MODULE 3 3.7

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Aviation

SLOCAT Partnership on Sustainable, Low Carbon Transport

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Key findings

Demand trends

- Passenger activity contributed more than 70% of aviation-related carbon dioxide (CO_2) emissions in 2019.
- Aviation accounted for less than 1% of global freight activity in 2019 but was responsible for 7% of the CO_2 emissions from freight transport that year.
- The number of air passengers carried globally grew an estimated 47% in 2022, due to the rapid recovery of international routes following sharp declines early in the COVID-19 pandemic. Air passenger demand was expected to return to pre-pandemic levels in the first quarter of 2023 and to rise 3% above 2019 levels by the end of 2023.
- In March 2022, 36 countries closed their airspace to Russian airlines in reaction to the country's invasion of Ukraine, with the Russian Federation responding reciprocally. This gave airlines in China, India and the Middle East market advantages over airlines based in Europe and the United States. Aviation emissions are likely to increase significantly as a result.
- Out of an estimated 98.3 million global aviation jobs as of 2020, roughly 40% were lost during the COVID-19 pandemic.
- With the rebound in air travel demand, airlines and airports have experienced inefficiencies that can greatly increase aviation emissions yet are largely avoidable. Inefficiencies include carrying additional fuel on planes to reduce the cost of refuelling at certain airports and increasing flight speeds to compensate for airport delays due to short staffing.
- Jet fuel prices rose to USD 150 per barrel in March 2022, up 39% from the previous month (February 2022) and 121% from the previous year (March 2021).

Emission trends

- As countries emerged from pandemic-related lockdowns, aviation emissions reached around 720 million tonnes in 2021, regaining nearly one-third of the drop that occurred in 2020. Aviation contributed more than 2% of global energy-related emissions in 2021, showing faster emission growth than road, rail or maritime transport.
- Aviation has contributed around 4% to human-induced climate change to date, despite being responsible for only 2.4% of annual global CO_2 emissions.
- An estimated 1% of the world's population accounts for more than half of the total emissions from passenger air travel, and private jet travel has a disproportionate impact on the climate, contributing 4% of global aviation emissions.
- If pre-pandemic growth trends continue, aviation will contribute 6-17% of all greenhouse gas emissions within the carbon budget of scenarios aimed at keeping global temperature rise below 1.5 degrees Celsius (°C) to 2°C. The sector could reduce emissions to meet the targets of the Paris Agreement through 1) a decrease in air travel demand of 2.5% annually with the current fuel composition or 2) a shift to 90% carbon-neutral fuels by 2050.
- Incremental improvements in aircraft fuel efficiency have slowed over time. Even though new aircraft are up to 20% more efficient than models they replace, such improvements have been insufficient to compensate for rising demand.
- Aviation's CO_2 emissions could fall 9% to 94% below 2019 levels by 2050 by scaling up sustainable aviation fuels (SAF), improving operational efficiency and powering aircraft with liquid hydrogen.
- Reductions in air passenger demand due to fuel price increases, a shift from aviation to high-speed rail, reduced business travel and levies on frequent flyers could provide modest emission reductions in certain contexts.

Policy developments

- In October 2022, the member states of the International Civil Aviation Organization adopted a long-term global goal of net zero carbon emissions by 2050, but the goal remains aspirational and is insufficient to meet the targets of the Paris Agreement.
- To align efforts to decarbonise the sector, the International Aviation Climate Ambition Coalition was established at the 2021 United Nations (UN) Climate Change Conference in Glasgow, United Kingdom (COP 26).
- Aviation was identified as of one of the "hard-to-abate" sectors targeted for decarbonisation under the Mitigation Work Programme of the UN Framework Convention on Climate Change, agreed to at the 2022 UN Climate Change Conference in Sharm el-Sheikh, Egypt (COP 27).
- Sustainable aviation fuel accounted for less than 1% of aircraft fuel as of 2023, but scaling up its production to meet global demand is possible by 2040.
- As of 2021, SAF was an estimated two to eight times more expensive to produce than conventional jet fuel, although public and private sector efforts are aligning to make SAF more economical.
- Europe's largest airlines have lobbied policy makers to weaken the European Union's ambition on decarbonising aviation, despite companies' public commitments towards net zero emissions.
- Electric aircraft development has accelerated in numerous countries, spawning new partnerships among established passenger and freight transport providers and emerging technology companies.
- Several emerging companies are developing small and medium-sized aircraft powered by hydrogen fuels.

Overview

Between mid-2020 and mid-2023, the demand for air travel gradually rebounded as the world emerged from the worst of the COVID-19 pandemic.[1] However, the global disruption caused by the Russian Federation's invasion of Ukraine in February 2022 stalled the recovery and drove up jet fuel prices.[2] Air travel restrictions early in the pandemic had severe impacts on tourism, impeding efforts to achieve several of the United Nations Sustainable Development Goals (SDGs), including SDG 1 (no poverty) and SDG 10 (reduced inequalities). By 2022, international tourism had recovered to nearly two-thirds of pre-pandemic levels in Africa and the Americas, but less than one-quarter in Asia, due to a slower emergence from lockdowns in the region.[3]

Key emission trends continue to reveal that a small share of the global population (1%) accounts for a disproportionately high share of aviation carbon emissions, even as inequities in access to air travel prevail globally.[4] Meanwhile, efforts to rein in emissions, including with sustainable aviation fuels, hydrogen, and electrification, show early promise but remain far from the required speed and scale.

Among policy developments, the International Aviation Climate Ambition Coalition emerged at the 2021 UN Climate Change Conference in Glasgow, United Kingdom (COP 26), and aviation was identified as one of the "hard-to-abate" sectors targeted for decarbonisation under the Mitigation Work Programme of the UN Framework Convention on Climate Change (UNFCCC), agreed to at the 2022 UN Climate Change Conference in Sharm el-Sheikh, Egypt (COP 27).[5] In 2022, the International Civil Aviation Organization (ICAO) adopted a long-term aspirational goal of net zero carbon emissions for international aviation by 2050, which has been criticised for its lack of binding commitments and interim targets, and thus for its failure to create incentives for urgent climate action.[6]

Demand trends

Passenger activity contributed more than 70% of aviation-related carbon dioxide (CO_2) emissions in 2019.[7] Aviation accounted for less than 1% of global freight activity in 2019 but was responsible for 7% of the CO_2 emissions from freight transport that year.[8] During the COVID-19 pandemic in 2020, one-third of the revenue of airlines came from air cargo.[9] Air cargo traffic reached an all-time high in 2021 and gradually returned to 2019 levels by the end of 2022.[10]

The number of air passengers carried globally grew an estimated 47% in 2022, due to the rapid recovery of international routes following sharp declines early in the COVID-19 pandemic.[11] The number of passenger aircraft in service in 2022 paralleled overall demand, which rose to around 75% of pre-pandemic levels (see Figure 1).[12] Estimated air cargo demand in 2022 was similar to 2021 levels and was only marginally higher than pre-pandemic levels.[13]

Air passenger demand was expected to return to pre-pandemic levels in the first quarter of 2023 and to rise 3% above 2019 levels by the end of 2023.[14] Air passenger demand in 2024 is expected to be even stronger (around 4% above 2019 levels).[15] The ICAO lowered its projection for annual growth in aviation demand to 2050 from 4.2% to 3.6%.[16] Strategies to reduce demand under a scenario of net zero emissions include a shift to high-speed rail, reduced business flights and levies on frequent flyers.[17]

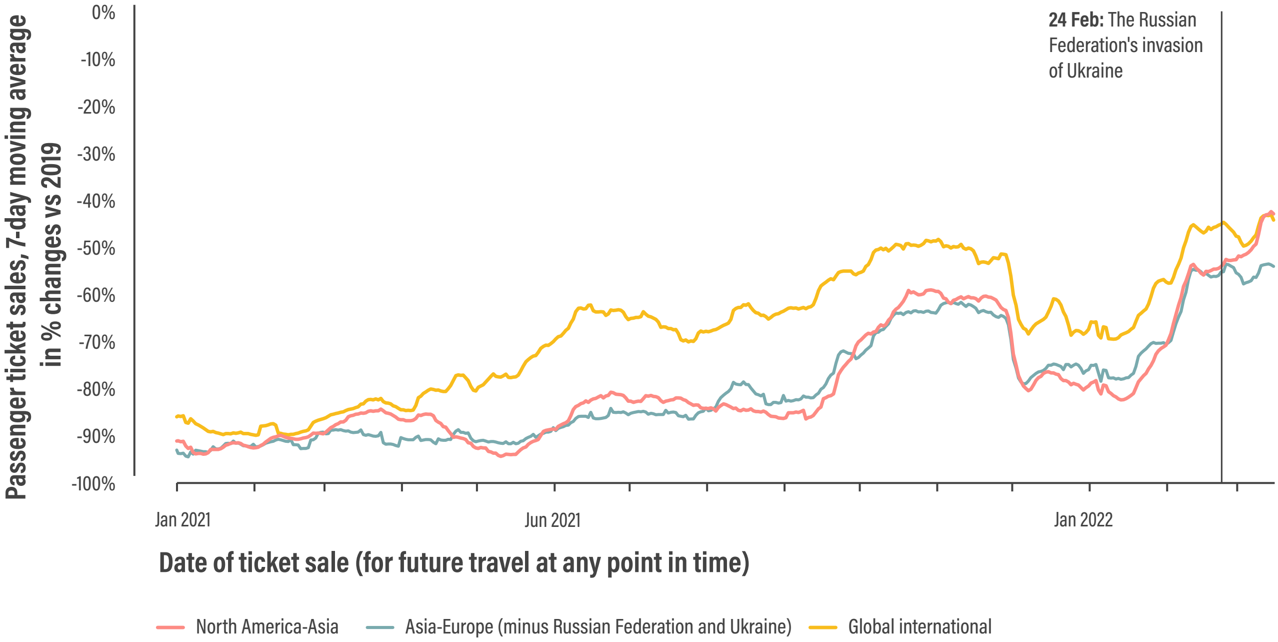
In March 2022, 36 countries closed their airspace to Russian airlines in reaction to the country's invasion of Ukraine, with the Russian Federation responding reciprocally.[18] This gave airlines in China, India and the Middle East market advantages over airlines based in Europe and the United States. Aviation emissions are likely to increase significantly as a result.[19] For example, Finnair had 40% longer flights to China, British Airways had a 20% longer diversion to China, and other European airlines were adding 15-40% flight times for the same routes.[20] Many US-based airlines lost access to polar flight paths, adding flight time and fuel expense to existing routes and causing the cancellation of some planned route expansions, resulting in an estimated annual loss of USD 2 billion.[21]

Out of an estimated 98.3 million global aviation jobs as of 2020, roughly 40% were lost during the COVID-19 pandemic.[22] With the rebound in air travel demand, airlines and airports have experienced inefficiencies that can greatly increase aviation emissions yet are largely avoidable.[23] Inefficiencies include carrying additional fuel on planes to reduce the cost of refuelling at certain airports and increasing flight speeds to compensate for airport delays due to short staffing.[24]

Jet fuel prices rose to USD 150 per barrel in March 2022, up 39% from the previous month (February 2022) and 121% from the previous year (March 2021).[25] Before the

FIGURE 1. Demand trends for international air travel, January 2021 to March 2022

Source: See endnote 12 for this section.



pandemic, fuel costs accounted for around 25% of airlines' operating expenses.[26] In 2020 and 2021, airlines' variable costs fell, causing the fuel cost share to decline, but by early 2022 it had returned to pre-pandemic levels.[27] Airlines can absorb fuel costs or pass them on to passengers as higher fares, which may reduce demand in a time of high inflation.

Emission trends

As countries emerged from pandemic-related lockdowns, aviation emissions reached around 720 million tonnes in 2021, regaining nearly one-third of the drop that occurred in 2020.[28] Aviation contributed more than 2% of global energy-related emissions in 2021, showing faster emission growth than road, rail or maritime transport.[29] By late 2022, aviation emissions rose slightly to recover roughly a third of the drop attributed to the pandemic in 2020.[30]

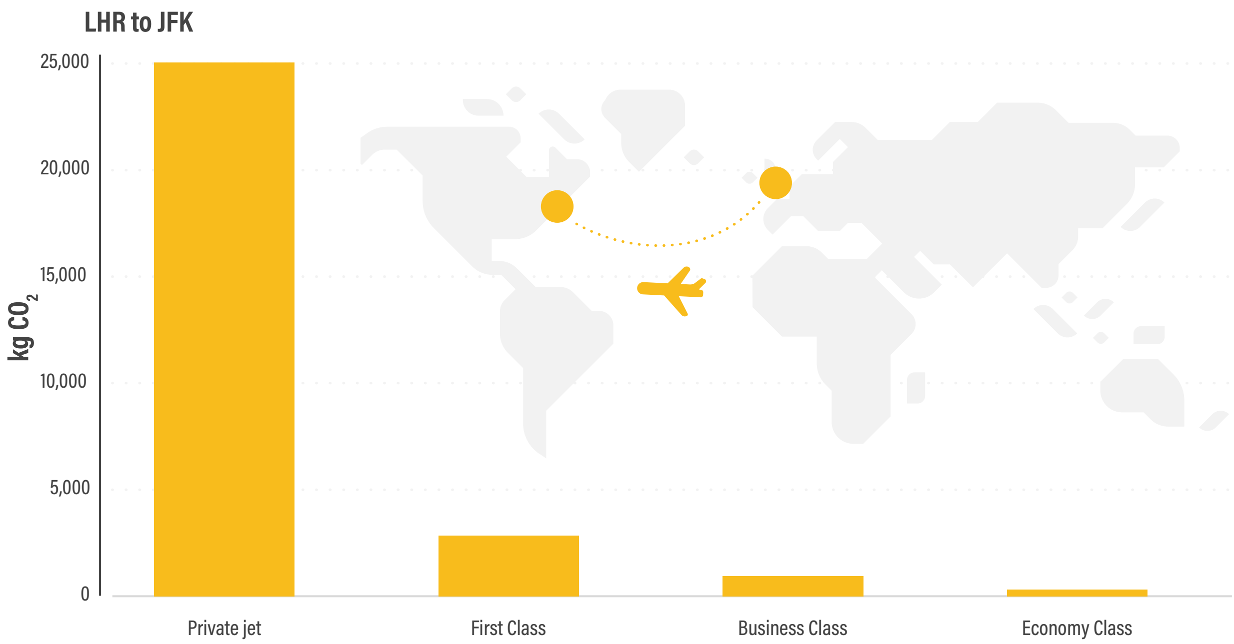
Aviation has contributed around 4% to human-caused climate change to date, despite being responsible for only 2.4% of annual global CO_2 emissions.[31] In 2018, commercial aviation contributed the vast majority of aviation CO_2 emissions (an estimated 88%), followed by military operations (8%) and private flights (4%).[32] In addition to the CO_2 emitted through combustion of jet fuel, aircraft release water vapour that leads to formulation of cirrus clouds, trapping additional heat in the atmosphere.

An estimated 1% of the world's population accounts for more than half of the total emissions from passenger air travel, and private jet travel has a disproportionate impact on the climate, contributing 4% of global aviation emissions.[33] As of 2018, only 11% of all people worldwide travelled by air, with at most 4% of the population taking international flights.[34]

- Carbon emissions from a passenger flying from London (UK) to New York (USA) in a commercial jet are equivalent to 4 weeks of emissions from a typical European household (if flying in economy class) or as much as 38 weeks of emissions (if flying in first class).[35]
- Passengers travelling from London to New York in a private jet produce around 25 tonnes of CO_2, equivalent to six years of emissions from a typical European household (see Figure 2).[36]
- An analysis of the activity of private jets owned by US celebrities shows that the planes emit 482 times more CO_2 emissions than the average person globally does annually.[37]

FIGURE 2. Relative emissions of different classes of airline services from London to New York

Source: See endnote 36 for this section.



- Employee travel accounts for an estimated five-sixths of the emissions of McKinsey & Co., leading the company to target a 30% reduction in greenhouse gas emissions from business travel per employee by 2025.[38]

If pre-pandemic growth trends continue, aviation will contribute 6-17% of all greenhouse gas emissions within the carbon budget of scenarios aimed at keeping global temperature rise below 1.5 degrees Celsius (°C) to 2°C.[39] The sector could reduce emissions to meet the targets of the Paris Agreement through 1) a decrease in air travel demand of 2.5% annually with the current fuel composition or 2) a shift to 90% carbon-neutral fuels by 2050.[40] The drop in emissions during 2020 and 2021 is expected to delay aviation's contribution to climate change by only around five years, if demand growth recovers to pre-pandemic levels.[41]

Incremental improvements in aircraft fuel efficiency have slowed over time. Even though new aircraft are up to 20% more efficient than models they replace, such improvements have been insufficient to compensate for rising demand.[42] The energy intensity of passenger aviation fell 2.4% annually from 2000 to 2010 then dropped to 1.9% annually from 2010 to 2019, reflecting a slowdown in efficiency gains (see Figure 3).[43]

Aviation's CO_2 emissions could fall 9% to 94% below 2019 levels by 2050 by scaling up sustainable aviation fuel (SAF), improving operational efficiency and powering aircraft with liquid hydrogen.[44] SAF offers the largest mitigation potential, contributing around 60% of the emission reductions under various decarbonisation scenarios (see Figure 4).[45] Improvements in the operational and technical efficiency of aircraft represent 33% of the reduction potential, while the use of hydrogen accounts for 4-5%.[46]

Reductions in air passenger demand due to fuel price increases, a shift from aviation to high-speed rail, reduced business travel and levies on frequent flyers could provide modest emission reductions in certain contexts.[47] One hypothesis suggests that higher fuel costs could lead to a slight reduction in air travel demand and encourage a greater shift to high-speed rail through 2050 (*see Section 3.5 Inter-city Rail*).[48] However, at present, such "Avoid" and "Shift" strategies towards decarbonising aviation are likely to be outweighed by "Improve" strategies at the required scale and pace.

- Through its 2021 Climate Law, France banned domestic flights where rail alternatives of less than 2.5 hours are available.[49] However, France opted not use its EU presidency term (January to June 2022) to urge other governments to adopt similar policies.[50]

FIGURE 3. Energy intensity of domestic (top) and international (bottom) passenger aviation, 2000-2021 and projections to 2030 under a net zero scenario

Source: See endnote 43 for this section.

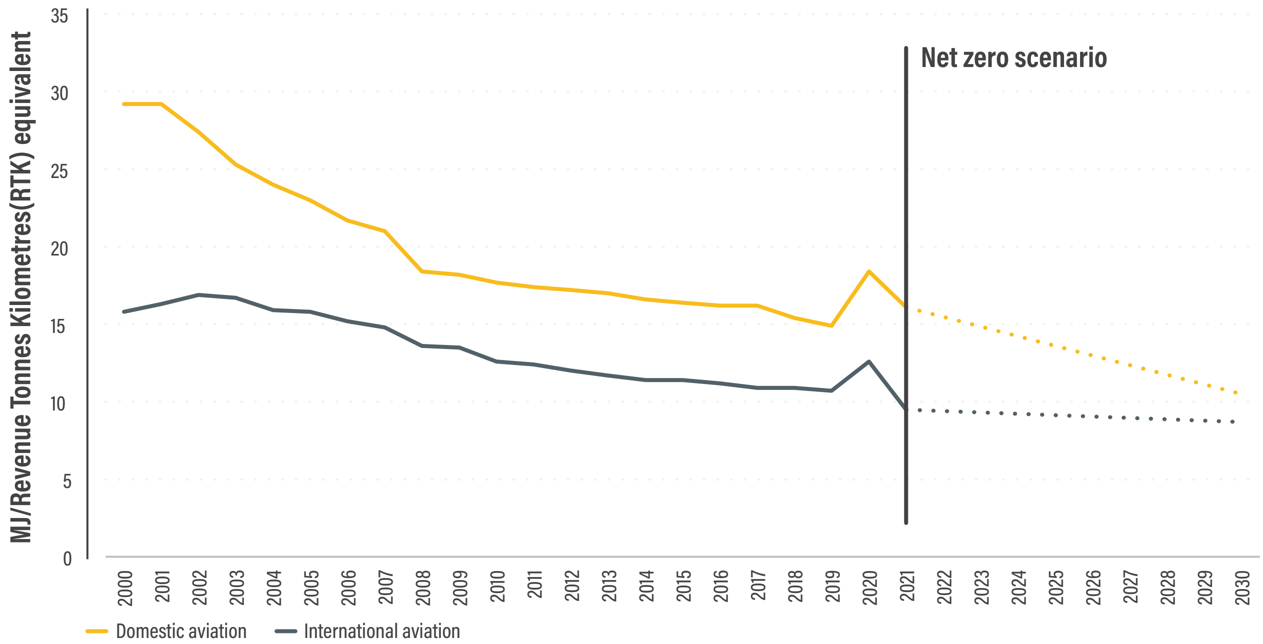
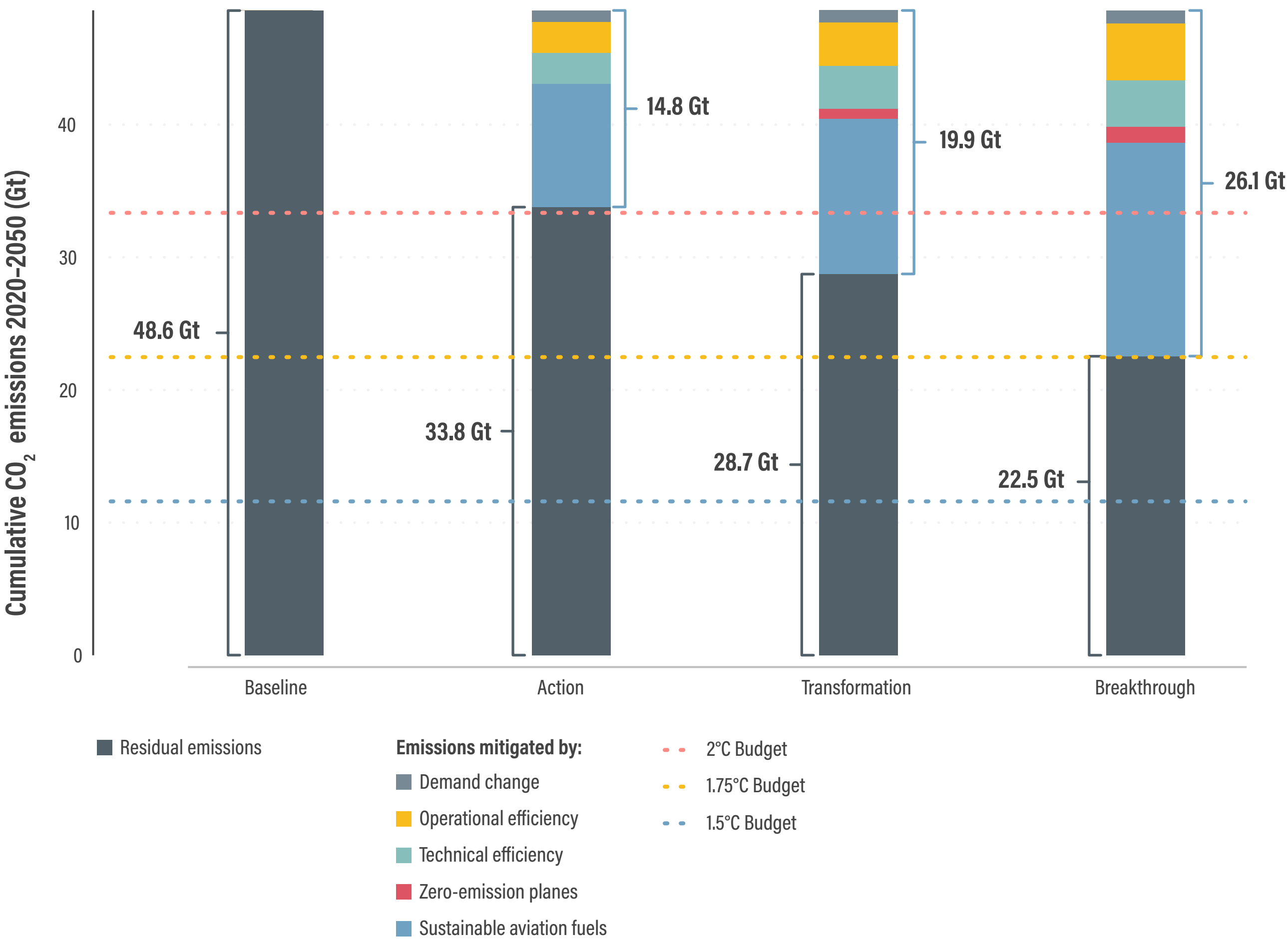


FIGURE 4. Scenarios for CO_2 emission mitigation from aviation, 2020-2050

Source: See endnote 45 for this section.



- Changing work patterns and remote work have reduced demand for domestic business travel but have expanded demand for summer air travel in the northern hemisphere.[51]
- A 2022 report projects that a levy on frequent flyers (i.e., an escalating price based on the number of flights taken) could earn 98% of its revenues from the wealthiest 20% of air travellers.[52]

Policy developments

In October 2022, the member states of the International Civil Aviation Organization adopted a long-term global goal of net zero carbon emissions by 2050, but the goal remains aspirational and is insufficient to meet the targets of the Paris Agreement (see Figure 5).[53] The goal has been criticised for its lack of interim targets and binding commitments for countries – and thus for its failure to create any incentives to take meaningful action towards achieving it.[54]

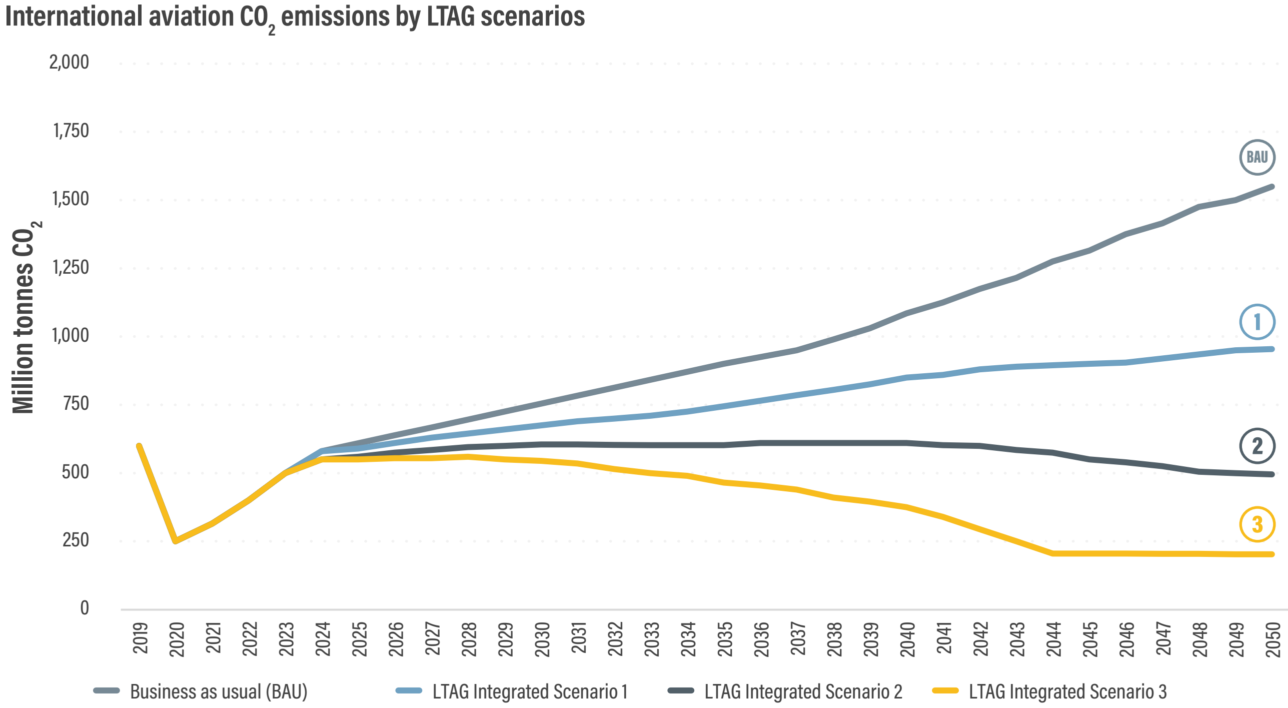
To align efforts to decarbonise the sector, the International Aviation Climate Ambition Coalition was established at the 2021 United Nations Climate Change Conference in Glasgow, United Kingdom (COP 26).[55] The Glasgow Climate Pact adopted at COP 26 states that "limiting warming to 1.5˚C requires a 45% reduction in global CO_2 emissions by 2030 relative to 2010 levels".[56]

- The Netherlands is considering establishing a ceiling on CO_2 emissions from international flights originating in the country.[57]
- Of the 144 second-generation Nationally Determined Contributions (NDCs) submitted by countries under the Paris Agreement as of March 2023, 15 NDCs mention aviation, or 10% of the total.[58] For example, the EU's updated NDC mentions the region's intention to expand the scope of aviation emissions covered under the EU Emission Trading Scheme.[59]

Aviation was identified as one of the "hard-to-abate" sectors targeted for decarbonisation under the UNFCCC Mitigation Work Programme agreed to at the 2022 UN Climate Change Conference in Sharm el-Sheikh, Egypt (COP 27).[60] The Pact

FIGURE 5. Decarbonisation scenarios under the International Civil Aviation Organization's long-term aspirational goal of 2022

Source: See endnote 53 for this section.



Note: LTAG = long-term aspirational goal

Photo: dsleeter_2000

agreed to establish mechanisms to rapidly scale up ambition and implementation to close the 1.5°C gap in the current decade.[61] The first global dialogue of the UNFCCC Mitigation Work Programme was convened in June 2023, focused on the topic of a just energy transition.[62]

Sustainable aviation fuel (SAF) accounted for less than 1% of aircraft fuel as of 2023, but scaling up its production to meet global demand is possible by 2040.[63] SAF, which includes biofuels and e-fuels, can provide significant emission reductions compared to conventional fuels if it can be produced sustainably at the required scale.[64] Because the volume of biofuels from waste and residues will not be sufficient to meet demand, energy crops will also be required.[65] E-fuels are relatively inefficient due to energy losses in the production and transport of hydrogen and the combustion of the fuel.[66]

- The United States has created a roadmap to expand annual SAF production to 3 billion gallons (11.4 million litres) by 2030 and 35 billion gallons (13.3 million litres) by 2050, with the aim of meeting 100% of jet fuel demand with SAF and reducing the life-cycle emissions of aircraft 50% by that year.[67]

- Fuels such as hydrogen, e-fuels and biofuels offer advantages that are particularly important for long-distance shipping and aviation; however, they require much more space, and fuels such as e-kerosene are 3-5 times more energy intensive than electricity, on a well-to-tank basis.[68]

As of 2021, SAF was an estimated two to eight times more expensive to produce than conventional jet fuel, although public and private sector efforts are aligning to make SAF more economical.[69]

- In 2022, Airbus successfully tested the use of 100% SAF on a flight of the first A380 plane the company ever made, and it aims to introduce the world's first zero-emission jet by 2035, based on SAF tests on other aircraft.[70]

- Chevron USA and Gevo (a US-based advanced biofuels company) announced plans in 2021 to jointly invest in facilities to scale up production of SAF from non-food sources.[71]

- The EU struck a deal to require the use of SAF for all flights in the region, starting at 2% in 2025 and scaling up to 70% by 2050.[72] The compromise agreement was less ambitious than the original proposal but sets a tangible baseline to allow for increasing ambition over time.[73]

- The United Kingdom set a target in 2021 to use 10% SAF by 2030 and has engaged private sector partners to help reach this target with grants totalling GBP 165 million (USD 205 million) through the country's Advanced Fuel Fund.[74]

Europe's largest airlines have lobbied policy makers to weaken the EU's ambition on decarbonising aviation, despite companies' public commitments towards net zero

emissions.[75] Proposed policies from front groups representing European airlines would limit the EU's SAF plan (ReFuelEU) only to flights within the region.[76] Such a policy would reduce the projected 2050 emission savings from ReFuelEU by nearly 40%.[77]

Electric aircraft development has accelerated in numerous countries, spawning new partnerships among established passenger and freight transport providers and emerging technology companies.[78] As of October 2022, efforts to develop electric aircraft were in process in Australia, Brazil, China, France, Germany, India, Indonesia, Japan, the Republic of Korea, the Russian Federation, the United Kingdom and the United States.[79] However, electric aircraft have relatively low potential to reduce total aviation emissions and have a long development timeline, and thus may have little real impact before 2050.[80]

- Air Canada announced in 2022 that it would order 30 hybrid-electric aircraft from Sweden's Heart Aerospace to replace turbo-prop aircraft on regional routes.[81]
- In 2021, DHL Express announced an order of 12 all-electric cargo planes from Eviation, an emerging US-based manufacturer.[82]
- Norway set a target in 2018 for all short-haul flights to be electric by 2040.[83] The first electric plane prototypes were announced in 2022 and were expected to begin commercial operation by 2028.[84]

Several emerging companies are developing small and medium-sized aircraft powered by hydrogen fuels.[85] Hydrogen-powered aircraft pose numerous technical challenges, including needs for innovative fuel storage methods, lightweight cryogenic tanks and redesigned aircraft frames. Investments are under way to scale up fuel production and to support next-generation aircraft.

- Airbus has invested in the world's largest clean hydrogen infrastructure fund.[86]
- In 2022, American Airlines announced an equity investment in Universal Hydrogen, which is building a green hydrogen distribution network for use in aviation.[87]
- A consortium including Dutch aircraft manufacturer Fokker and the Delft University of Technology plans to launch the world's first hydrogen-fuelled flight of a 40-80-seat passenger plane from Rotterdam (Netherlands) to London (UK) by 2028.[88]
- The United Kingdom is backing the development of an aircraft that would allow a zero-carbon, non-stop flight from London to San Francisco (USA) for nearly 300 passengers.[89]

3.7 AVIATION

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