4

Aviation industry net-zero tracker

The industry must prioritize sustainable aviation fuel and aircraft design improvements while advancing novel propulsion technologies to reduce long-term emissions.

- With passenger numbers recovering to pre-COVID-19 pandemic levels, the aviation industry is encountering difficulties related to increasing emissions.
- Despite SAF production tripling in a year, it still accounts for a small portion of total jet fuel use, indicating the need for significant investment.

18%
Increase in absolute CO_2 emissions (2022-2023)

14%
Decrease in emission intensity (2022-2023)

37%
Increase in demand (2022-2023)

AVIATION

Key performance data 2023[87,88,89,90]

2.5%	0.94 Gt CO_2e	8%	118 gCO_2e/RPK
Contribution to global CO_2e emissions	Scope 1 and 2 emissions (2023)	Emissions reduction (2019-2023)	Emissions intensity (2023)
3%	2.1 times	<1%	$5 trillion
Decrease in emission intensity (2019-2023)	Demand increase by 2050 in IEA's NZE scenario, compared to 2023	Low-emission aviation fuel consumption	Additional investment required for net zero by 2050

Performance summary

- Global air passenger traffic surged by nearly 37% in 2023, with total revenue passenger kilometres (RPK) reaching 94% of pre-COVID-19 pandemic levels from 2019. This highlights a strong recovery in the industry.[91]
- The absolute direct emissions were 0.94 Gt CO_2e[92] in 2023 – an 8% reduction from 1.02 Gt CO_2e[93] in 2019.
- The industry has decreased emission intensity by 3%[94] in the last five years.
- In 2023, SAF volumes reached over 600 million litres (0.5 Mt), double the 300 million litres (0.25 Mt) produced in 2022, but still only amounting to 0.2% of all aviation fuel for the year.[95] SAF production volume is projected to triple to 0.53%[96] of aviation's fuel need in 2024.
- Energy intensity reduced by 19% from 14.9 megajoules of energy used per revenue tonne kilometre (MJ/RTK) in 2020 to 12.1 MJ/RTK in 2022.[97]

Future emissions trajectory

- The industry is forecasted to reduce emissions intensity by 13%[98] by 2030 and 76%[99] by 2050, compared to 2023 levels, according to IATA Net-Zero Roadmap S2 scenario. The absolute direct CO_2e emissions are expected to be 1.12 Gt[100] in 2030 and 0.47 Gt[101] in 2050.
- In the aviation industry, 75%[102] of publicly traded companies consider climate change in their operational decision-making processes.

Readiness key takeaways

Category	Score	Trend	Key takeaways
Technology	2	⊖	– HEFA and other biofuels are the most advanced, with TRL of 8-10,[103] and are already commercially available. – Battery-electric and hydrogen fuel cell technologies are in the early prototype stage, with a TRL of 4-5, and are projected to become commercially viable by 2030.[104]
Infrastructure	2	⊖	– 100 MTPA of clean hydrogen, 700 MTPA of CCUS, and 400 MTPA of biofuel are required by 2050.[105] – Efforts are needed to build capacity for SAF, as less than 1%[106] of the 2050 SAF production capacity is currently available.
Demand	2	⊖	– Less than 1%[107] of current aviation energy consumption comes from low-emissions sources. – The green premium to produce SAF is estimated to be 2-5 times more expensive than conventional jet fuel.[108] – Identifying more potential feedstocks and diversifying SAF production could be a solution to meet the demand.
Capital	1	⊖	– Industry requires over $5 trillion[109] in cumulative investments to achieve net zero by 2050 (i.e. $179 billion[110] annual investment, compared to current CapEx of $68 billion[111] annually) – Of the investment required by 2050, 52% is for fuel production and 36% is for upstream renewable electricity generation by the ecosystem.[112]
Policy	3	⊖	– Establishing clear blending mandates, reducing cost differentials, de-risking projects and increasing SAF usage in public-sector travel are crucial initiatives. – In 2024, Japan, Brazil, Malaysia and the UK all introduced mandates for SAF entering into force in the coming years.

Sector priorities

Company-led solutions

Mid-term (by 2030)

- Reduce fuel consumption through air traffic management (ATM) improvement and operational efficiencies.
- Scale the use of SAF.

Long-term (by 2050)

- Invest in R&D for low-TRL technologies and efficiency measures to reduce energy demand.

Ecosystem-enabled solutions

Mid-term

- Reduce the cost differential between SAF and fossil jet fuel (e.g. by direct or indirect subsidies).

Long-term

- Develop refuelling/recharging infrastructure for zero-emission aircraft at key airports.
- Develop CCUS facilities to meet the 2050 demand.

Performance

The sector currently accounts for 2.5%[113] of global CO_2e emissions. Fossil fuels (mostly Jet-A and Jet A-1 kerosene) account for over 99%[114] of fuel consumption in the industry, making them a critical driver for emission intensity.

TABLE 4

Aviation industry performance

Performance metric	Change (2019-2023)
Industry activity (RPK)	-5.9%[115]
Emission intensity (gCO_2/RPK)	-3%[116]
Total CO_2e emissions	-8%[117]

In 2023, industry traffic (RPKs) reached 94%[118] of 2019 levels and rose 37% compared to 2022. The aviation industry has seen a significant rebound post-pandemic, with global revenues projected to surpass pre-2019 levels.

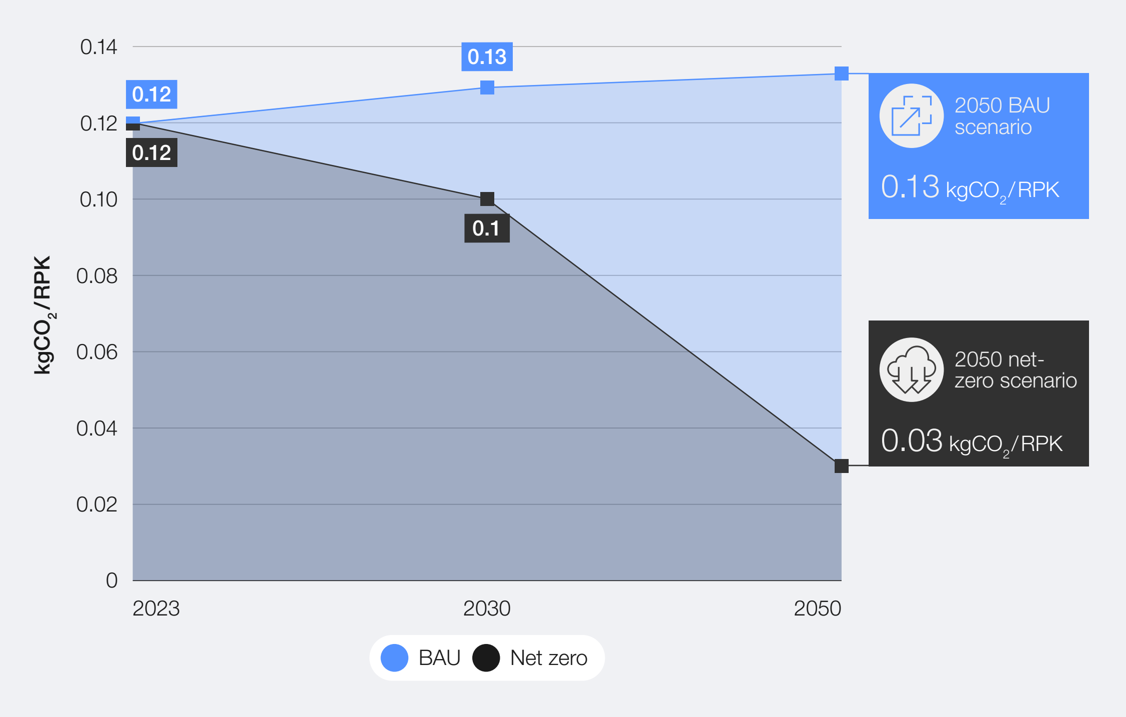
Airlines have started using SAF in limited quantities, aiming to reduce their dependence on traditional fossil fuels. However, the high cost and limited availability of SAF present significant challenges for scaling its use. Among the largest SAF users in 2023, DHL[119] partnered with IAG Cargo and Air France-KLM[120] to sign a major 10-year agreement for the supply with TotalEnergies, marking more milestones on the journey towards sustainable air freight.

Airbus[121] is making progress towards zero-emission propulsion, announcing a number of collaboration agreements with global airports in 2024. New market entrants such as ZeroAvia[122] are developing hydrogen-electric powertrain plans to bring a retrofitted hydrogen-powered aircraft with this ramped up capability to market by 2027.

Readiness

FIGURE 23

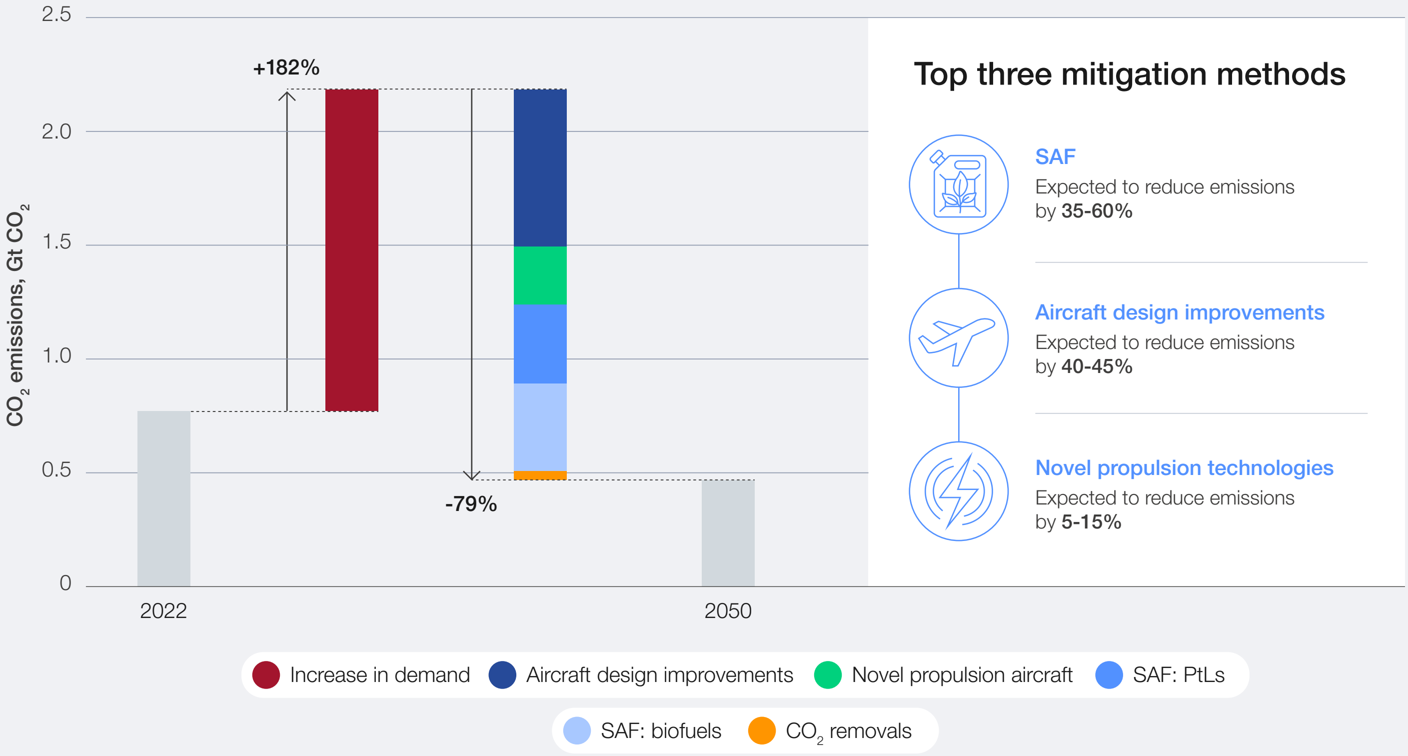
Emissions intensity trajectory for aviation sector



Source: IATA and ICCT.

Overall aviation activity demand is expected to more than double by 2050, increasing by a factor of 2.1 compared to 2023.[123] The Asia-Pacific[124] region is expected to account for about half of new passengers by 2036, driven by rapid income growth. In order to align with the Net Zero Emissions by 2050 Scenario, scaling up longer-term solutions like SAF and electric or hydrogen-powered aircraft is essential. Key strategies include diversifying SAF feedstocks, establishing blending mandates, reducing cost differentials and de-risking projects.

FIGURE 24 **Decarbonization levers and top mitigation methods (MPP's NZE Scenario)**



Source: MPP.

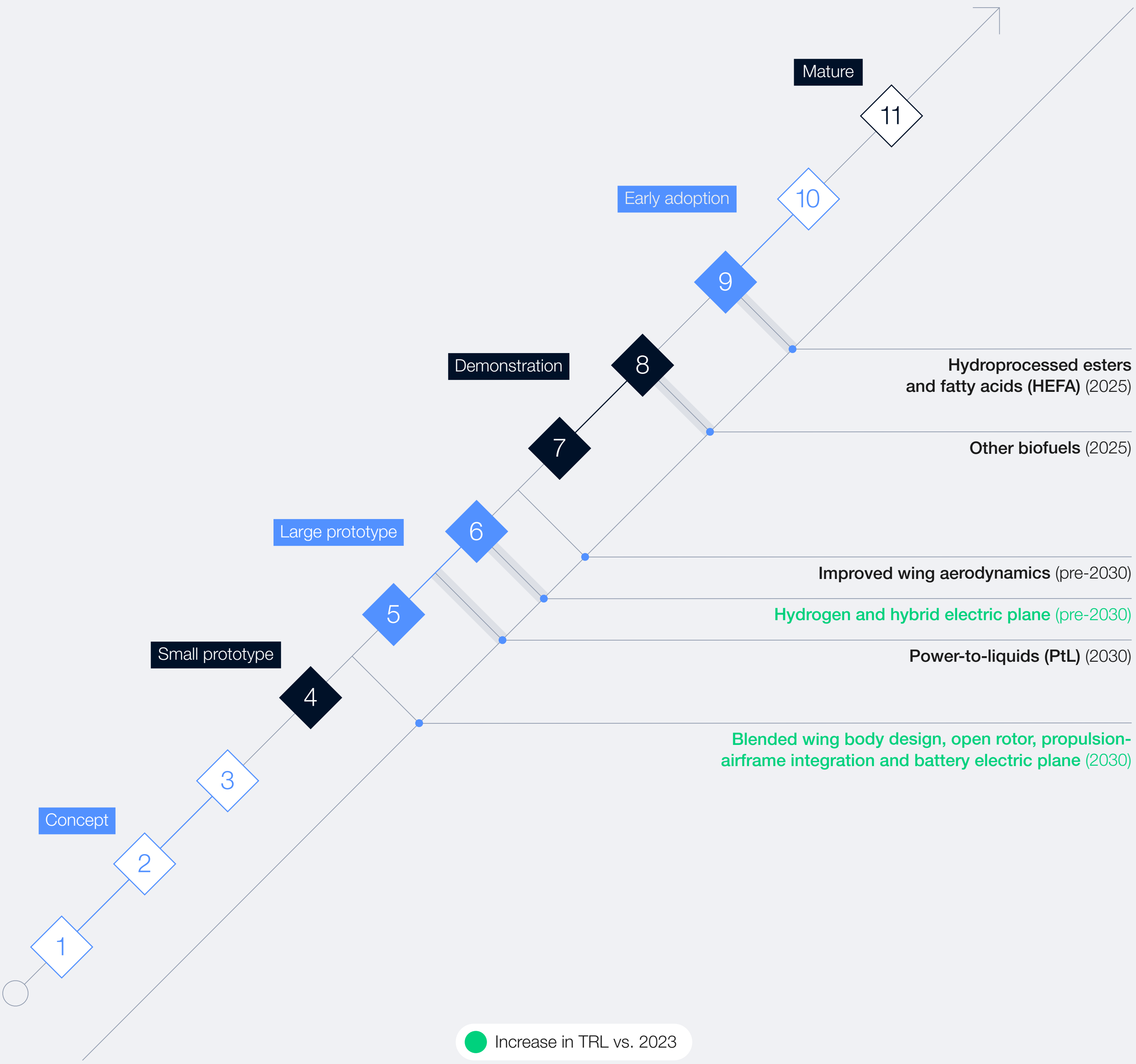
2

AVIATION

Technology

Technologies to implement aviation decarbonization levers are at different readiness levels. Three leading pathways have emerged: SAF, fuel efficiency and novel propulsion technologies.

FIGURE 25 **Decarbonization TRLs and year of commercial availability**



Source: Accenture analysis derived from data from IEA ETP Clean Energy Technology Guide and MPP.

Technology pathway 1: SAF

SAF includes biofuels made through various pathways such as hydroprocessed esters and fatty acids (HEFA), the Fischer-Tropsch process (FT) and alcohol-to-jet (AtJ), as well as synthetic aviation fuels made from captured carbon and low-emissions hydrogen electrolysis, known as power-to-liquids (PtL) or e-fuels. HEFA is currently the most mature, and likely to remain so until 2030, with 85%[125] of announced SAF production facilities using this pathway. PtL is advancing rapidly and offers long-term scalability due to its reliance on renewable resources, but costs remain high. Regulatory frameworks, like the EU's ReFuelEU initiative, are pushing for increased adoption, with targets of 70%[126] SAF blends of which half (35%[127]) must be PtL by 2050.

Technology pathway 2: Aircraft design and air traffic management improvements

Over the past decade, the aviation industry has made huge progress in making its aircraft and flight procedures more efficient. Within normal fleet turnover cycles, the replacement of retired aircraft with new, more efficient aircraft leads to regular efficiency improvements. Fuel efficiency measures in aviation, such as advanced engine designs and lightweight materials, are progressing rapidly but are still in early-stage development. Retrofitting winglets to aircraft wings could be a short-term solution to reducing emissions. Continued investment is essential in enhancing fuel efficiency for conventional engines, along with improved airframe design, ground operations, ATM and route planning. Other advancements such as reducing cabin weight or switching to electric taxiing, optimized approach/departure procedures, vertical speed inefficiency reductions during cruise from improved aerodynamics, improved congestion management, single-engine taxiing, and engine washes also offer potential for reducing emissions.

Technology pathway 3: Novel propulsion technologies

Novel propulsion technologies in aviation, such as hydrogen fuel cell/combustion, battery-electric and hybrid-electric aircraft are gaining momentum but at large prototype and demonstration stages of readiness and expected to be commercially available by 2030. Hydrogen-powered aircraft, like Airbus' ZEROe concept,[128] aim for commercial availability by 2035, with a TRL of 5-6, still in large prototype stages. For hydrogen, key challenges include its production, transportation and assessing its environmental impact (e.g. contrail formation when burned). Battery-electric aircraft, while promising for short-haul flights, currently suffer from low energy density, holding just one-fiftieth of the energy of jet fuel by weight. The main challenge with battery-electric aircraft is using batteries with high enough energy density, which do not exist for large passenger planes, limiting their potential application to small and short-range flights. Hybrid-electric aircraft, which combine traditional fuel with electric propulsion, are closer to commercialization and are expected to play a crucial role in the near term. Hybrid-electric aircraft, like the Ampaire Electric EEL,[129] are at demonstration phases (TRL 6-7), targeting broader use by 2030.

AVIATION

2 Infrastructure

The aviation industry needs SAF facilities to facilitate the conversion of feedstocks into fuel. Production is in early stages, with SAF accounting for less than 1%[130] of total fuel usage. The transition to alternative fuels beyond producing SAF will also require the adaptation and retrofitting of existing airport facilities. In the case of Chicago, Neste[131] needed to add new port terminals hundreds of miles away, while for other cases, new blending facilities or hydrant systems at airports may be required to supply SAF while keeping in mind the current blend limit of 50%. Some airports have begun implementing hydrogen-operated ground support equipment (GSE), and the UK has launched its first hydrogen landside-to-airside pipeline demonstrator.[132] However, there is currently no airport hydrogen infrastructure for aircraft propulsion anywhere in the world.

Substantial investments in renewable energy infrastructure are also required to meet future demand, alongside advancements in CCS technologies to mitigate emissions from conventional aviation operations during the transition phase. Selected airports are generating renewable energy on-site and are also deploying charging stations for both road vehicles and GSE.

FIGURE 26 **Infrastructure for decarbonization capacity**

	Current capacity used	Capacity required (2050)
SAF/biofuels	0.08 MTPA	400 MTPA
Clean hydrogen production	~0 MTPA	44 MTPA
CO_2 transport and storage	0.004 MTPA	700 MTPA

Source: Accenture analysis derived from data from IATA and IEA.

AVIATION

2 Demand

Less than 1%[133] of current aviation energy consumption comes from low-emissions sources, highlighting the nascent stage of SAF adoption. To meet the net-zero target by 2050, the IATA states that SAF must constitute at least 5.2% of the total jet fuel requirement by 2030.[134] The green premium to produce SAF is estimated to be 2-5 times more expensive than conventional jet fuel.[135] Despite the higher costs, SAF has lower density but higher energy content per kilogram of fuel compared to conventional kerosene. This gives some aircraft fuel-efficiency advantages, due to lower fuel burn and less fuel mass to achieve the same distance. Government incentives and policies are crucial to offset the high costs and encourage the adoption of SAF.

Increasing production through pathways that are already certified, fast-tracking of certification for new pathways and identifying more potential feedstocks are essential strategies to meet the growing demand for SAF. Identifying and prioritizing high-potential production projects for investment support and delivering a global SAF accounting framework are also key in supporting SAF production.

FIGURE 27 **Air passenger market – world share, 2023[136] and top 5 busiest global airports by monthly seats – October 2024 (millions), 2024[137]**

	Air passenger market – 2023 world share % (industry RPKs)	
1	Asia-Pacific	31.7%
2	Europe	27.1%
3	North America	24.2%
4	Middle East	9.4%
5	Latin America	5.5%

	Top five busiest global airports by seats (millions)	
1	Atlanta Hartsfield-Jackson International Airport	5.43
2	Dubai International	5.12
3	Tokyo International (Haneda)	4.77
4	London Heathrow	4.48
5	Dallas Dallas/Fort Worth International Airport	4.46

AVIATION

Capital

The aviation industry will require a capital investment of $5 trillion[138] to develop and implement low-emission technologies and infrastructure. This investment is required from the broader aviation ecosystem to build the necessary infrastructure, such as SAF production facilities and hydrogen refuelling stations at airports.

It is projected by MPP that out of the total additional investment required, about 52% ($2.6 trillion) is anticipated from fuel producers, 44% ($2.2 trillion) from energy providers (including CO_2 capture companies), less than 0.1% from airports, and 4% ($0.2 trillion) from airlines.[139] Thus, the vast majority of investment needs to be carried out to deliver low-carbon fuel, with significant pass-through of cost to airlines and eventually to passenger and cargo customers.

FIGURE 28 **Investments required by the sector and enabled by the ecosystem**

$5 trillion required in investment by 2050

Investments by the sector (around 5% of investments)

- Retrofit airports with SAF infrastructure
- Demand creation via offtake agreements
- Invest in R&D for low-TRL technologies
- Air traffic management improvement
- CO_2 capture (from PSC and DAC)
- Build refuelling/recharging infrastructure
- Airport hydrogen storage infrastructure

Enabled by the ecosystem (around 95% of total investments)

- SAF production
- Low-temperature electrolysers (for hydrogen production)
- CO_2 capture plants for SAF
- Manufacture more efficient turbines and aerodynamic airframes
- Manufacture hydrogen and battery electric aircraft
- Renewable electricity production

SAF · Fuel efficiency measures · Novel propulsion technologies

Note: Original equipment manufacturers (OEMs) and manufacturers are classified as the ecosystem in this figure.

Source: Accenture analysis based on data from MPP.

3

AVIATION

Policy

The EU, US and several other high-aviation countries have led the world in both mandate and incentive policies encouraging the adoption of low-carbon technologies, especially SAF. For example, the European aviation ecosystem has come together to develop an action plan to unlock final investment decisions (FIDs) for e-SAF projects in Europe.[140]

Nevertheless, aviation is inherently a cross-border activity and will require harmonization and mutual recognition of carbon accounting frameworks and sustainability standards to ensure transparency and accountability for low-carbon technology deployment. States will need to work with sustainability verification organizations to strengthen the accuracy of emissions reporting and ensure that ecosystem actors adhere to clear, consistent guidelines. The IATA's TrackZero[141] initiative underscores the industry's commitment to promoting standardization and transparency in emissions tracking, facilitating collaboration among airlines and stakeholders to share best practices, and supporting the development and adoption of SAF to reduce reliance on fossil fuels. Book and claim systems, which decouple physical SAF from its environmental attributes, allow buyers to pay for SAF while avoiding the extra cost and inefficiency of transporting SAF to areas that lack the infrastructure to receive it. The proper implementation of book and claim systems will require coherent and reliable policy frameworks across borders.

Improved carbon accounting will also ensure policy compliance and provide essential clarity to both consumers and industry stakeholders, promoting accountability across the sector.

TABLE 5 **Aviation industry policy summary**

Policy type	Policy instruments	Key examples	Impact
Market-based	**Carbon price**	EU Emissions Trading System (ETS)[142]	Sets a cap on carbon emissions that tightens over time. Obligated industries are required to buy allowances for each ton of carbon emitted above this cap and are thus incentivized to reduce emissions due to the cost of purchasing carbon credits or allowances. A total of 20 million "free" allowances are reserved for airlines that use SAF, serving as a quasi-incentive.
	Product standard	ASTM standards for SAF pathways[143]	ASTM is of crucial importance for the aviation fuel industry as it is the basis of the international standard for jet fuel quality, and SAF in particular. It defines which feedstocks must be used, the processes that act on those inputs and the properties of the outputs for each pathway.
Mandate-based	**Direct regulations**	ICAO CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation)[144]	CORSIA obligates certain airlines to offset all international aviation emissions above a baseline from 2019, and thus creates demand for certified carbon offset projects outside the aviation sector. Low-carbon technologies reduce emissions outright and thus lower the amount needed to be offset through CORSIA.
		FAA Aircraft CO_2 standards[145]	These standards mandate fuel efficiency improvements, which reduces emissions per flight, leading to cumulative reductions in CO_2 emissions over the life of an aircraft.
	Government targets	ReFuelEU Aviation mandate[146]	Mandates that from 2025 onwards, a proportion of the fuel supplied at EU airports must be SAF. Starting with a 2% share of SAF from 2025, this proportion is set to gradually increase to 70% from 2050.
Incentive-based	**Subsidies**	US Inflation Reduction Act 45Z tax credit[147]	Lowers the cost of SAF production, making it more competitive with conventional jet fuel, driving greater adoption by airlines.
	Incentives	UK revenue certainty mechanism for SAF[148]	As uncertainty over future revenues remains a barrier to investment, a revenue certainty mechanism will provide greater certainty to investors for a defined period of time, driving investment in SAF production in the UK.
	Direct R&D funds/grants	EU's Clean Sky Initiative[149]	This initiative funds projects on SAF, electric aircraft and advanced aerodynamics to cut carbon footprints.

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