minimum shares of SAF that must be blended into aviation fuel supplied at EU airports, starting at 2% in 2025 and rising to 6% in 2030, 20% in 2035 and 70% by 2050.[111] ReFuelEU creates the world's largest mandated market for SAF and provides a strong, long-term demand signal intended to drive investment in production, particularly within the EU; however, implementation challenges remain due to the high costs. Within the overall SAF share, a specific, escalating sub-mandate for e-SAF aims to accelerate the development and deployment of this advanced, potentially highly sustainable pathway; it starts at an average of 1.2% for 2030-2031, rising to 5% in 2035 and 35% by 2050.[112] (See 5.1 Transport Energy Sources for national-level efforts on SAF.)

As of early 2025, the United States was pursuing its 2050 net zero goal for aviation primarily through incentives, research, and public-private partnerships, as outlined in the updated 2024 US Aviation Climate Action Plan.[113] The centrepiece of the US SAF strategy is the SAF Grand Challenge, setting ambitious production goals of 3 billion gallons (11.4 billion litres) by 2030 and 35 billion gallons (132.5 billion litres) by 2050, intended to meet 100% domestic demand. [114] By September 2024, domestic SAF production and imports had reached 93 million gallons, with the potential for 2.6 billion to 4.9 billion gallons annually by 2030 based on active projects. [115] The initial funding of the SAF Grand Challenge was made available through the US Inflation Reduction Act.[116]

In January 2025, the incoming Trump administration halted the disbursements of funds to the implementation of 2024 US Aviation Climate Action Plan through an executive order.[117] In July 2025, the so-called One Big Beautiful Bill Act reduced SAF production incentives from USD 1.75 per gallon to USD 1 per gallon.[118] The bill reinforced crop-based production using corn and soybeans, resulting in increases of food prices and emissions from land use.[119]

The 2024 US Aviation Climate Action Plan also includes significant investment in R&D of aircraft and engine technology – such as NASA's Sustainable Flight National Partnership and the Federal Aviation Administration's Continuous Lower Energy, Emissions and Noise (CLEEN) Program – as well as operational improvements through air traffic management modernisation (NextGen, Trajectory-Based Operations).[120] In addition, the Plan highlights US international leadership within the ICAO, airport emission reduction initiatives, and research into non-CO_2 impacts and carbon removals.[121]

The US approach contrasts with the mandate-led strategies in the EU and United Kingdom by relying more heavily on financial incentives and technological push. Its success hinges on the effectiveness and longevity of these incentives in driving sufficient private investment and ensuring the sustainability of the resulting SAF production. The emphasis on "whole-of-government" co-ordination across multiple agencies is a key strength, enabling a multi-faceted approach to the complex challenges involved.

Increasingly, policy focus globally has expanded to include the impacts of non-CO_2 emissions. Starting in January 2025, aircraft operators under the EU Emissions Trading Scheme will be required to monitor and report the non-CO_2 climate impacts of their flights (initially those within the European Economic Area, Switzerland and the United Kingdom).[122] This monitoring, reporting and verification (MRV) system will use dedicated information technology tools, such as the European Commission's NEATS system, to calculate a CO_2 equivalent value per flight based on factors such as flight trajectory, weather conditions and aircraft/engine properties.[123]

Some European countries have implemented or considered demand-side measures that restrict short-haul flights where viable transport alternatives exist. In France, a 2022 law prohibits domestic flights on routes where a direct train journey of less than 2 hours and 30 minutes is available.[124] Policy analysis has explored extending this ban to routes with train alternatives under five hours, which could greatly increase the number of affected routes and potential emission savings.[125] However, critics argue that airlines may simply reallocate the freed-up slots to longer, potentially more carbon-intensive international flights; thus, short-haul bans should be implemented alongside broader measures that address potential rebound effects or emission leakage.[126]

Although the adoption of SAF and other decarbonisation technologies is expected to increase the cost of flying, it also serves as a key mechanism for moderating the growth in aviation demand. As of 2018, demand from 1% of the world's population produced 50% of aviation emissions, while around 80% of people had never set foot on a plane.[127] Research from 2022 found that, globally, the wealthiest 5% people accounted for 55% of aviation activity and emissions.[128] However, the impact of increased

flying costs will vary across regions and socio-economic groups.[129] **Addressing these distributional effects is crucial to maintain public support and ensure that the transition is perceived as fair.**[130]

Policies aimed at mitigating these impacts could include targeted subsidies for essential routes, progressive taxation schemes that shield infrequent flyers, and using the revenue from aviation taxes to support lower-income groups or invest in alternative transport infrastructure. In western Europe, the highest-income households (over USD 103,505 or EUR 100,000 per year) are at least six times more likely to take three or more return flights per year than those on the lowest incomes (under USD 20,701 or EUR 20,000 per year).[131] Among the lowest-income group in western Europe, nearly 70% of households do not fly in any given year, compared with just over 20% among the highest-income households.[132]

Some countries are applying the "polluter pays" principle more directly to aviation through taxes and levies, including aviation fuel taxes, national ticket taxes, frequent flyer levies and international solidarity levies to internalise the environmental costs of flying, moderate demand and generate revenue to fund climate mitigation or cleaner technologies such as SAF.[133] Growing consideration of direct pricing mechanisms indicates a potential shift towards making passengers and airlines bear a greater share of the climate cost of aviation, with the aim of ensuring a just transition.[134]

With a small percentage of the population accounting for a large share of flights and emissions, frequent flier levies are seen as an equitable tool targeting those who fly most frequently and often furthest (typically, higher-income individuals).[135] **This contrasts with the potentially regressive impact of flat taxes or general price increases resulting from SAF adoption, which could disproportionately affect those who rely on flying for essential connectivity.**[136]

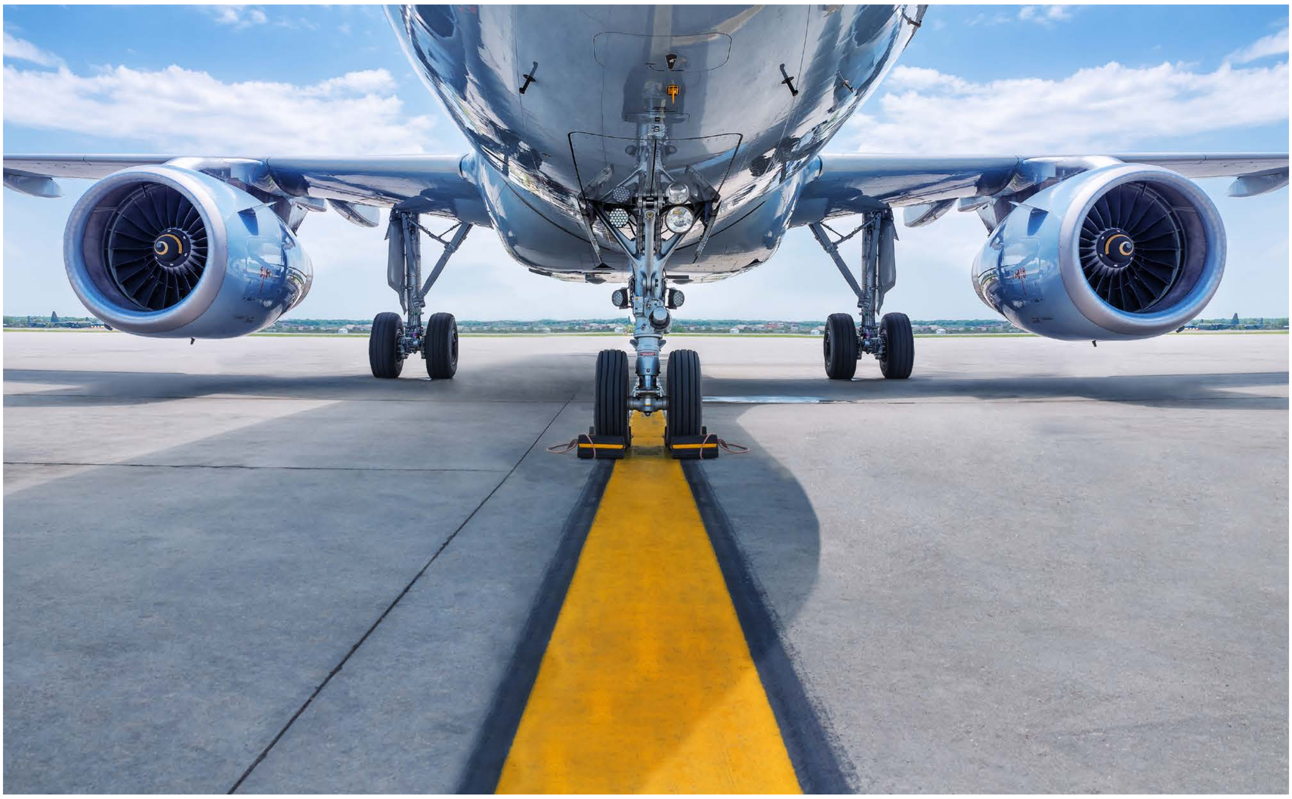
- Ticket taxes such as France's "Taxe Chirac", the UK Air Passenger Duty and a Dutch ticket tax have been implemented and legally upheld against challenges based on international agreements such as the Chicago Convention.[137]
- Proposals in France aim to revamp the ticket tax, making it progressive based on distance and class, potentially reducing emissions 7.5% and generating substantial revenue of USD 3.8 billion (EUR 3.7 billion).[138] The proposed 'grands voyageurs' (i.e., frequent traveller tax) involves a progressive tax increasing with the number of flights taken annually, projected to cut emissions 13.1% and to raise USD 2.55 billion (EUR 2.46 billion).[139]
- The Global Solidarity Levies Task Force is co-ordinating growing international momentum to implement levies on aviation (either fuel or tickets, potentially frequent flier levies) to generate predictable funding – estimated at USD 6.2 billion to USD 20.7 billion (EUR 6-20 billion) annually) for climate adaptation and mitigation in vulnerable countries.[140]

Despite the substantial revenue potential of taxes and levies, which could be channelled towards climate finance or subsidising SAF, significant implementation hurdles remain. These include persistent legal complexities surrounding fuel tax exemptions (despite arguments for their permissibility) and the challenge of international co-ordination for global levies. While recognising the need to support the reduction and stabilisation of CO_2 emissions from all sources, ICAO and its Member States have expressed concern on the use of international aviation as a potential source for the mobilisation of revenue for climate finance to other sectors, in order to ensure that international aviation would not be targeted in a disproportionate manner.[141]

As of December 2023, within the broad "transport services" sector, 337 companies globally had validated targets for emission reductions under the Science Based Targets initiative (SBTi), which provides a framework for companies to set emission reduction targets aligned with climate science.[142] The SBTi published an "Interim 1.5°C Aviation Pathway" in February 2023, enabling airlines and potentially other companies in the sector to set science-based net zero targets.[143] However, the exact number of aviation companies with validated targets under this pathway is not specified.

- The SBTi Corporate Net-Zero Standard (CNZS) is under revision, with potentially significant changes introduced for target setting for Scope 3 emissions, clearer integration of carbon removals, as well as reporting on progress in achieving targets.[144] The revision will be crucial for the SBTi to remain one of the most widely recognised standards and a reference for companies to set science-based targets.
- A separate assessment noted that more than three-quarters of the world's 20 largest airlines have now established public targets for SAF uptake.[145]

In July 2024, Air New Zealand, only the second carrier globally to have its targets validated under the SBTi aviation framework, abandoned its SBTi-validated goal to reduce its carbon intensity 28.9% below 2019 levels by 2030 (including a 16.3% cut in absolute emissions).[146] **Although the carrier reaffirmed its long-term goal of net zero emissions by 2050, its decision to abandon the 2030 goal underscores the practical difficulties the industry faces in delivering deep emissions cuts in the near term, given**



the state of technology deployment, fuel supply chains and enabling policies. Stated reasons for Air New Zealand's shift included delays in the delivery of new, more fuel-efficient aircraft due to global manufacturing issues; the prohibitive cost and insufficient availability of SAF; and challenging policy settings.[147] Other airlines may similarly question their ambitious 2030 targets if the necessary conditions for success do not materialise rapidly.

Major aircraft manufacturers play a pivotal role in decarbonisation through the development and delivery of more efficient aircraft and enabling the use of future fuels. Their strategies and targets reflect the key technological pathways being pursued.

- Airbus is focused on improving its fleet efficiency (around a 25% gain in the latest generation), achieving 100% SAF capability by 2030 and advancing key technologies for next-generation aircraft.[148] It researches non-CO_2 impacts and invests in carbon removals. Airbus has SBTi-validated targets, including a 63% absolute reduction in operational (Scope 1 & 2) emissions by 2030 and a 46% reduction in the emissions intensity (Scope 3) of its commercial aircraft in service by 2035.[149] The company links its activities to contributing to various UN SDGs.[150]
- Through its "Cascade Climate Impact Model", Boeing is prioritising fleet renewal (newest jets 20-30% more efficient), operational efficiency improvements (working with airlines and air traffic management providers), SAF enablement (targeting 100% compatibility by 2030, investing in testing, and partnering on production) and advancing future technologies.[151] Key technology projects include the Transonic Truss-Braced Wing (TTBW) demonstrator with NASA.[152]
- Embraer aims for carbon neutrality in its operations (Scope 1 & 2) by 2040 (including 100% renewable energy use by 2030) and supports the industry goal of net zero aviation by 2050.[153] Its strategy focuses on improving the efficiency of aircraft (the E2 family offers around a 25% improvement), achieving 100% SAF compatibility and developing electric/hybrid propulsion (Energia family concepts).[154]
- As a state-owned enterprise, COMAC's approach reflects the Chinese government's emphasis on balancing economic growth with environmental responsibility. The company is focused on developing more fuel-efficient aircraft and increasing the adoption of SAF. Additionally, COMAC is investing in R&D for next-generation technologies, in line with China's strategic focus on innovation and technological self-sufficiency.[155]

A clear convergence exists among major aircraft manufacturers on the core technological levers for decarbonising aviation, which provides a degree of confidence for technological development. These levers are: enhancing conventional aircraft efficiency, enabling universal SAF use in the near term, and investing in R&D

for potentially transformative hydrogen and/or electric propulsion for the longer term.

However, the primary climate impact of aircraft manufacturers lies not in their own operations (Scope 1 & 2 emissions) but in the emissions generated by the aircraft they sell, throughout their decades-long service lives (Scope 3 emissions). **Ensuring that all manufacturers accept their life-cycle responsibility and set ambitious targets covering the in-use emissions of the aircraft they sell is critical for driving progress. Airbus' adoption of a specific Scope 3 intensity reduction target reflects an important signal.**[156]

There are two main carbon market schemes in the aviation sector: the EU Emissions Trading System (ETS) and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). To avoid double-claiming benefits under the different schemes, airlines must carefully account for SAF use.[157]

- The EU ETS' cap-and-trade system applies to flights within the European Economic Area.[158] It sets a declining cap on emissions, and operators must surrender allowances to cover their verified emissions. Recent revisions have strengthened the system, phasing out free allowances for aviation by 2027 to increase the sector's contribution to EU climate goals. The EU ETS is also expanding its scope to include monitoring and reporting of non-CO_2 climate effects, starting in 2025.[159] Revenues generated or allowances saved through SAF use can potentially support further decarbonisation.
- CORSIA is the ICAO's global market-based measure to address CO_2 emissions from international flights above a defined baseline, with the goal of achieving carbon-neutral growth.[160] Airlines operating international flights between participating states can offset any emissions exceeding this baseline by purchasing and cancelling CORSIA Eligible Emissions Units (EEUs) generated from approved carbon reduction projects elsewhere.[161] As of autumn 2024, global emissions had reportedly not yet reached the threshold triggering offsetting obligations under CORSIA.[162] From 2024 to 2035, the baseline is set at 85% of 2019 emission levels, and the scheme is expected to mitigate between 1.2 billion and 2 billion tonnes of CO_2 during this period.[163] Participating in CORSIA remains voluntary until 2027.[164]

This fragmentation of carbon reduction efforts for aviation, lacking a single, globally consistent carbon price signal, potentially leads to compliance complexities and competitive distortions. The EU ETS and CORSIA interact: the EU uses ETS rules to implement CORSIA obligations for extra-EEA flights operated by EU-based airlines. The EU ETS covers intra-EEA flights, whereas CORSIA targets the growth in international emissions (but has yet to require offsetting); various national taxes or levies add another layer.

The environmental integrity of CORSIA, as an offset-based mechanism, depends critically on the quality of the EEUs and the robust implementation of accounting rules under Article 6 of the Paris Agreement by host countries providing the offsets. This involves rigorous processes for authorisation, tracking, reporting and applying "corresponding adjustments" to national emission inventories to prevent double counting of emission reductions.[165] Ensuring this integrity across numerous countries with varying capacities is an ongoing governance challenge for the ICAO and the international climate regime, also requiring co-ordination between the ICAO and the UN Framework Convention on Climate Change. With the progress made on Article 6 at the 2024 UN Climate Change Conference in Azerbaijan (COP 29) and the existence of stringent CORSIA Emissions Units Eligibility Criteria as approved by the ICAO Council, governments hosting activities that generate EEUs now have the guidelines they need to authorise the use of these units under CORSIA.[166]

Financial support mechanisms are crucial enablers of the SAF transition, given the high cost of the fuels and the significant investment risks associated with developing new technologies and production facilities.

- For risk mitigation, access to low-interest loans and loan guarantees from public finance institutions (such as the European Investment Bank or national development banks) and export credit agencies is seen as vital, particularly for first-of-a-kind projects.[167]
- To support market aggregation and facilitation, concepts such as Green Market Makers, potentially using blended finance (public/private capital), aim to bridge the price gap, provide liquidity, absorb risk and facilitate off-take agreements. Demand pooling instruments have also been proposed.[168]
- Efforts are under way to improve access to international climate finance, especially for low- and middle-income countries. The ICAO Finvest Hub aims to improve access to international climate finance for aviation decarbonisation, particularly for low- and middle-income countries, by connecting countries and project developers with funding opportunities, whereas and proposals for Global Solidarity Levies target high-emitting sectors (e.g., aviation) for climate and development financing to other sectors.[169]

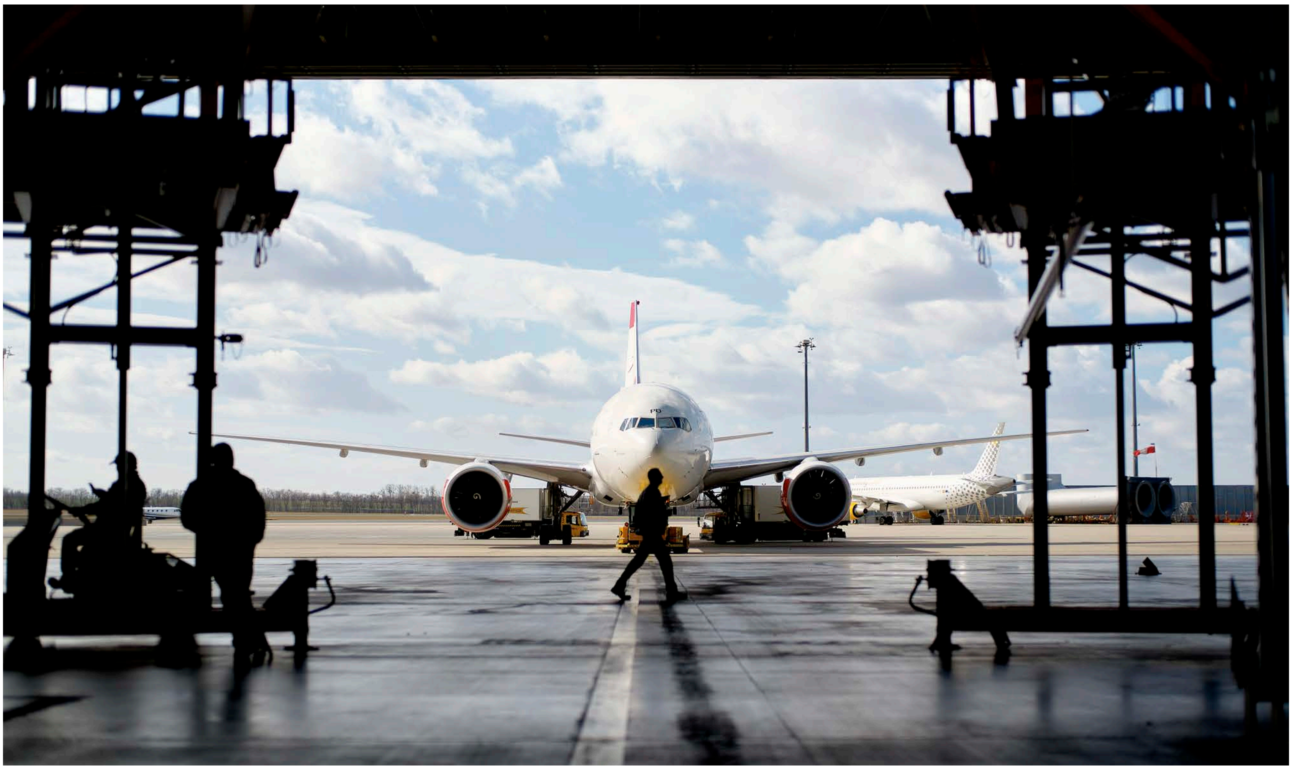
The policy landscape appears to be evolving beyond traditional R&D support towards more sophisticated financial instruments designed specifically to de-risk commercial-scale investment. This reflects a growing understanding that bridging the commercialisation "valley of death" for advanced fuels and technologies is now a primary bottleneck. However, the sheer scale of investment required globally suggests that no single funding source will be sufficient. Effectively financing the transition will likely necessitate a co-ordinated blend of public funding, private capital, innovative financing mechanisms, and potentially dedicated international climate finance, requiring careful orchestration among diverse actors.

Although the primary focus of aviation decarbonisation is on avoiding and reducing emissions at the source, there is growing recognition of the potential role of carbon dioxide removal (CDR) in addressing the residual emissions that remain after maximising reduction efforts. CDR activities remove CO_2 from the atmosphere and durably store it in geological, terrestrial, or ocean reservoirs, or in products. It is distinct from carbon capture and storage (CCS) from fossil fuel point sources, and from carbon offsetting that typically involves funding emission reductions elsewhere. CDR is primarily considered a means to neutralise the residual emissions that might come from legacy aircraft still in operation or from specific flight operations where SAF or low-emission aircraft are not yet feasible, or that could persist if the deployment of primary mitigation measures falls short of expectations.

- The Destination 2050 roadmap for European aviation relies on CDR – specifically direct air carbon capture and storage (DACCS) – to achieve net zero emissions by 2050, modelling it to address the final 10% (around 29 million tonnes) of emissions.[170]
- The ICCT's carbon budget analysis suggests that without a rapid shift to zero-emission aircraft or 100% low-emission SAF, substantial amounts of CDR (potentially tens of billions of tonnes via direct air capture, or DAC) would be required to offset the committed emissions from conventional aircraft delivered in the coming decades.[171]
- The US Aviation Climate Action Plan acknowledges the potential need for robust out-of-sector measures, including CDR, to close any remaining emission gap, and mentions US government support for R&D of CDR (for example, through the Department of Energy's Carbon Negative Shot).[172]
- Airbus has indicated investment in DAC technology and agreements for purchasing carbon removal credits, positioning it as part of the company's broader decarbonisation toolkit.[173]

CDR should ideally be viewed as a complementary measure for genuinely hard-to-abate residual emissions, and not as a substitute for prioritising direct emission avoidance and reduction through efficiency improvements, SAF deployment, operational optimisation and the development of zero-emission aircraft technologies. Over-reliance on future CDR carries risks related to cost, scalability, technological maturity, permanence of storage and potential environmental side effects.

High-quality CDR offers an alternative pathway for companies or the aviation sector to achieve net zero emission targets



compared to traditional carbon offsetting programmes, which have faced increasing scrutiny regarding their environmental integrity, additionality and potential for double counting. Investing in verified CDR that demonstrably removes atmospheric CO_2 provides a more direct way to counterbalance residual emissions than relying on potentially less credible offset credits.

The decarbonisation of aviation is not an isolated challenge but is deeply intertwined with broader energy systems and requires unprecedented levels of collaboration across multiple stakeholder groups. No single entity – be it a government, a company or an industry body – possesses all the levers, resources or expertise required. Progress necessitates co-ordinated action, information sharing, and alignment of strategies and investments across this diverse ecosystem.

This includes:

- Cross-governmental co-ordination among different government departments (transport, energy, environment, finance, agriculture) at the national level and co-operation among countries internationally.
- Cross-value chain collaboration among airlines, aircraft and engine manufacturers, fuel producers and suppliers, airports, technology providers, and the finance sector, to align efforts along the value chain.
- Cross-industry dialogue among potential competitors to access renewable resources, to ensure that the global optimum of resource allocation is reached.[174]
- Formal and informal public-private partnerships between government bodies and private industry, which are crucial for R&D, infrastructure development and policy implementation.
- Collaboration with academia and research centres for innovation and independent analysis.

This need for collaboration stems from the sheer complexity of the transition. Developing and scaling SAF involves agriculture, waste management, chemical processing, energy production and logistics. Developing new aircraft involves advanced materials, propulsion physics and complex systems integration. Optimising operations requires co-ordination among airlines, airports and air navigation service providers. Financing the transition requires alignment among project developers, governments, and public and private financial institutions. Furthermore, aviation's decarbonisation is inextricably linked to the broader global energy transition, particularly the scale-up of renewable electricity and green hydrogen needed for e-fuels, requiring integrated planning across sectors.

Collaboration also faces challenges, as different stakeholders have varying, sometimes conflicting, interests. Fuel producers may desire long-term off-take certainty, while airlines might prefer shorter-term flexibility. Competition for limited resources such as sustainable feedstocks or renewable energy can create tensions among companies or even sectors. Differing views on the optimal policy mix (e.g., mandates versus incentives) also exist. Successful collaboration requires not only a willingness to work together but also effective mechanisms for dialogue, negotiation, risk-sharing, and incentive alignment to bridge these differences and foster collective action towards the common goal. Initiatives such as the proposed Green Market Makers aim to provide such mediating structures.[175]

Building aviation's resilience requires a collaborative effort across the interconnected aviation network to ensure operational continuity and safety in a changing climate. There is a need for aviation stakeholders (airports, airlines, air navigation service providers) to conduct systematic climate risk assessments and develop adaptation plans. This involves understanding local climate projections, assessing vulnerabilities, prioritising risks and identifying adaptation measures. Potential infrastructure adaptation measures include enhancing drainage systems, reinforcing structures against higher wind loads, using heat-resistant materials for pavements, protecting critical equipment from flooding or heat, potentially relocating critical infrastructure and building sea defences for coastal airports. Measures to enhance aircraft systems and operations include improving weather forecasting and decision support tools to better manage disruptions, adapting operational procedures for extreme heat or storms, enhancing aircraft systems' resilience to turbulence or icing, and potentially adjusting network planning and schedules to account for increased weather variability.

National adaptation plans are also beginning to incorporate transport sector strategies. France's third National Climate Change Adaptation Plan (PNACC3) includes measures relevant to aviation resilience.[176]

Partnerships in action

- In 2025, the first **ICAO Aviation Climate Week** brought together 500 delegates to discuss global aviation's path to net zero carbon emissions by 2050; focal topics included SAF, the clean energy transition and implementation support.[177]
- The **ICAO Global Coalition for Sustainable Aviation**, with 58 members as of August 2025, brings together partners such as academia, aircraft manufacturers, airlines, SAF producers and other companies to facilitate new approaches and solutions for sustainable aviation.[178] In 2021, the coalition presented a report featuring a collection of innovations.[179]
- In 2024, the **International Transport Forum** and the **ICAO** released a joint agreement to advance sustainable aviation, with the ambition to deepen collaboration, data sharing and research.[180] The agreement enables research to address complex challenges: for example, the ITF report *Decarbonising Aviation: Exploring the Consequences* looks at connectivity, sustainable tourism, just transition and other impacts of moving towards net zero aviation.[181]

4.9 AVIATION

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