Photo by Stefan Simonetti, Kearney, Chicago

Aviation: pathways to net zero

November 2025

KEARNEY FORESIGHT | Energy Transition Institute

Aviation: pathways to net zero

This FactBook provides a comprehensive overview of aviation's role in global climate change and explores the suite of technological, operational, and policy pathways guiding the sector toward net-zero emissions. It highlights key decarbonization trends and market and regulatory developments, and assesses the environmental and social implications of emerging solutions. The FactBook concludes with an evaluation of the feasibility, scalability, and investment requirements needed to achieve a low-carbon aviation future.

Aviation represents about 2.5 percent of global CO_2 emissions, but its total climate impact is closer to 4 percent, largely due to contrails and other non-CO_2 effects. The demand for aviation has tripled since 2000, driving an increase in emissions, although this rise was partially truncated by energy efficiency gains, leading to a fall in carbon intensity. However, aviation remains difficult to decarbonize due to the limited maturity and scalability of current solutions.

Sustainable aviation fuel (SAF) is a promising solution for aviation decarbonization. It could contribute substantially to emission reductions, potentially about 55 percent by 2050, but its large-scale adoption faces major hurdles. SAF can lower emissions related to fuel burn by 50 to 90 percent, depending on feedstock and production pathway, yet only one certified route, HEFA (hydroprocessed esters and fatty acids), is currently produced at scale. Limited feedstock availability and production costs that are three to 15 times higher than conventional jet fuel remain significant barriers. Even with planned projects, SAF supply by 2030 is projected to fall well short of expected demand.

Technological innovation will be a major catalyst in advancing the net-zero pathway. Incremental advances such as lightweight composites and winglets offer small gains, while next-generation engine concepts such as ultra-high-bypass turbofans and open-rotor designs could cut fuel burn by 20 to 25 percent. Hydrogen and electric propulsion promise near-zero in-flight emissions but face severe constraints in storage, energy density, and infrastructure readiness.

Operational improvements can deliver 10 to 15 percent reductions in fuel burn and corresponding CO_2 emissions at relatively low cost. Optimized airspace management, efficient trajectories, and contrail-avoidance routing have already demonstrated measurable benefits. Electric taxiing reduced auxiliary power use, and weight optimization further enhance fuel savings, while leading airports are targeting net-zero ground operations by 2050.

Policy and regulatory frameworks are rapidly evolving. The ICAO CORSIA offset mechanism will become globally binding in 2027 and the EU ETS Phase IV will phase out free allowances by 2027. Ambitious SAF targets and mandates have been formulated and adopted globally to accelerate its development and deployment with EU mandating SAF blending of 2 percent by 2025, 6 percent by 2030, and 70 percent by 2050. Non-CO_2 policies are also emerging, with the EU, the US, and the UK investing in contrail and NOx monitoring programs.

Each pathway carries its own potential to mitigate warming impact. Some are mutually incompatible—or even competing—while their climate benefits are not generally additive. The mechanism by which these technologies are selected—how trade-offs are assessed, how synergies are captured, and how risks are managed—will be as critical as the innovations themselves. Recognizing this dynamic is essential to maintaining a rational and evidence-based outlook on aviation's decarbonization journey.

Aviation demand is expected to rise in the medium and long term with all the sub-segments registering growth. Airlines are doubling down on SAF deployment and next-generation fleets that reduce CO_2 emissions by a quarter compared with earlier aircraft. However, slower aircraft deliveries due to supply chain bottlenecks are delaying the benefits of fleet renewal.

Considering only direct CO_2 emissions, aviation's carbon emissions per passenger kilometer is comparable to other modes of transportation, but overall climate impact is about two times greater when accounting for contrail effect. Short- and medium-haul flights account for 63 percent of total aviation CO_2. Environmental and social impacts extend beyond emissions. Land use concerns arise as HEFA-based SAF alone could demand up to 76 percent of global soybean area by 2030, straining farmland. Despite a 10 to 15 dB reduction in noise from new aircraft, community concerns persist—amplified by air-quality impacts around airports. Social scrutiny of aviation's environmental footprint continues to intensify, even as the sector remains a major contributor to global GDP and employment.

Novel technology-based solutions are projected to deliver most of the emissions reductions by 2050. However, high costs, slow deployment (for example, constrained by fleet renewal pace), and scalability challenges create a gap between current progress and net-zero targets. As this report illustrates, progress toward net-zero flight will depend not only on the innovation of these advances but also on the rigor with which the industry selects and integrates them, considering infrastructure and fleet renewal constraints, among other factors.

1. Aviation contributes ~2.5% of global CO_2 emissions but non-CO_2 effects like contrails amplify its overall climate impact.
2. Despite halving carbon intensity since 2000, aviation remains hard to abate due to dependence on high-energy fuels.
3. SAF (sustainable aviation fuels) are expected to deliver the bulk of future emissions reductions. Other decarbonization levers include innovative technology solutions, operational efficiency measures, and policy tools.
4. High costs, resource constraints, and scalability challenges hinder the rapid and widespread deployment of these solutions.
5. A substantial gap persists between current progress and 2050 net-zero targets, requiring faster technology and infrastructure rollout with supportive policy.

This is an executive summary of the Kearney Energy Transition Institute's latest FactBook, Aviation: pathways to net zero.

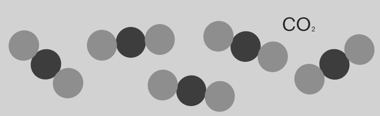
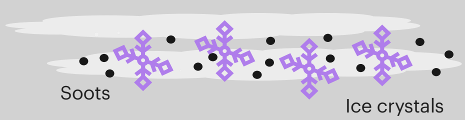
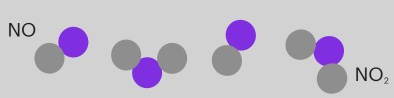
For the complete FactBook, please visit https://www.energy-transition-institute.com/factbooks.

Aviation and climate change

Aviation operations accounts for approximately 2.5 percent of global CO_2 emissions but nearly 4 percent of total radiative forcing due to additional non-CO_2 effects.

Key climate drivers include contrail formation, NOx chemistry, and soot emissions, which together can double aviation's warming impact. However, high uncertainties remain around their magnitude.

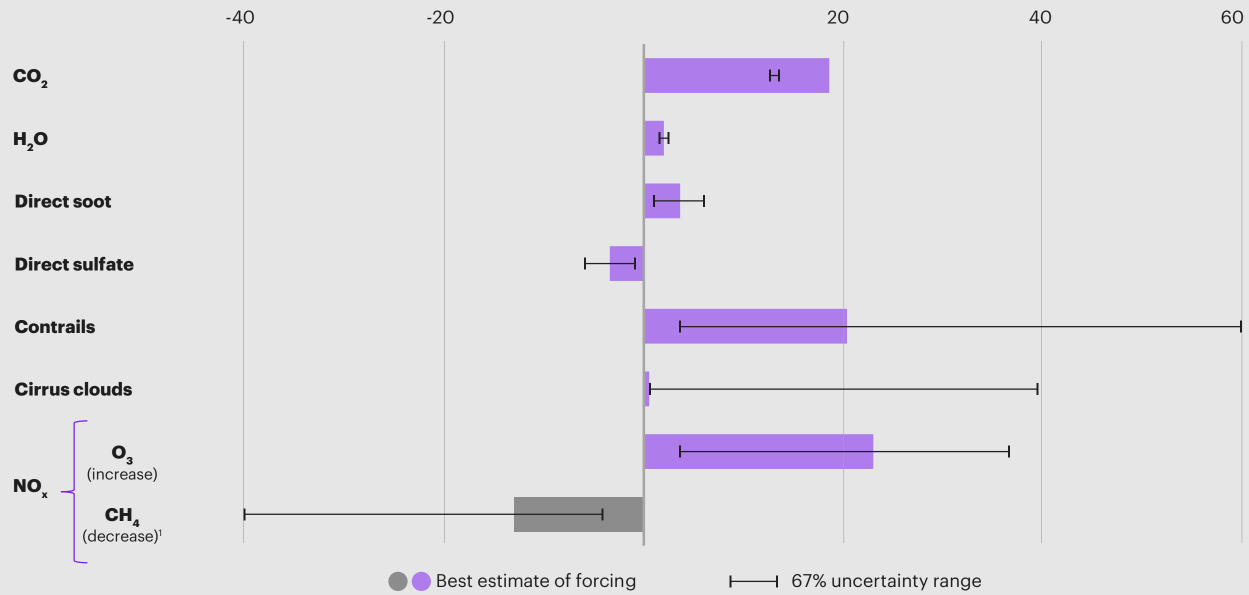
Figure 1
Aircraft operations contribute to climate change through direct greenhouse gases emissions

CO_2 emissions		**CO_2** traps heat by absorbing and reemitting infrared radiation, reducing the atmosphere's ability to release energy into space.	**GHG related**
Contrails and cirrus formation		**Contrails** form from water vapor and soot in cold and humid conditions; they can warm by trapping infrared radiation or cool by reflecting solar radiation, and persistent ones evolve into **cirrus-like clouds** that alter natural cloud cover and radiative balance.	**Contrails/ cirrus/ polar stratospheric clouds**
Modification of ozone chemistry		**NOx emissions** at cruise altitude increase ozone, causing short-term warming, but also reduce methane, generating a longer-term cooling effect.	**Atmospheric chemistry**

Sources: IPCC, 2018, Special report: Aviation and the global atmosphere; Kearney Energy Transition Institute analysis

Figure 2
Species contributing to climate change

Radiative forcing (mW/m²)

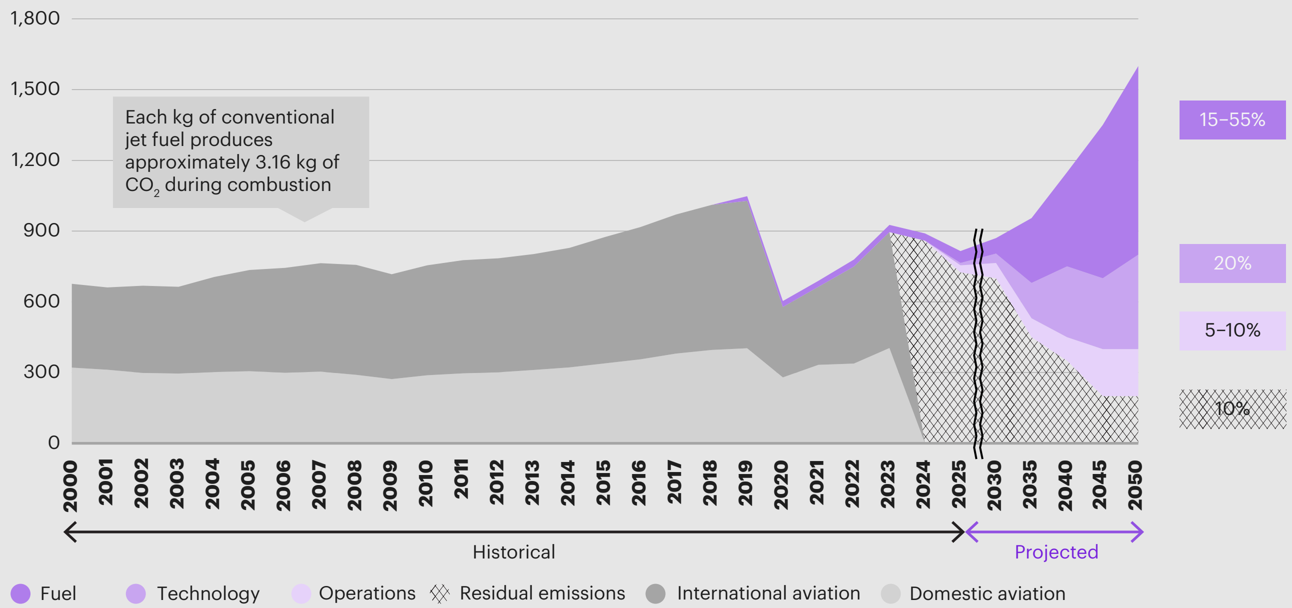


Note: Radiative forcing occurs when the quantity of energy entering the atmosphere exceeds the quantity leaving, accumulating and raising temperatures, e.g., greenhouse gas effect.
1. NOx emissions increases atmospheric concentration of hydroxyl that breaks down CH4, reducing its concentration and creating a net negative radiative forcing contribution.
Sources: ISAE Supaero, 2021, Aviation et climat; IPCC, 2018, Special report: Aviation and the global atmosphere; Kearney Energy Transition Institute analysis

The non-CO_2 climate impact of aviation is typically assessed using radiative forcing rather than GWP (Global Warming Potential) because emissions from aviation include short-lived climate forcers—such as contrails and NOx-induced effects—that create a wide range of impacts over relatively shorter timescales. In contrast, GWP is more suitable for longer-lived GHG gases that remain in the atmosphere for decades or centuries, such as CO_2.

Figure 3
Aviation CO_2 emissions: historical trends and net-zero pathways

Historical and projected aviation CO_2 emissions from fuel consumption ($MtCO_2$, 2000–2050)



Sources: ICAO, LTAG Integrated Scenario 3; ISAE Supaero, 2021, Aviation et climat; Kearney Energy Transition Institute analysis

Despite energy efficiency improvements that have halved carbon intensity since 2000, total aviation emissions exceeded 900 $MtCO_2$ in 2024. The sector's hard-to-abate nature stems from its reliance on high-energy-density fuels, long asset life cycles, and limited low-carbon substitutes.

Mitigation efforts require simultaneous progress across three levers: sustainable aviation fuels (SAF), technology innovations such as new propulsion systems and operations efficiency, and robust policy frameworks.

Sustainable aviation fuels

Sustainable aviation fuels represent the most impactful near-term lever for decarbonization. SAFs can reduce emissions related to fuel burn by 50 to 90 percent, while also cutting soot and contrail formation.

Five key production pathways: HEFA, G-FT, AtJ, PtL, and IBN-SPK are certified under ASTM standards, though only HEFA operates at commercial scale today.

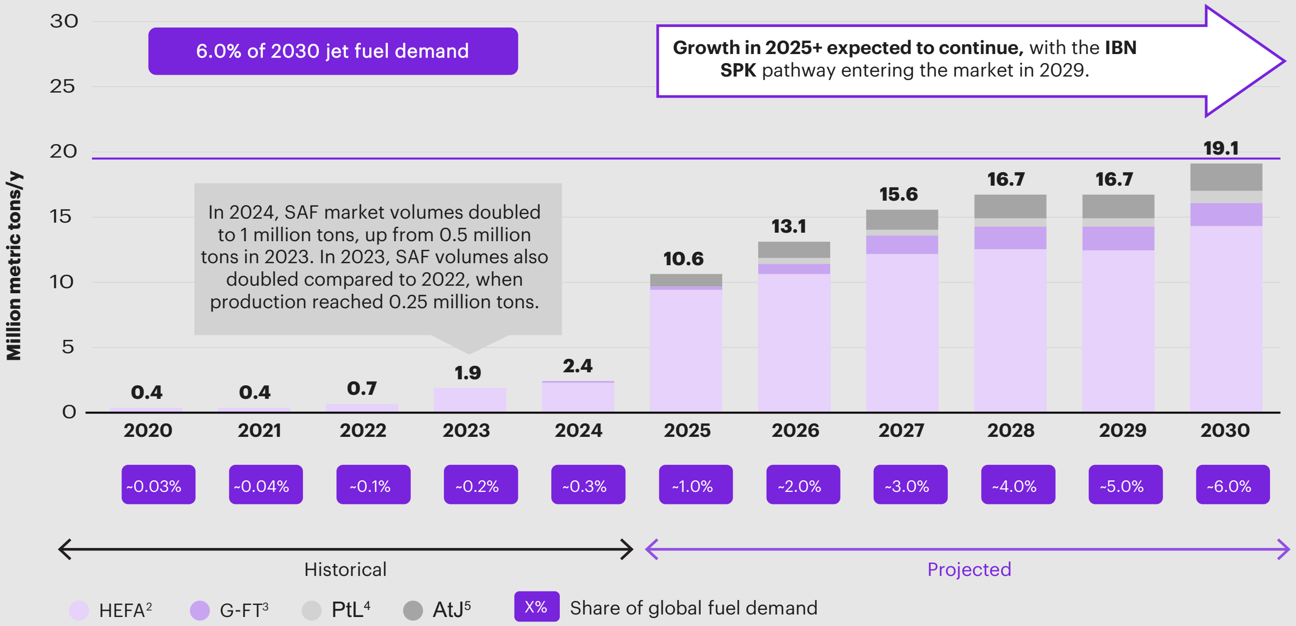
Figure 4
Overview of the certified SAF pathways

	HEFA[1]	G-FT[2]	AtJ[3]	PtL[4]	IBN SPK[5]
Detailed process description	- Removal of oxygen fraction of the feedstock by **hydrotreatment** - Split of feedstock in different hydrocarbons (mainly diesel and kerosene) through **hydrocracking**	- **Gasification** of the solid biomass at elevated temperatures to obtain "syngas" - **Purification** of the gas and synthesis of kerosene and other hydrocarbons in a catalytic reaction known as the Fischer-Tropsch process	- **Dehydration of alcohol feedstock** (ethanol, butanol) to produce olefins - **Oligomerization** of olefins to form longer hydrocarbon chains - **Hydroprocessing and isomerization** to refine hydrocarbons into SAF	- Combination of hydrogen and captured CO_2 to produce **syngas** - **Conversion of syngas into liquid hydrocarbons,** including kerosene, through the Fischer-Tropsch synthesis - **Hydroprocessing** and fractionation to refine the hydrocarbons into SAF	- **A bacterial fermentation** process converts the sugar-based and acetic acid feedstocks into isobutene (IBN) gas - The **IBN** undergoes catalytic processing to produce synthetic paraffinic kerosene (IBN-SPK)
Opportunity description	Already implemented at large scale but **not scalable due to feedstock availability** and logistical constraints	**Financing of the first large-scale** plant projects ongoing, however significant **techno-economical uncertainty**	**Financing of the first large-scale** plant projects ongoing, however significant techno-economical uncertainty	**First small-scale pilot plant starting,** primarily where cheap high-volume electricity is available	**First large-scale plant** in operation toward 2030, however significant **techno-economical uncertainty**
GHG reduction[6] (%)	55–65 (50–60 gCO_2eq/MJ)	80–90 (70–80 gCO_2eq/MJ)	55–65 (50–60 gCO_2eq/MJ)	90–100 (80–90 gCO_2e/MJ)	55–65 (50–60 gCO_2eq/MJ)

1. Hydroprocessed esters and fatty acids; 2. Gasification Fischer–Tropsch; 3. Alcohol-to-jet (LanzaJet plant); 4. Power to liquid; 5. Isobutene synthetic paraffinic kerosene; 6. Relative to current state for fuel burn; Sources: Global Bioenergies, 2023, A growing player of the environmental transition; Global Bioenergies, 2024, From cosmetics to SAF: Fostering the environmental transition through biosciences; ADEME, 2022, Elaboration de scenarios de transition écologique du secteur aérien; ICAO, 2024, CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels; Kearney Energy Transition Institute analysis

Figure 5
Growth outlook for SAF capacity by technology

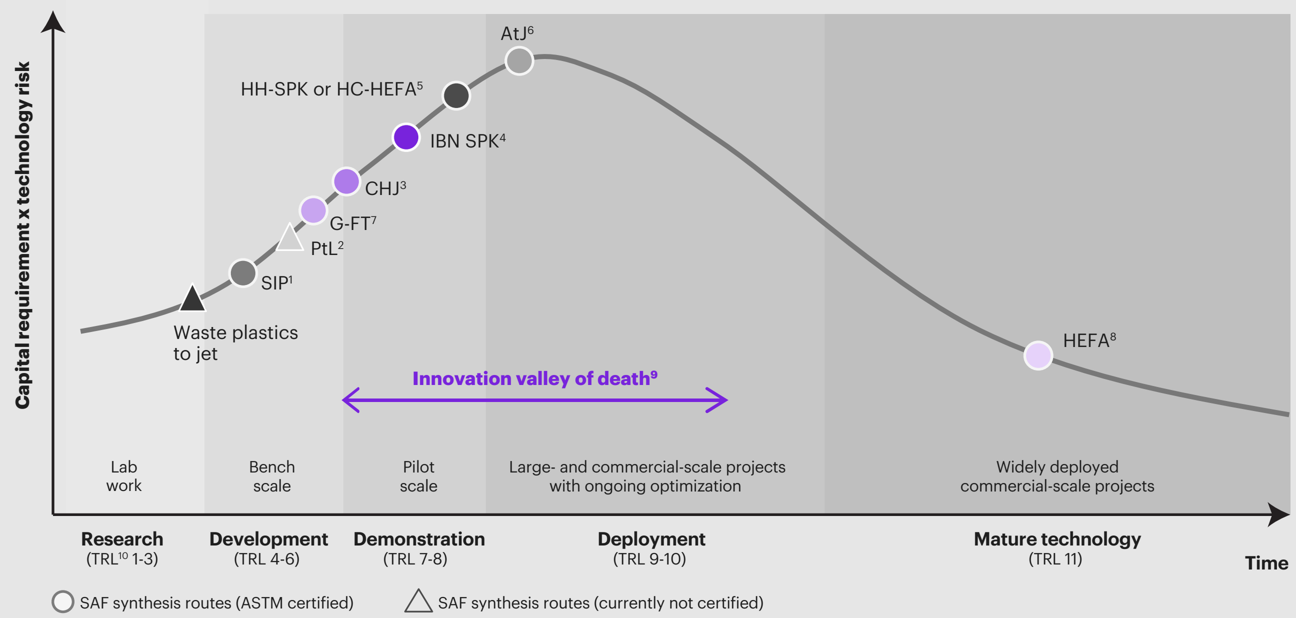
Cumulative global SAF nameplate production capacity by technology[1] (Mt/y, 2020–2030)



1. SAF production yields are flexible and can vary greatly, from a default of around 15% to 50% or more of nameplate capacity.; 2. Hydroprocessed esters and fatty acids; 3. Gasification Fischer–Tropsch; 4. Power to liquid; 5. Alcohol-to-jet.
Sources: BNEF, 2024, United Airlines Is Betting Big on a Pricey Green Aviation Fuel; Global Bioenergies, 2023, A growing player of the environmental transition; Global Bioenergies, 2024, From cosmetics to SAF: Fostering the environmental transition through biosciences; Kearney Energy Transition Institute analysis

Figure 6
Mapping maturity of SAF synthesis routes

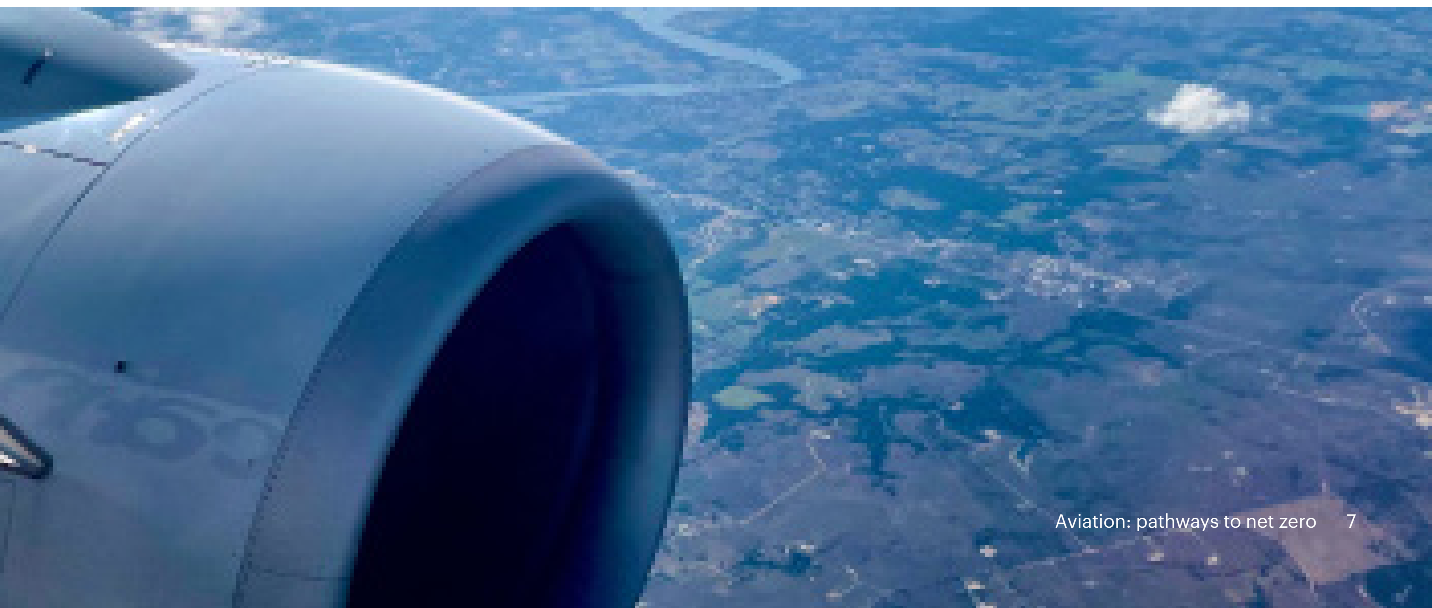
Maturity curve for SAF synthesis technologies



1. Synthesized iso-paraffin; 2. Power to liquid; 3. Catalytic hydrothermolysis jet fuel; 4. Isobutene synthetic paraffinic kerosene; 5. Hydroprocessed hydrocarbons; 6. Alcohol-to-jet; 7. Gasification Fischer–Tropsch; 8. Hydroprocessed esters and fatty acids; 9. Refers to a critical phase in new technology development where the initial momentum and early-stage funding have subsided, but the technology has not yet reached commercialization; 10. TRL (technology readiness level) scale adapted from IEA (2020), Assessing technology readiness: The ETP Clean Energy Technology Guide; Sources: Kearney Energy Transition Institute analysis

Global SAF output reached 1 million tons in 2024—doubling annually but still accounting for less than 0.1 percent of total jet fuel demand. By 2030, capacity could reach 19 Mt (about 6 percent of demand), dominated by HEFA, with new entrants in PtL and AtJ.

Costs remain 3–15x higher than conventional jet fuel, requiring policy support and carbon pricing to bridge the gap. Selecting the right technology for investment depends on scalability and cost, which in turn are influenced by regional factors like energy prices and feedstock availability.



Upper limits of SAF blending ratio

Currently, SAF can be used in blends up to 50 percent.

Conventional jet fuels contain 8 to 25 percent aromatics by volume, essential for maintaining elastomeric seal integrity in aircraft fuel systems. However, today's commercially available SAF is aromatic-free, making it incompatible in its pure form with aircraft and the current fuel infrastructure.

To ensure safety and infrastructure compatibility, SAF must therefore be blended with conventional jet fuel—although certification for 100 percent SAF use is targeted by 2030.

Most SAF synthesis technologies are at pilot or commercial deployment scale, with HEFA being the only mature technology.

Aviation technology solutions

Aircraft design innovations and propulsion technologies will be critical to the net-zero journey. Technological improvements fall into three categories: airframe design upgrades, advanced engine architectures, and alternative propulsion systems.

Together, these could reduce flight emissions by 25 to 95 percent compared to today's fleet, though certification and scalability timelines vary widely.

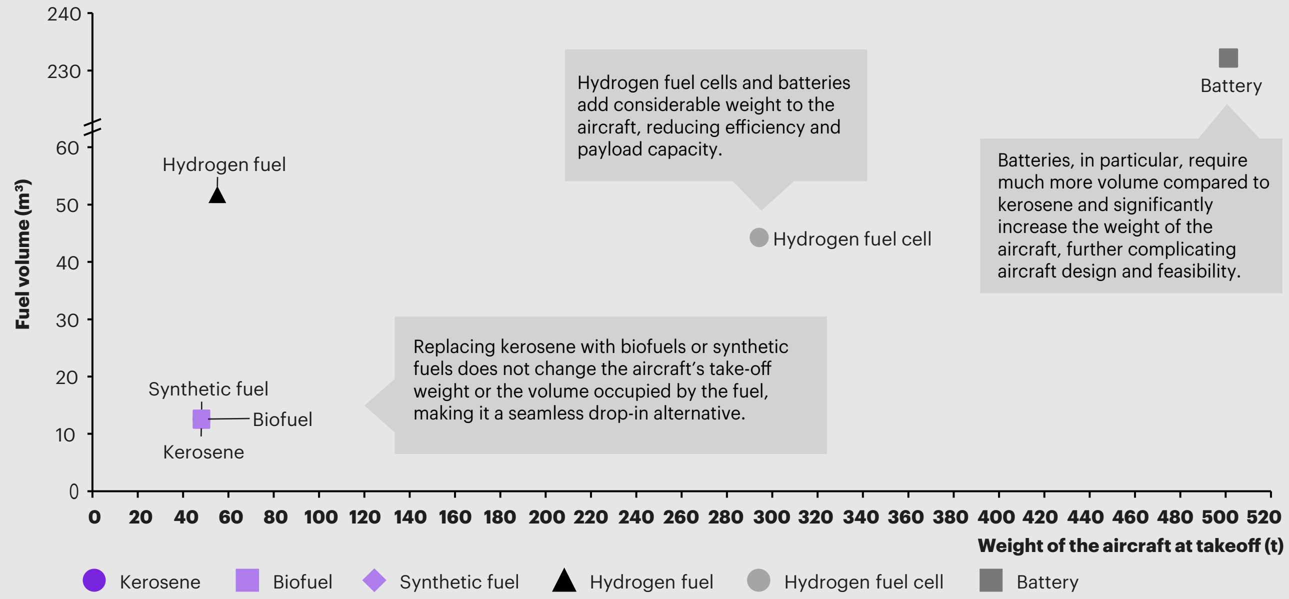
Figure 7
Aviation technology solutions

	A Airframe design	B Engine concepts	C New propulsion systems
Description	Developments in aircraft structure to improve aerodynamics and lift, reduce weight, and increase efficiency	Developments in combustion engine architecture	Using an alternative energy carrier in place of jet fuel for aircraft propulsion
Existing improvements	– Composites – 3D printing – Lightweight cabin interiors – Winglets – Adaptive flaps – Riblets	– Ultra-high bypass ratio – High-pressure-ratio core – Modern turboprop – Geared turbofan	None
Next-gen improvements	– Double bubble fuselage – Laminar flow control – Next generation wings	– Boundary layer ingestion – Open rotor – UltraFan	– Hybrid – Electric – Hydrogen

Sources: ATAG, 2021, Waypoint 2050 (2nd edition); Institut Montaigne, 2022, Decarbonizing Aviation; Kearney Energy Transition Institute analysis

Figure 8
Volume and weight implications of alternative aircraft propulsion systems

Aircraft propulsion system impact by volume and mass
(for a 200-passenger aircraft traveling a distance of 2,000 km)



Sources: Institut Montaigne, 2022, Decarbonizing Aviation: All Abroad; Yusaf, T. et al., 2024, Sustainable hydrogen energy in aviation – A narrative review, International Journal of Hydrogen Energy; Kearney Energy Transition Institute analysis

Aircraft efficiency improvements have traditionally focused on incremental airframe and engine optimizations such as lighter composite materials, winglets, and ultra-high-bypass turbofans. Emerging innovations now go further:

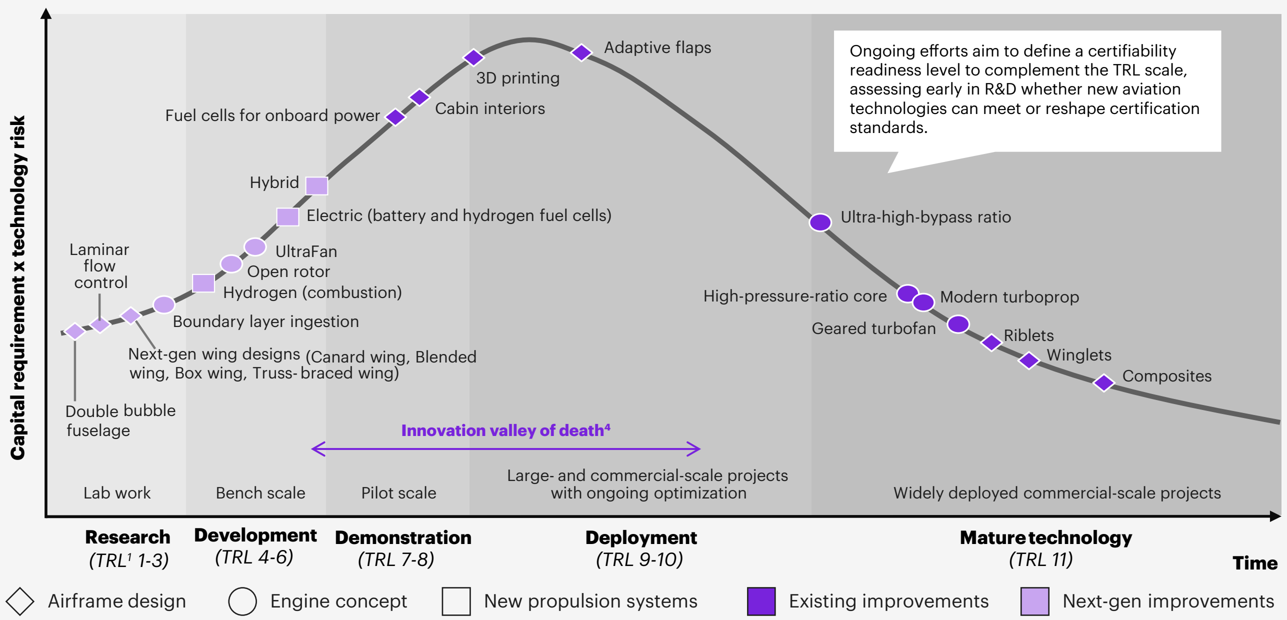
Next-generation airframe designs aim to surpass the efficiency limits of the conventional "tube-and-wing" configuration.

Advanced engine technologies pursue higher fuel efficiency through larger **fan diameters, higher bypass ratios,** and novel concepts such as **open-rotor designs.**

Future breakthroughs will depend on disruptive propulsion systems such as hybrid-electric and hydrogen-based. Currently, replacing kerosene with alternative aviation fuels is the only option that does not change aircraft weight or design.

Figure 9
Mapping maturity of aviation technology solutions

Maturity curve for aviation technology solutions



1. TRL (technology readiness level) scale adapted from IEA (2020), Assessing technology readiness: The ETP Clean Energy Technology Guide
Sources: ATAG, 2021, Waypoint 2050 (2nd edition); Institut Montaigne, 2022, Decarbonizing Aviation; Kearney Energy Transition Institute analysis

New propulsion technologies are being researched and developed to address specific applications:

— **Electric aviation** for short-haul and low-payload urban air traffic

— **Hydrogen fuel cells** for short-haul and regional air travel, but current low energy density limits it to very small prototypes

— **Hydrogen-fueled** aircrafts could serve short- and medium-range routes but require fuel tanks up to four times larger than current jet designs

Some technologies under airframe design and engine concepts are already mature and widely deployed. However, alternative propulsion systems remain in the early development phase, underscoring the need for long-term R&D and certification readiness.

Operational improvements

Operational efficiency provides an immediate, low-cost option to emissions reduction while complementing technological advances. Optimized airspace management, flight trajectory planning, and improved ground operations can collectively reduce fuel consumption by up to 15 percent.

Figure 10
Key levers for achieving operational improvements in aviation

	A Traffic and airspace optimization	B Flight and trajectory optimization	C Ground operation optimization	D Operations and operating practices
Description	Better utilization of the airspace in which airlines operate	Improving how aircraft are used in-flight by airlines	Addressing emissions produced between the gate and the runway	Enhancements in operations, equipment selection, and maintenance
Improvements	– Trajectory-based operations – Advanced navigation – SES/SESAR[1] – Continuous decent/climb – Flexible use of military airspace – Collaborative decision-making – Space-based navigation	– Wake energy retrieval – Flight planning – Optimized trajectories	– Electric/hydrogen taxiing – Stationary power and ventilation – Reduced engine use during taxiing	– Cabin and equipment weight optimization – Fuel and water usage – Interior and cargo cleanliness

1. Single European Sky ATM Research Project is the technological pillar of the EU's single sky initiative.
Sources: Institut Montaigne, 2022, Decarbonizing Aviation: All Abroad; Airlines for Europe, Airports Council International, Aerospace, Security and Defence Industries Association of Europe, CANSO Europe, and ERA, 2025, Destination 2050: A Route to Net Zero European Aviation; Kearney Energy Transition Institute analysis

Air traffic management reforms, particularly through the European Single Sky (SES/SESAR) initiative, could cut intra-European emissions by nearly 6 percent per flight by enabling more direct routing and continuous climb/descent profiles.

Within the suite of operational improvements, contrail management is emerging as a promising near-term opportunity for mitigating non-CO_2 impacts. Recent projects have demonstrated contrail avoidance using real-time meteorological data and AI forecasting. Flight trials achieved over 50 percent reduction in detectable contrails with only 2 percent increase in fuel burn, proving cost-effective for mitigating non-CO_2 effects.

On the ground, electric or hydrogen taxiing, energy-efficient terminal operations, and single-engine taxi procedures can together reduce emissions by up to 7 percent. Best practices such as weight optimization, improved aircraft cleaning, and tankering reduction can further support fuel savings.

Policy and regulation

Effective policy remains the backbone of aviation's transition. Global and regional frameworks are converging around net-zero 2050 targets, with strong emphasis on market-based mechanisms, SAF mandates, and emissions trading systems.

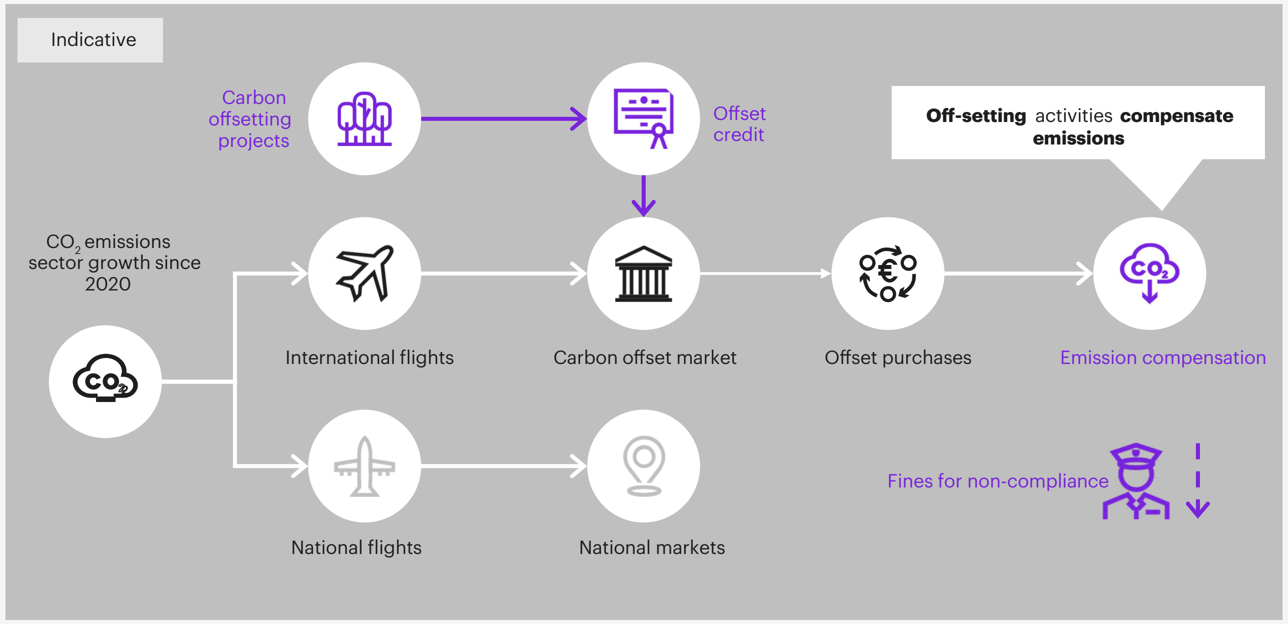
Figure 11
Selected aviation's net-zero targets

Net-zero targets

Type	Organization	Scope	Description
Binding targets	ICAO	Global	85% of 2019 emissions as CORSIA's baseline from 2024 until the end of the scheme in 2035
	EU	Local	EU ETS and free allocation in the aviation sector fully phased out by 2026
	UK	Local	UK has committed to achieve net-zero aviation emissions by 2050 with all domestic flights and airports; in England this net-zero target is more ambitious, expected to be achieved in 2040
Aspirational targets[1]	ICAO	Global	ICAO Member States adopted a collective long-term global aspirational goal (LTAG) of net -zero carbon emissions by 2050
	IATA	Global	The 77th IATA AGM in Boston approved a resolution for the global air transport industry to achieve net -zero carbon emissions by 2050
	DESTINATION 2050[2]	Local	Net-zero carbon aviation in Europe by 2050
	US	Local	The US aviation sector aims to achieve net-zero greenhouse gas emissions by 2050

1. By industry bodies and countries/regions. Additionally, individual industry players have also announced their own net-zero goals.
2. Road map developed by Royal Netherlands Aerospace Centre (NLR) and SEO Amsterdam Economics and commissioned by A4E, ACI EUROPE, ASD, CANSO Europe and ERA. Sources: Kearney Energy Transition Institute analysis

Figure 12
CORSIA carbon offset trading scheme



Note: CORSIA is Carbon Off-setting and Reduction Scheme for International Aviation
Sources: ICAO; Kearney Energy Transition Institute analysis

Worldwide, governments and regulators have positioned SAF as the primary pathway to net zero aviation. Europe leads in policy integration, mandating a 2 percent SAF blend by 2025, 6 percent by 2030, and 70 percent by 2050 under the ReFuelEU regulation. Asia Pacific nations are following suit, with several establishing or finalizing national SAF targets, while the United States pursues a broader strategy—supporting technology innovation, enhancing operational efficiency, modernizing airport infrastructure, and leveraging carbon markets to meet its 2050 net-zero goal.

Yet policy fragmentation and uneven implementation remain key obstacles to global alignment. Achieving scale will require coordinated standards, transparent life cycle emissions accounting, and long-term financing mechanisms to unlock investment and prevent market distortions.

Aviation and carbon markets

ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) is set to become globally mandatory in 2027, covering 99 percent of international emissions.

Aviation has been included in the EU Emissions Trading System (EU ETS) since 2012. With free allowances set to decline and end entirely by 2027, the cost of CO_2 emissions from conventional jet fuel is expected to rise significantly.

Emerging policies on NOx and contrails signal progress (for example, SESAR and FAA programs), though regulation of these non-CO_2 effects still lags behind CO_2 policy frameworks.

Aviation market evolution and projections

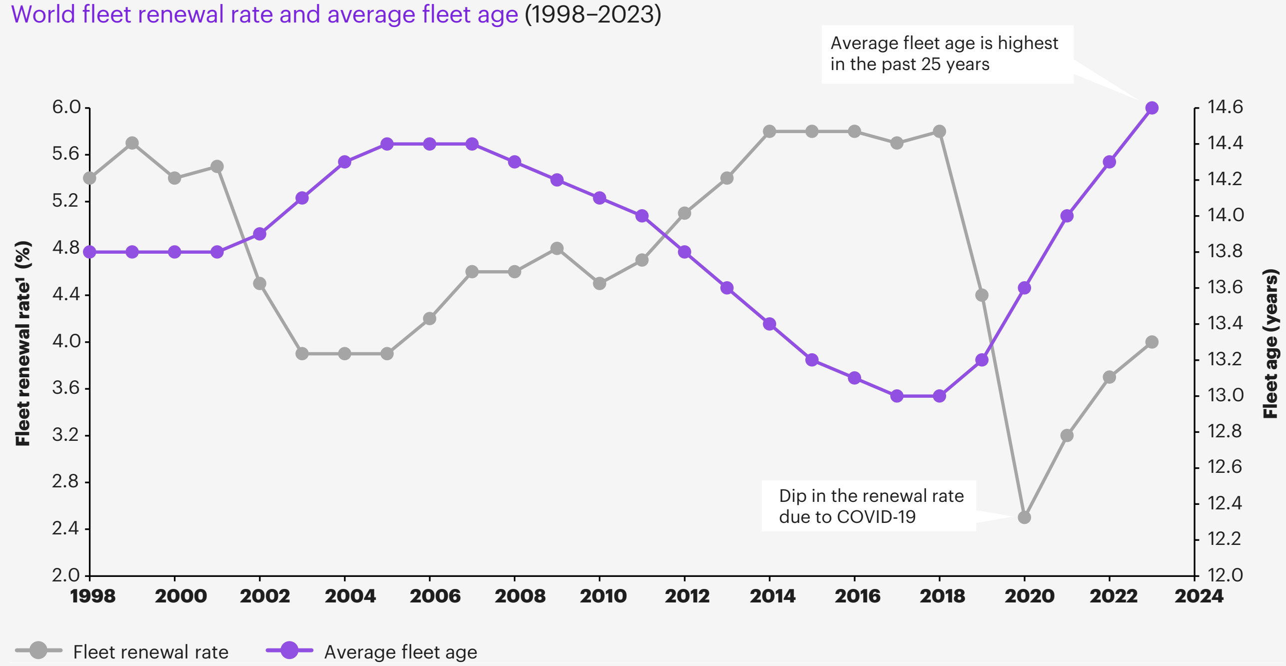
Aviation demand continues to expand rapidly, driven by economic growth and connectivity needs, especially in emerging regions. To decarbonize, airlines are prioritizing SAF, currently using less than 1 percent SAF in their operations, targeting 10 percent by 2030 and an average of 41 percent by 2050.

Airlines are accelerating fleet modernization to cut fuel consumption and carbon emissions, as next-generation aircraft deliver roughly 25 percent lower CO_2 emissions than their predecessors. Fleet replacement and expansion plans aim to replace 19 percent of the current fleet within five years, reinforcing this push toward efficiency.

However, supply constraints are slowing progress. Aircraft deliveries dropped by 50 percent in 2020 compared to the 2018 peak and have remained subdued due to ongoing supply chain disruptions. As a result, the average age of the global fleet has risen by more than 18 months, from just over 13 years in 2018 to 14.6 years in 2023, delaying the full benefits of fleet renewal.

Figure 13
Evolution of global aircraft fleet age and replacement rates

World fleet renewal rate and average fleet age (1998–2023)



1 Renewal rate refers the value of number of delivered aircraft divided by the total number of fleet at the beginning of applicable calendar year.
Sources: Airbus, 2024, Global market forecast; Cirium, 2025, Shaking out the Airbus and Boeing 2024 delivery numbers; Volgina, N. and Kidun, E., 2021, Global Civil Aircraft Industry: Modern Trends; IATA, 2024, Chart of the Week (May 10); Aviation Week, 2024, Fleet discovery; Kearney Energy Transition Institute analysis

Environmental and social impacts

Flight emissions are comparable to other modes of transportation considering direct CO_2 emissions (on passenger-kilometer basis) alone, but overall climate impact is about two times greater when accounting for the contrail effect. Short- and medium-haul flights generate around 63 percent of global aviation emissions.

Aviation infrastructure occupies less land than rail but more than road transport. However, large-scale SAF expansion could exert land-use pressure—meeting 2030 SAF demand via HEFA alone could consume between 66 and 76 percent of the global soybean harvested area.

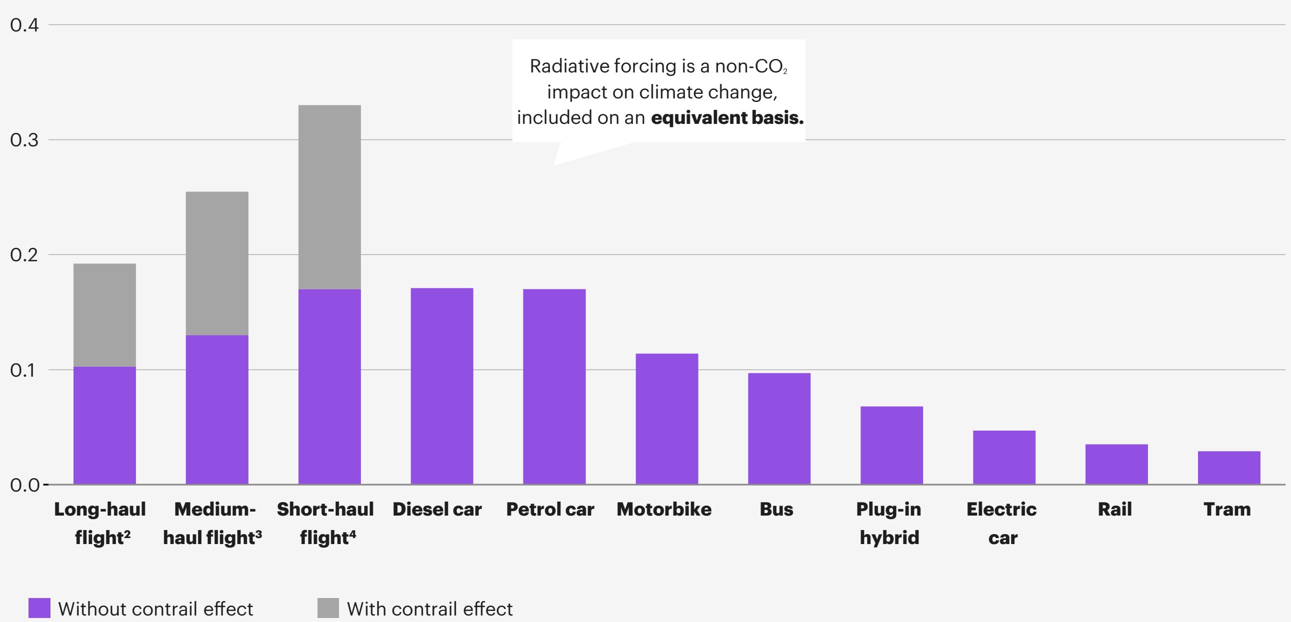
Noise is a significant nuisance; however, noise levels are decreasing due to improved engine designs.

During takeoff, noise peaks at 90 to 110 dBA, while ground operations, such as APU usage and taxiing, produce lower noise levels, ranging from 65 to 80 dBA.

Figure 14

Comparative carbon footprint analysis of transport modes

Carbon footprint per passenger-kilometer traveled for selected modes of transport[1] ($kgCO_2e/pkm$, 2022)



1. These are average values; individual case values can differ significantly on a case-by-case basis.; 2. Considering economy return flight outside Europe; 3. Considering economy return flight in UK; 4. Considering economy return flight in Europe

Sources: GOV.UK, 2022, Greenhouse gas reporting; NASA, 2022, The Contrail Education Project; ADEME, 2022, Elaboration de scenarios de transition écologique du secteur aérien; SkootEco, 2025, Understanding the Air Travel Carbon Footprint: The True CO2 Emissions from Flying; Kearney Energy Transition Institute analysis

Solutions' feasibility and scalability

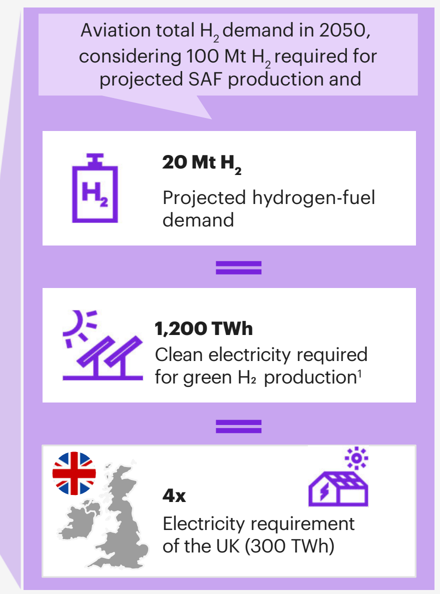
Technology-based solutions are projected to account for about 90 percent of the emissions reduction for the aviation sector by 2050, according to ICAO.

However, these solutions are costly, have different maturity levels, and face uncertainty in scaling quickly enough to meet net-zero targets creating a net-zero gap between the sector's net-zero goals and current implementation.

Figure 15

Decarbonization solutions and adoption challenges—zoom: hydrogen scale-up challenges

Solution	Key challenges	Description
Sustainable aviation fuel	Feedstock availability	– Competition from other uses/industries for biomass-based SAF – Infrastructure gap for PtL pathway
	High production costs	– Feedstock scarcity inflating input costs – High capex – Immature technology (PtL)
Air traffic management	Technical limit, integration issues	– Technical incompatibilities between systems – Lack of global harmonization
Ground operations	Insufficient infrastructure	– Lack of electric charging and hydrogen handling infrastructure at the airports
Fleet renewal	Demand–supply mismatch	– Delays in production due to supply chain disruption
New propulsion systems	Technical limitations, uncertainty over costs	– Low energy density of hydrogen – Green hydrogen costs
Airframe and engine design	Regulatory and production delays, operational trade-offs	– New designs face lengthy approval timelines – Supply chain disruptions – Higher maintenance and recycling needs



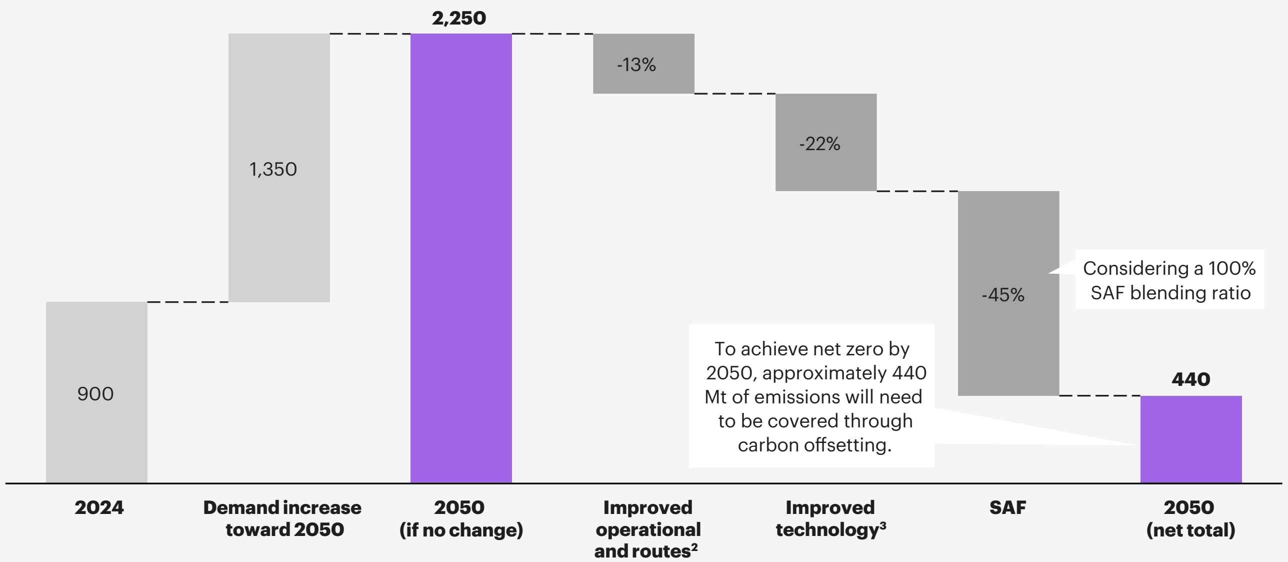
Technology-based solutions detailed in the FactBook

1. Considering production via PEM electrolyzer and accounting for requirements of compression/liquefaction and transmission losses

Sources: Aerospace Technology Institute, 2022, Aviation Emissions – Modelling the road to Net Zero 2050; Airbus, 2025, Airbus advances key technologies for next-generation single-aisle aircraft; IATA, 2024, Aircraft Technology Net Zero Roadmap; IEA, 2025, Aviation; Kearney Energy Transition Institute analysis

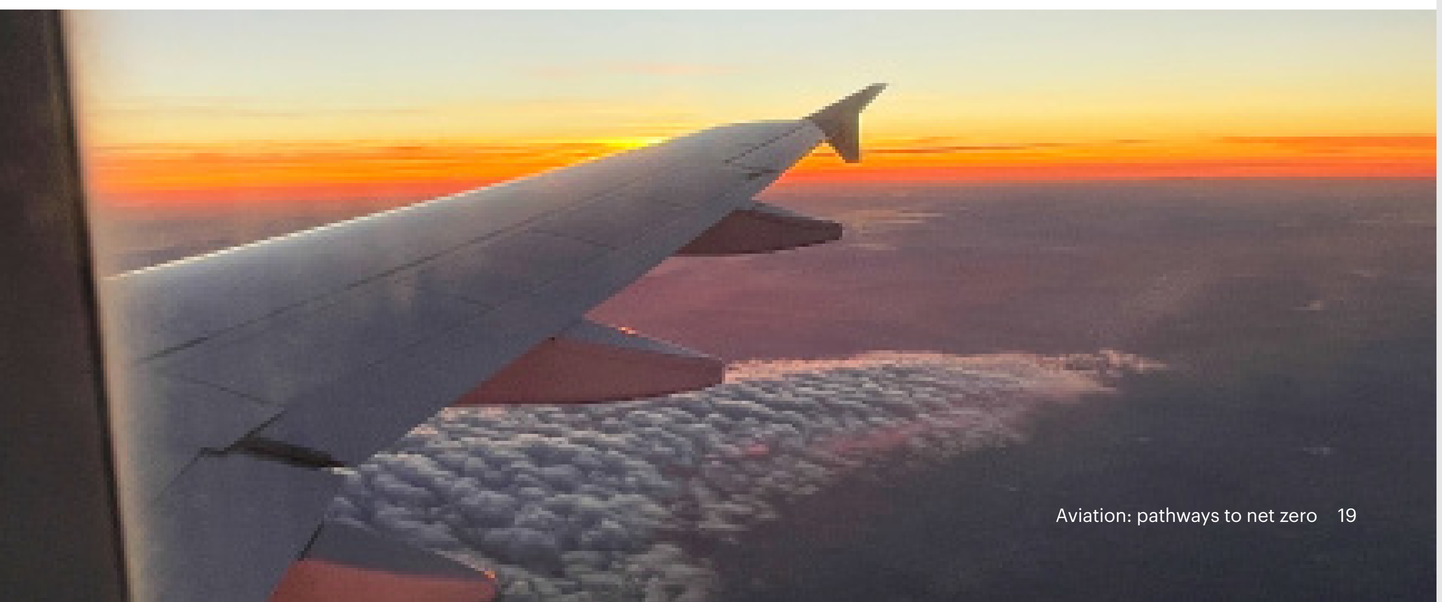
Figure 16
Projected CO_2 reductions and remaining gap for global aviation

Global CO_2 emissions for aviation[1] (Million tons, 2024–2050)



1 The analysis is considering that aviation only consists of passenger aviation, which currently represents 71% of emissions.; 2 Operational and route efficiency included optimizing airspace, routes, ground operations, loads, and maintenance practices to reduce fuel burn.; 3 Technology improvements refer to efficiency gains including aerodynamics, improved engine performance, and load factor improvements.
Sources: Kearney Energy Transition Institute analysis

Aviation's path to net zero will demand a coordinated, multi-pronged approach—combining rapid SAF scale-up, targeted R&D in new technology solutions, operational excellence, and robust policy alignment, supported by high-integrity carbon offsets and removals to address residual emissions.



Acknowledgements

The Kearney Energy Transition Institute wishes to acknowledge the following people for their review of this FactBook: Marc Delcourt and Martin Stephan (respectively, CEO and chief business officer at Global Bioenergies), Prof. Laurent Joly (Director of the Institute for Sustainable Aviation), as well as Dr. Adnan Shihab Eldin, Dr. Martha J. Crawford, Richard Forrest, Antoine Rostand, Erik Peterson, and Maria de Kleijn, members of the Kearney Energy Transition Institute board. Their review does not imply that they endorse this FactBook or agree with any specific statements herein. The review/assessment is based on own reviewers' views and opinions and does not necessarily reflect the views or positions of any entities they represent.

About the Kearney Energy Transition Institute

The Kearney Energy Transition Institute is a nonprofit organization that provides leading insights on global trends in energy transition, technologies, and strategic implications for private sector businesses and public sector institutions. The Institute is dedicated to combining objective technological insights with economic perspectives to define the consequences and opportunities for decision-makers in a rapidly changing energy landscape. The independence of the Institute fosters unbiased primary insights and the ability to co-create new ideas with interested sponsors and relevant stakeholders.

About Kearney

Since 1926, Kearney has been a leading management consulting firm and trusted partner to three-quarters of the Fortune Global 500 and governments around the world. With a presence across more than 40 countries, our people make us who we are. We work impact first, tackling your toughest challenges with original thinking and a commitment to making change happen together. By your side, we deliver—value, results, impact.

Authors

Jean Boschat
Partner
jean.boschat@kearney.com

Romain Debarre
Partner and Managing Director, ETI
romain.debarre@kearney.com

Prashant Gahlot
Global Insights Expert
prashant.gahlot@kearney.com

Nathalie Ledanois
Manager
nathalie.ledanois@kearney.com

Sandy McLaughlin
Specialist Sr Analyst
alexander.mclaughlin@kearney.com

Ioannis Poulopoulos
Specialist Sr Analyst
ioannis.poulopoulos@kearney.com