THE IMPACT OF THE NET ZERO GOALS BY 2050 IN THE AVIATION SECTOR

ALG

September 2025

DECARBONISING AVIATION: THE ROAD TO NET ZERO BY 2050

Climate change is one of the most pressing global challenges of our time, and achieving net-zero greenhouse gas emissions by 2050 has become a central objective in addressing it.

Net zero refers to balancing the amount of greenhouse gases released into the atmosphere with those removed. In line with the Paris Agreement—which aims to limit the rise in global average temperature to well below 2°C above pre-industrial levels, while pursuing efforts to cap it at 1.5°C—the Intergovernmental Panel on Climate Change (IPCC) has identified reaching net zero by 2050 as a key milestone. Governments and industries worldwide are increasingly aligning their strategies and policies with this target.

To achieve global net zero, all economic sectors must contribute, and aviation represents a particularly challenging case.

In today's globalized world, aviation plays a critical role in connecting people, goods, and economies across long distances in minimal time.

It is a key enabler of international trade, tourism, and business, making it indispensable to the global economy.

According to Airport Council International (ACI) and the International Civil Aviation Organization (ICAO)[1], as the worldwide economy develops, aviation continues to expand, with passenger traffic expected to grow at an average annual rate of 3.6% until 2050.

This growth is driven by rising demand in emerging markets, increasing global mobility, and the continued integration of international supply chains.

However, the expansion of aviation comes with a growing environmental footprint.

The European Commission reports that aviation currently contributes about 2% of global CO_2 emissions[2], and its decarbonization presents unique challenges.

Unlike other transport modes, such as road or rail, aviation remains heavily dependent on fossil-based fuels.

[1] Climate EC Europa

[2] Climate EC Europa

Scalable technological alternatives, including electric propulsion, are not yet viable for medium and long-haul flights.Sustainable Aviation Fuels (SAF) represent a promising pathway toward decarbonization, but their production capacity, cost competitiveness, and supporting infrastructure remain limited.

The sector lacks the maturity and scale required for rapid adoption. Meanwhile, international decarbonization policies and regulatory frameworks are gradually taking shape.

Initiatives such as ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), along with ambitious regional strategies in Europe and beyond, mark a progress. Further harmonization is needed, but these efforts provide a foundation for aligning global action with aviation's decarbonization goals.

The ambition to reach net zero by 2050 is clear. The critical question is not if, but how—and at what cost and pace. Aviation faces a dual challenge: reducing emissions quickly enough to meet climate targets while maintaining competitiveness within a fragmented regulatory landscape.

This paper examines the policies, technologies, and strategies at stake, as well as their implications for industry decision-makers navigating the complex path toward sustainable aviation.

HOW IS THE AVIATION SECTOR CURRENTLY MOBILISING TO ACHIEVE ITS NET ZERO TARGETS BY 2050?

Achieving climate neutrality in aviation will not result from a single breakthrough. Rather, it requires a coordinated combination of policy action, technological innovation, and pragmatic deployment of proven initiatives.

The regulatory landscape plays a central role in guiding this transition. At the global level, the International Civil Aviation Organization (ICAO) sets overarching standards, while regional frameworks such as the European Union Emissions Trading System (EU ETS) provide a European approach. Complementing these, global market-based mechanisms like CORSIA establish a coordinated backbone for worldwide action.

Building on this context, the main strategies for achieving net zero can be grouped into three pillars:

1. **Technological improvements:** development of next-generation propulsion systems and aircraft designs.
2. **Sustainable Aviation Fuels (SAF):** large-scale production and deployment.
3. **Operational enhancements:** efficiency gains through improved air traffic management and optimized flight operations.

Scaling these strategies presents significant challenges, including the need for strong policy support, public–private collaboration, and coordinated investment to accelerate progress.

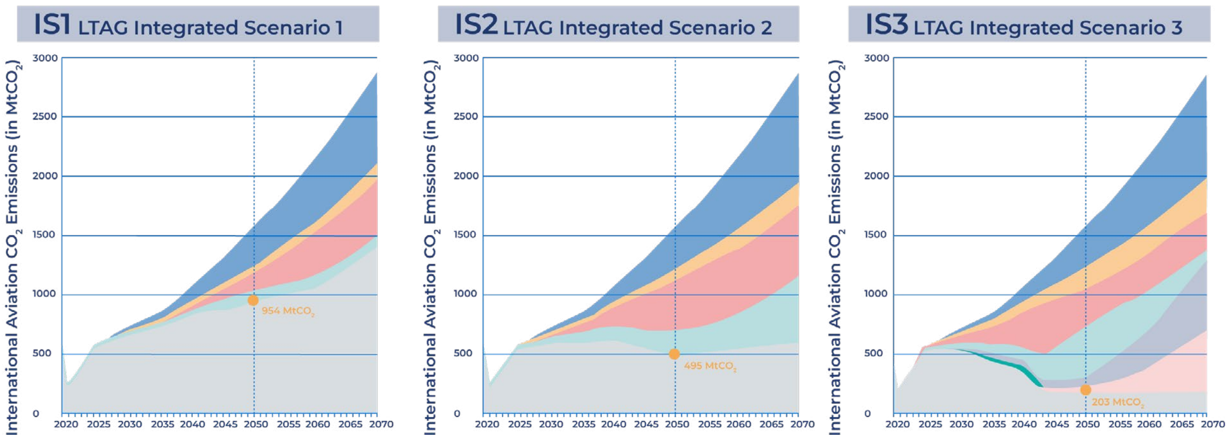
By combining the broader strategic landscape with ALG's specific contributions through its projects, this paper provides a clear perspective on the opportunities, limitations, and priorities shaping aviation's transition toward climate neutrality.

1. INTERNATIONAL AND EUROPEAN REGULATORY CONTEXT TO ACHIEVE NET ZERO IN 2050

a) At the international level (ICAO)

ICAO's adoption of the Long-Term Aspirational Goal (LTAG) in 2022 marked a milestone in aligning international aviation with climate targets. For the first time, States reached a consensus to achieve net-zero carbon emissions from international aviation by 2050, integrating the sector with the temperature goals of the Paris Agreement.

The LTAG outlines three illustrative scenarios, reflecting different levels of ambition based on a combination of technological innovation, SAF, and operational improvements. These scenarios offer strategic framework to support States and industry stakeholders in developing long-term decarbonisation strategies.



Caution required with the interpretation of absolute CO_2 emissions levels after 2050 due to modelling assumptions e.g., frozen aircraft technology after 2050. Under these assumptions, CO_2 emissions are higher than in an alternativa scenario (and modelling approach) where aircraft technology would continue to improve after 2050.

- Aircraft technology
- Operations
- LTAG-SAF Biomass based fuel
- LTAG-SAF Gaseous waste based fuels
- LTAG-SAF Atmospheric CO2 based fuels
- Non drop in fuels: Cryogenic Hydrogen
- LTAG-LCAF: Lower carbon pretoleum fuels
- Residual CO2 Emissions

Figure 1: CO2 emissions from international aviation associated with LTAG Integrated scenarios [3]

[3] ICAO

The scenarios were developed to cover a range of readiness, feasibility, and ambition. Integrated Scenario (IS1) reflects a low-ambition but highly attainable trajectory, grounded in today's expectations for technology, operations, and sustainable fuel supply, and requiring limited adjustments to the current system.

IS2 represents a medium-ambition pathway, with moderate feasibility, assuming accelerated technology uptake, expanded access to sustainable fuels, and some degree of infrastructure adaptation.

IS3 outlines a high-ambition but low-feasibility pathway that depends on maximum technological progress, broad international alignment, and significant infrastructure transformation.

The implementation of the LTAG is supported by existing and emerging policy tools, most notably CORSIA, which remains the only global market-based mechanism currently in place to mitigate international aviation emissions.

The LTAG has also acted as a key driver of alignment across the international aviation community. Key organisations such as the European Union Aviation Safety Agency (EASA), ACI, the International Air Transport Association (IATA), the International Federation of Air Line Pilots' Associations (IFALPA), and various Air Navigation Service Providers (ANSPs), have developed roadmaps and strategies aligned with ICAO's climate objectives.

These actors are now working to harmonise standards, certification pathways, and operational frameworks to ensure global interoperability and coherence in the transition towards sustainable aviation.

b) At the European level

Within the European Union, the European Green Deal and the Fit for 55 package set the overarching climate policy framework, with legally binding targets to reduce greenhouse gas emissions across all sectors of the economy. For aviation, the Fit for 55 package sets out a suite of measures aimed at driving sustainability and lowering emissions.

These include adjustments to CO_2 pricing under the EU ETS, the application of CORSIA for international flights, the introduction of a European kerosene tax, and a binding mandate for SAF blending. Together, these instruments are designed to accelerate the sector's decarbonisation:

The EU Emissions Trading System (EU ETS) applies to intra-European flights and is being progressively strengthened by reducing the number of free allowances and tightening the overall emissions cap.

The ReFuelEU Aviation Regulation introduces a mandatory and gradually increasing share of SAF in aviation fuel supplied at EU airports, starting in 2025 and scaling up significantly by 2050. This measure aims to stimulate SAF production and market uptake, reducing life-cycle emissions from aviation fuels.

The Renewable Energy Directive (RED II/III) supports the uptake of renewable energy in transport, including advanced biofuels and e-fuels for aviation, by setting specific targets and sustainability criteria. RED III reinforces the role of renewable fuels of non-biological origin, such as synthetic kerosene, in helping aviation meet its climate targets.

Energy Taxation Directive (ETD), introduces a minimum tax rate for kerosene and promotes the use of SAF through more favourable tax treatment.

These instruments establish a legally binding policy ecosystem that positions the EU as a global leader in aviation climate regulation, complementing and reinforcing international efforts under ICAO.

The EU has established the world's most comprehensive aviation decarbonisation framework, positioning its carriers as early movers. Yet this leadership comes with higher structural costs compared to less-regulated regions, risking competitive distortions and traffic shifts. To preserve both climate integrity and market position, EU airlines must offset compliance costs through operational excellence, SAF partnerships, and innovation—while regulators work to advance global harmonisation.

c) Market-Based measures (CORSIA and EU-ETS)

CORSIA, developed by ICAO, is designed to stabilise net CO_2 emissions from international aviation at 2019 levels. Airlines are required to offset any emissions growth beyond that baseline by purchasing verified carbon credits from approved climate mitigation projects.

ICAO reports that CORSIA is the first global, sector-wide offsetting mechanism and currently covers about 60% of international aviation's CO_2 emissions[4]. The scheme launched its pilot phase in 2021, became fully operational in 2024, and will become mandatory for most participating states from 2027.

It applies only to international flights, with domestic aviation remaining subject to national policies.

In Europe the EU ETS covers all intra-European flights and stands as the world's first and largest carbon market. Free allowances are being phased out at a rate of 25% per year, with full phase-out expected by 2027.

From that point, airlines will be required to purchase allowances to cover all of their CO_2 emissions. Each allowance represents the right to emit one tonne of CO_2 and can be bought, sold, or traded within the market.

By linking emissions to a market-based carbon price, the EU ETS creates a transparent and robust financial signal that drives decarbonisation.

[4] ICAO

The European Commission sets the overall emissions cap and establishes the rules for monitoring, reporting, and verification (MRV), while Member States are responsible for national implementation and enforcement.

Revenues from the auctioning of allowances are increasingly channelled into climate innovation, supporting the scale-up of SAF and the development of next-generation clean transport technologies.

CORSIA and the EU ETS are essential market-based mechanisms that provide an economic signal to cut emissions, but they do not reduce emissions directly.

CORSIA relies heavily on offsets, while the ETS sets a price on carbon, both of which are effective in the short to medium term, yet transitional by nature. Achieving net zero by 2050 will require direct abatement—through SAF, technological innovation, and operational efficiency—since reliance on offsets can only play a residual role.

For airlines, this means that compliance costs will rise over time: those who act early to integrate SAF, renew fleets, and optimise operations will reduce their exposure to volatility and transform regulatory pressure into a source of competitive advantage.

Ultimately, only direct measures—not market mechanisms alone—will deliver the structural emissions cuts needed to reach net zero.

2. KEY PATHWAYS TOWARD NET ZERO IN AVIATION

To achieve net-zero emissions by 2050, three parallel levels of direct action are being pursued alongside market-based measures such as CORSIA and the EU ETS. In its Net Zero 2050 roadmap, IATA estimates that SAF will contribute around 65% of the total emission reductions needed to decarbonize the sector.

New aircraft technologies could contribute around 13%, while operational improvements, could account for an estimated 3% of total emissions reductions. On the other hand, offsetting and carbon capture are indirect approaches responsible for approximately 19% of the total reduction.

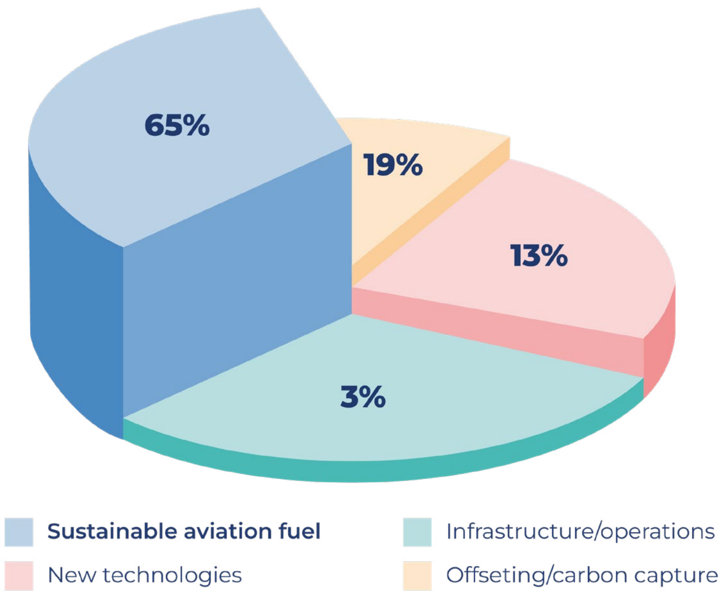


Figure 2: Contribution to achieving Net Zero Carbon in 2050, IATA[5]

[5] IATA

a) Aviation fuels

Aviation fuels represent the most significant opportunity for reducing CO_2 emissions in the sector. These fuels can be grouped into three main categories[6]:

SAF, which are produced from renewable sources such as biomass, waste, or captured atmospheric CO_2.

Lower Carbon Aviation Fuels (LCAF), which are derived from petroleum but refined to deliver reduced lifecycle emissions.

Non-drop-in fuels, such as hydrogen and electricity, which require entirely new aircraft technologies and infrastructure.

Among these, SAF stand out as the most impactful near-term solution. According to IATA, SAF can reduce lifecycle emissions by up to 80% compared to conventional jet fuel[7], depending on feedstock and production process. SAF is a drop-in fuel—compatible with current aircraft engines and airport infrastructure—which enables immediate deployment at scale and accelerates industry-wide decarbonisation.

On the regulatory side, the European Union has adopted ReFuelEU Aviation, which sets mandatory blending targets for fuel suppliers. From 2025, at least 2% of all fuel supplied at EU airports must be SAF, with the requirement increasing progressively to 70% by 2050.

[6] ICAO

[7] IATA

Significant advance is underway in the development and deployment of SAF across the entire value chain from feedstock supply to production, certification, and distribution.

A key driver is the ICAO ACT-SAF programme (Assistance, Capacity-building and Training for Sustainable Aviation Fuels), implemented in partnership with the European Union through EASA.

This initiative supports national and regional SAF strategies, with particular focus on supporting developing countries.

By building regulatory, technical, and institutional capacity, ACT-SAF enables states to scale up SAF production and adoption, fostering a more balanced and globally inclusive transition.

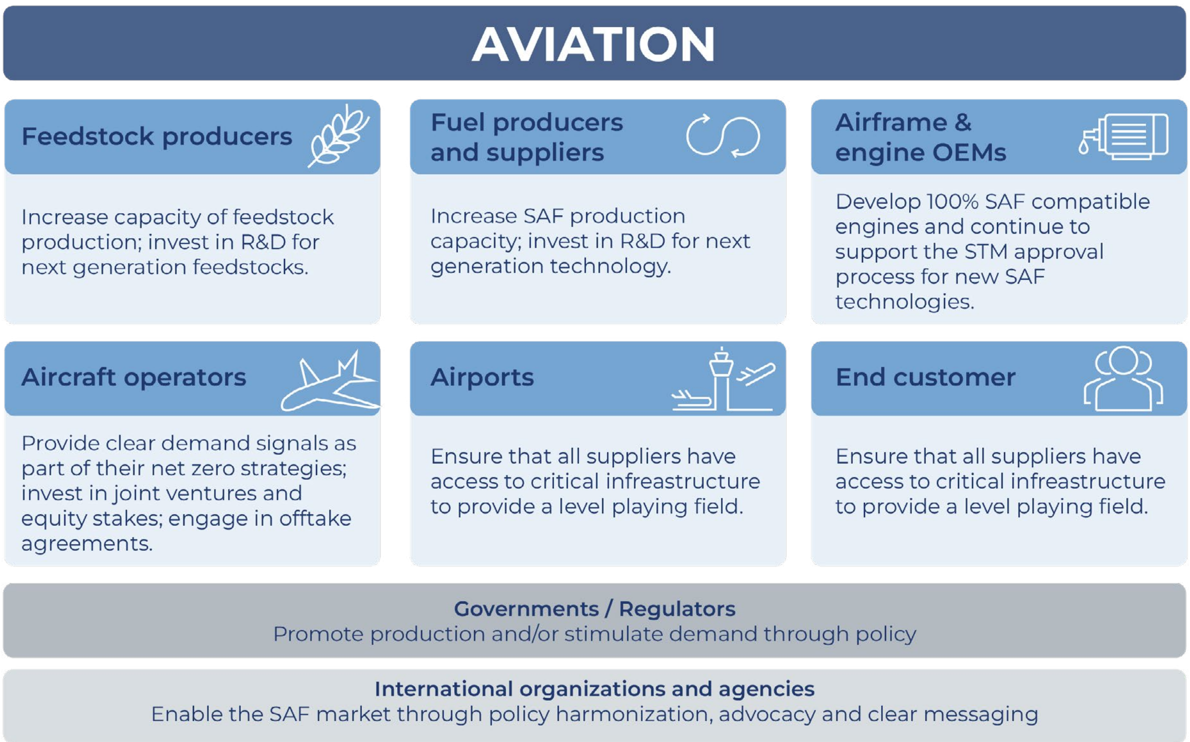


Figure 3: Stakeholder engagement across sectors for the deployment of SAF[8]

[8]Source: IATA SAF Handbook, May 2024

SAF represents the single most impactful lever for aviation decarbonization to 2035, with the potential to cut lifecycle emissions by up to 80%. Its “drop-in” compatibility makes it the only scalable near-term option to reduce emissions without waiting for new aircraft technologies.

However, severe barriers remain: limited feedstock, high production costs—currently 2–5 times higher than conventional fuel—and uneven regional mandates.

Without coordinated policy support, airlines risk facing both supply bottlenecks and structural cost disadvantages.

For industry stakeholders, this creates a double imperative: secure long-term SAF agreements early to guarantee supply and cost stability, while actively engaging with regulators to shape incentive frameworks.

Airlines and hubs that move first can lock in resilience and signal climate leadership, while late adopters risk exposure to price volatility, regulatory penalties, and reputational pressure.

Ultimately, scaling SAF cannot be left to market forces alone: it requires sustained public–private partnerships, global coordination, and large-scale investment across the entire value chain.

b) Technological improvements/innovation

Technological innovation is advancing on multiple fronts. Electric and hydrogen-powered aircraft are under active development, with near-term potential concentrated on short-haul and regional routes.

These solutions could enable zero-emission flight at the point of use, but widespread commercial deployment is unlikely before the 2030s given technical, regulatory, and infrastructure barriers.

In the meantime, continuous progress in lightweight materials, aerodynamic optimisation, and more efficient conventional engines is driving incremental reductions in fuel burn and emissions.

The ICAO LTAG[10] framework anticipates three types of technological evolution:

1. Improvements to current tube-and-wing aircraft designs, including retrofitting and engine upgrades.

2. The development of revolutionary aircraft concepts, such as hybrid-electric, fully electric, and hydrogen-powered aircraft.

3. The adoption of alternative energy sources, notably hydrogen and electricity, which could redefine aviation's power base.

[9]ICAO LTAG

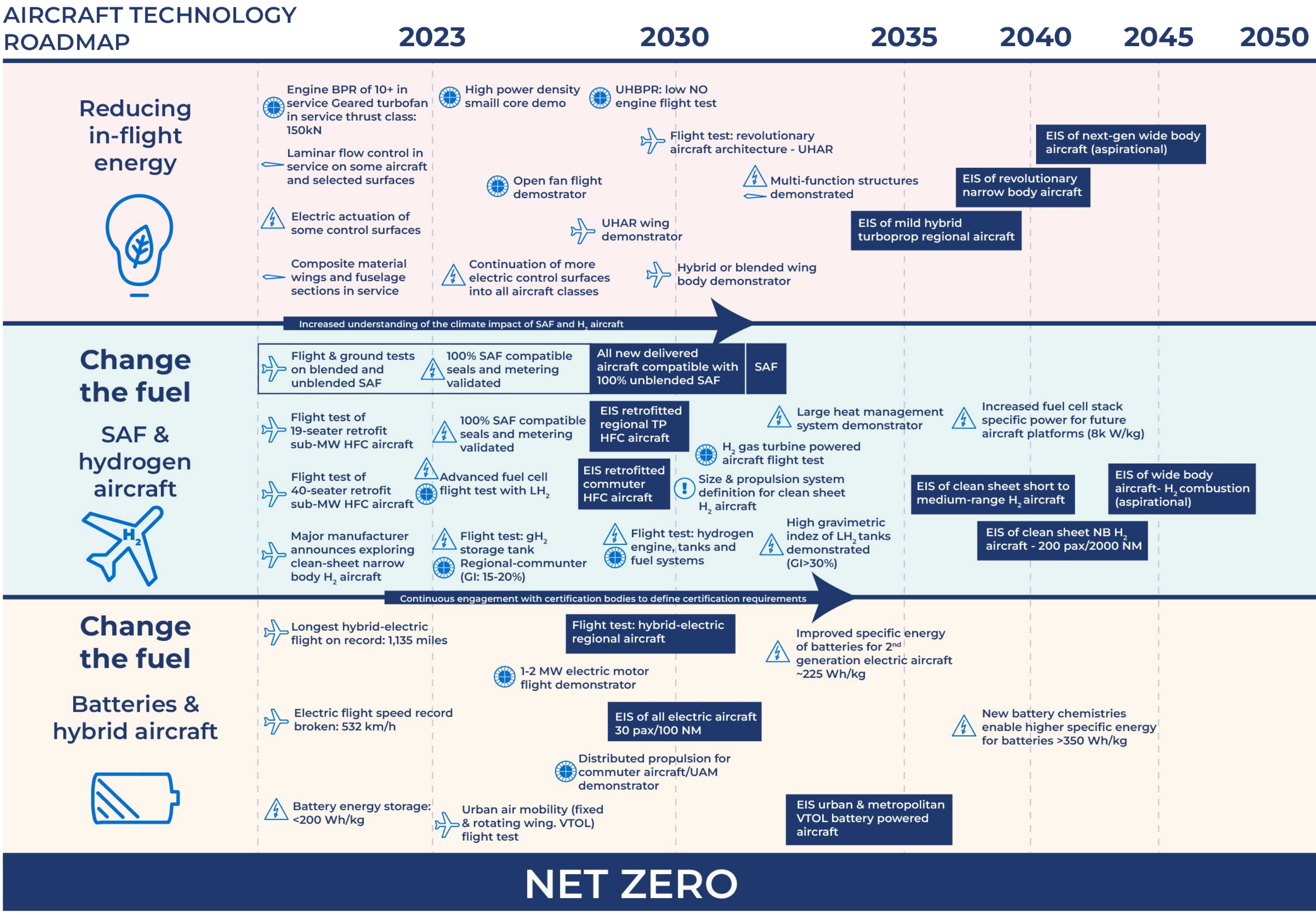


Figure 4: IATA Aircraft technology Roadmap[10]

[10] IATA

Zero-emission aircraft—electric or hydrogen-powered—are progressing rapidly but will not materially reduce long-haul emissions before 2035.

Their initial impact will be limited to short-haul and regional routes, leaving the bulk of global aviation emissions untouched for the next decade.

This means the sector cannot afford to wait for breakthrough technologies to deliver climate neutrality. In the short to medium term, the priority must be on deployable solutions such as SAF and operational efficiency, while keeping R&D pipelines strong to prepare for the next wave of technological shifts.

The winners will be those stakeholders that strike the right balance: investing today in measures that deliver immediate reductions, while positioning themselves to capture the benefits of zero-emission aircraft once they become commercially viable.

c) Operational improvements and ATM

Operational efficiency is a critical enabler of aviation decarbonisation in the short to medium term, delivering emissions reductions without requiring new aircraft or fuels. Gains can be achieved through optimised flight trajectories, improved ground operations, and the adoption of advanced flight concepts. Key levers include optimised air routes, enhanced ATM coordination, collaborative decision-making, and ground procedures.

Looking further ahead, innovative concepts such as formation flying—where aircraft operate in coordinated patterns to reduce drag and fuel burn—could unlock additional efficiency gains.

Operational improvements represent the most immediate and cost-effective lever for decarbonisation. Unlike SAF or new aircraft technologies, ATM modernisation and flight efficiency deliver tangible results today—through shorter routes, reduced holding times, and optimised ground operations. Initiatives such as SESAR, the implementation of Free Route Airspace, and the adoption of Performance-Based Navigation demonstrate how smarter airspace management can significantly reduce emissions.

According to the Destination-2050 Roadmap (2025), such operational measures could deliver almost 14 million tonnes of CO_2 savings by 2035. For airlines, this means that operational efficiency is not just an incremental gain but a strategic enabler: it reduces fuel burn, mitigates compliance costs, and provides visible progress toward net-zero targets while the sector scales up SAF and prepares for zero-emission aircraft.

3. CHALLENGES TO SCALING CLIMATE ACTION IN AVIATION

a) Policies support and public/private collaboration

Achieving lasting decarbonisation in aviation depends on coordinated action across governments, regulators, and industry. Public support is critical to scaling SAF production, upgrading infrastructure, and accelerating R&D for clean propulsion and energy systems.

Encouragingly, international initiatives—such as ICAO's ACT-SAF programme in partnership with EASA—are already laying the groundwork for greater alignment. Building on these efforts, further progress towards a globally harmonised and enforceable framework will be essential to unlock investment, ensure a level playing field, and drive systemic transformation at scale.

International schemes such as CORSIA provide a common baseline for global action, while regional initiatives like those of the European Union go further with binding targets and stronger regulatory instruments.

This divergence presents a key challenge: ensuring that different levels of ambition and policy maturity across regions do not create imbalances or slow down the sector's collective transition.

Strengthening coordination between international and regional frameworks will therefore be critical to deliver consistent investment signals and drive a globally coherent decarbonisation process.

The outcome is uneven across regions. Markets with more advanced regulatory frameworks, such as Europe, face higher compliance costs linked to SAF mandates, carbon pricing, and other obligations, while airlines in less regulated regions currently operate under lower cost structures.

These differences can affect competitive dynamics and highlight the importance of greater international coordination to minimise market distortions, reduce the risk of carbon leakage, and create the conditions for attracting investment and enabling a sector-wide transition.

b) Sector specific challenges

Every decarbonisation strategy in aviation faces unique sector-specific challenges that limit their immediate impact and complicate large-scale deployment.

SAF sits at the centre of near-term strategies, but its potential is constrained by limited availability and high costs.

According to analysis by SEO Amsterdam Economics[11], achieving just a 5% SAF blend by 2030 could add €2.1 billion in costs for the sector, while a 10% blend could raise that figure to €12.1 billion.

Unlocking large-scale deployment will require investment across the full value chain: expanding feedstock supply, scaling refinery capacity, streamlining certification, and upgrading logistics and airport infrastructure.

At the same time, uneven SAF mandates and incentives across regions risk slowing market growth and weakening price competitiveness, making global alignment a critical enabler of progress.

At the same time, electric and hydrogen-powered aircraft are progressing through research and prototype testing. Yet these technologies remain at an early stage and face major challenges—ranging from battery energy density and cryogenic hydrogen storage to safety certification, redesigned airframes, and new airport infrastructure.

[11] SEO

As a result, IATA estimates large-scale commercial viability is not expected before the 2030s[12], with meaningful impact more likely beyond 2035.

In the short to medium term (2025–2035), their role will be largely limited to short-haul and regional markets, with negligible effect on long-haul emissions.

On the operational side, improvements in flight efficiency can deliver measurable CO_2 reductions. The key is modernising and harmonising ATM, especially in congested and cross-border airspace.

This requires real-time data sharing, interoperable systems, and stronger collaboration between Air Navigation Service Providers (ANSPs). Without these enablers, efficiency gains remain limited and uneven across the network.

[12] IATA

c) Economic pressures and operational challenges

Decarbonising the aviation sector comes with significant economic pressures. SAF is currently two to five times higher than conventional jet fuel according to Eurocontrol[13], and supply remains geographically concentrated and insufficient to meet projected demand.

Airlines that take the lead in SAF adoption are therefore exposed to higher fuel costs without immediate economic returns, unless they are supported by effective public policies, subsidies, or price-stabilisation mechanisms.

At the same time, compliance with market-based mechanisms such as CORSIA and the EU ETS adds further costs for airlines.

Rising carbon allowance prices and limited availability of verified offsets intensify this financial pressure.

Airlines also face major investment needs in fleet renewal and retrofitting—both to improve fuel efficiency and to prepare for future electric or hydrogen aircraft. These require long planning cycles and substantial upfront capital.

ICAO's LTAG analysis estimates that cumulative investment in fuel infrastructure and supply chains could reach USD 3.2 trillion between 2020 and 2050.[14]

[13] EUROCONTROL

[14] ICAO

Another critical challenge is the risk of market distortion from fragmented climate regulation.

The EU has adopted ambitious measures—such as mandatory SAF blending and tighter carbon pricing—while many non-EU airports face lower regulatory costs.

This gap may trigger hub leakage, where airlines and passengers divert traffic to third-country hubs outside the EU to reduce costs. Such shifts undermine emissions reductions and weaken the competitiveness of EU airports.
Fuel tankering is a clear example of how cost-driven behaviour can undermine climate policy. Instead of refuelling at EU airports where SAF is blended, airlines may load extra fuel at cheaper non-EU airports.

As shown in the figure, this reduces SAF uptake and increases emissions, since carrying excess fuel adds weight and burns more fuel in flight.

In practice, tankering cancels out the environmental benefits of SAF mandates and weakens the incentive for investment in cleaner fuels.

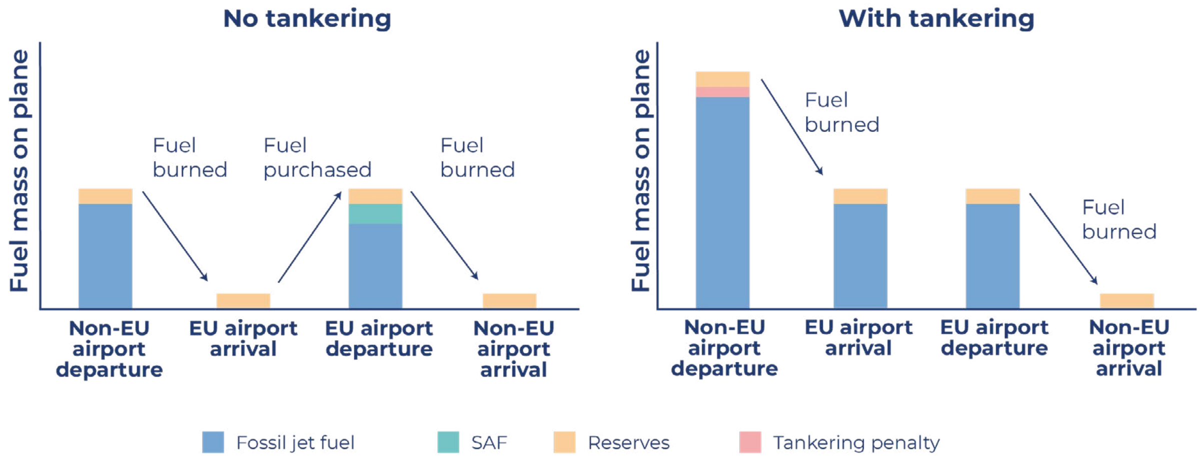


Figure 5: Impact of tankering at EU airport[15]

[15] IATA

Lastly, cost pressures are likely to be passed on to passengers as fuel prices, ETS compliance, and airport fees rise. SEO Amsterdam Economics[16] shows that regulatory measures could increase ticket prices by 1.5 eurocents per passenger-km on intra-EEA flights by 2030, rising to 2.1 eurocents by 2035.

On extra-EEA routes, the impact is smaller but still notable, with increases of 0.24 eurocents by 2030 and 0.80 eurocents by 2050, mainly driven by CORSIA and ReFuelEU. Without stronger international coordination and fair burden-sharing, such costs risk making the transition to net-zero economically challenging for both airlines and travellers.

	Price increase (eurocents per passenger km for return flights)					
	2030		2035		2050	
	Domestic or intra-EEA	EEA↔ non-EEA	Domestic or intra-EEA	EEA↔ non-EEA	Domestic or intra-EEA	EEA↔ non-EEA
EU-ETS	0.80	0.08	0.87	0.09	0.16	0.02
CORSIA	0	0.00	0	0.05	0	0.23
ETD	0.53	0.06	0.62	0.07	0.28	0.03
ReFuelEU	0.18	0.10	0.60	0.34	1.27	0.52
Total	1.51	0.24	2.09	0.55	1.71	0.80

Figure 6: Overview of average price increase from fit for 55 in eurocents per passenger kilometre[17]

[16] SEO Amsterdam Economics

[17] SEO & NLR (2022)

4. ALG'S CONTRIBUTION TO DECARBONIZATION THROUGH

a) EU flight emissions labelling scheme and machine learning (ML) exploration

The EU Flight Emissions Labelling (FEL) initiative is the first of its kind worldwide to place passengers at the centre of aviation decarbonisation.

By providing standardised and reliable information on the greenhouse gas emissions of individual flights, it enables travellers to make informed booking decisions and rewards airlines that adopt cleaner operations. Unlike most current estimates based on assumed aircraft performance, the FEL uses real-world airline data—actual fuel consumption, passenger and cargo loads, and Sustainable Aviation Fuel (SAF) usage.

This shift from assumptions to verified operational data creates a transparent and comparable benchmark across carriers, allowing incremental improvements to add up to measurable reductions.

ALG has contributed to this transition by exploring the potential use of advanced analytics and AI algorithms to improve the accuracy and robustness of emissions calculations and its methodology.

Integrating real operational data and combining it with Machine Learning models, the purpose is to provide algorithms that provide more accurate results and thus, are fairer with regards to the changes and improvements introduced by the operators in their operations and fleet.

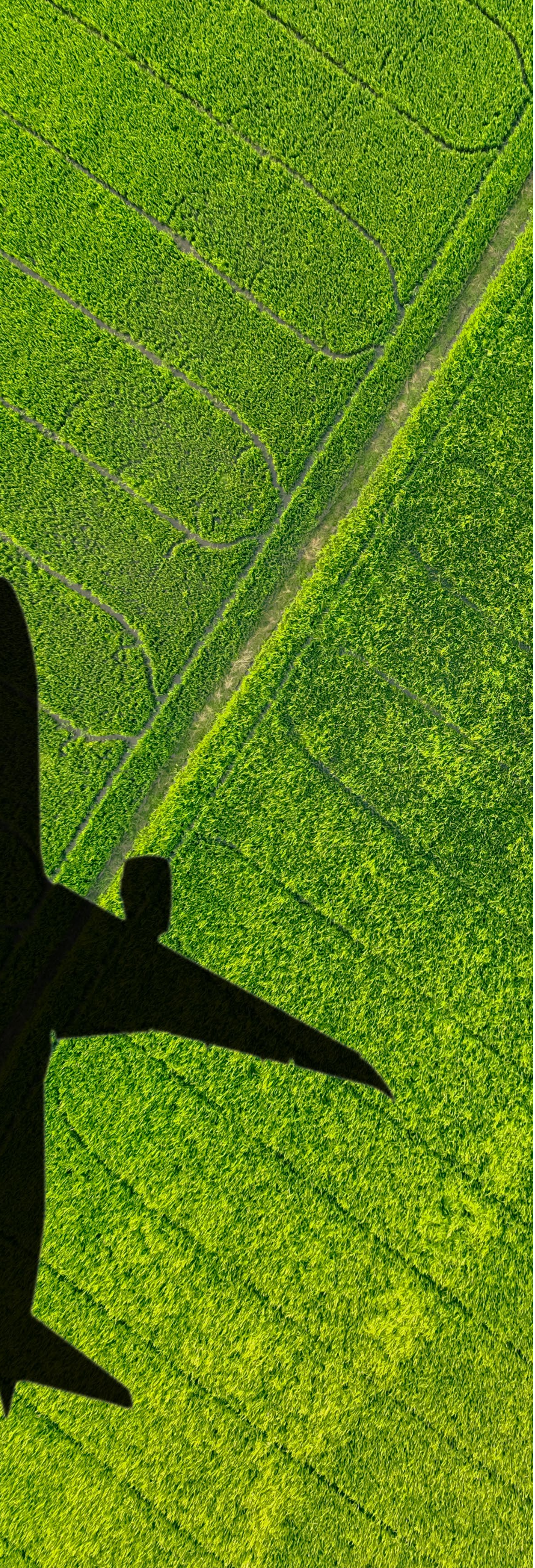
b) EU fuel schemes and digitalization for sustainability – EASA 'DATAPP' project

The progressive evolution of European fuel planning regulation is enabling a transition from the Basic Fuel Scheme toward Individual Fuel Schemes (IFS), providing airlines with greater flexibility to optimize fuel uplift based on real operational data.

This paradigm shift has significant implications for sustainability: by aligning fuel planning more closely with actual flight conditions, airlines can systematically reduce unnecessary fuel carriage, thereby lowering fuel burn and associated CO_2 emissions without compromising safety.

Such optimization not only improves efficiency at the airline level but also contributes directly to the European Union's broader climate neutrality objectives.

Within this regulatory context, ALG led the EASA DATAPP project, designed as a research effort to explore three critical areas, one of which focused specifically on the application of advanced digital methods for pre-flight and in-flight fuel management.



The project examined the main digital adoption challenges, identified regulatory and standards gaps that may hinder deployment, and provided targeted recommendations to facilitate industry adoption.

Among these, particular emphasis was placed on ensuring the trustworthiness of AI models that could be used to support the transition toward Individual Fuel Schemes, including aspects such as model transparency, validation, and integration into safety risk management and assurance.

By providing regulators and operators with a practical knowledge base, ALG created the conditions for safe adoption of digital fuel optimisation—directly linking data-driven innovation to measurable CO_2 reductions at European scale.

c) Integrating environmental impact into strategic infrastructure and operations studies

Decarbonization in aviation cannot be achieved solely through regulatory initiatives; it must also be embedded in the planning and design of infrastructure, operations, and long-term capacity strategies.

Understanding the emissions impact of alternative scenarios—such as new terminal layouts, runway configurations, or airside process optimizations—is essential to ensuring that growth plans remain compatible with net-zero objectives.

ALG integrates environmental impact as a fundamental dimension of its strategic studies, using its proprietary ADAPT platform to process ADS-B trajectory data, complemented by fast-time simulation services, advanced analytics, and robust emissions estimation models.

Together, these capabilities enable the quantification of the CO_2 footprint of alternative infrastructure and operational scenarios. This holistic methodology allows decision-makers to evaluate options not only on capacity and cost, but also on their contribution to emissions reduction.

By embedding this intelligence into the planning process, ALG helps airports and aviation stakeholders prioritize investments and initiatives that deliver the highest decarbonization impact while preserving operational performance.

d) Modernization of ATC service provision in the Caribbean region

ATM systems play a critical role in reducing emissions and minimizing the environmental impact of the air transport sector.

By enabling more efficient flight trajectories, optimizing airspace use, and reducing delays both in the air and on the ground, modern ATM systems help lower fuel consumption and associated greenhouse gas emissions.

Improved coordination and real-time data sharing further support environmentally sustainable operations, contributing to the global effort to decarbonize aviation.

ALG is supporting multiple ANSPs in the Caribbean region in modernizing their ATC service provision with the implementation of more advanced and automated systems and redesign of airspace configurations and procedures.

e) Driving european ATM innovation for sustainability

The SESAR (Single European Sky ATM Research) project is the leading European initiative to modernise ATM, with core objectives of safety, capacity, cost efficiency and sustainability.

The environmental dimension is central: SESAR estimates that the full deployment of ATM solutions could bring 9.3% of fuel reduction by 2050, saving up to 600 kg of fuel per flight and 400 million tonnes of CO_2[18].

These improvements come from more direct routing, trajectory based operations, digitalisation of surface operations and smoother traffic flows.

ALG has participated in many SESAR projects, bringing expertise in Cost-Benefit Analysis (CBA), modelling environmental performance, and supporting the definition of operational concepts (CONOPS). Some relevant contributions include:

Free Route in High Complexity Environments: assessment of environmental benefits from enabling more direct trajectories.

Digital Evolution of Integrated Surface Management: quantification of CO_2 reductions at airports through optimised taxiing and improved ground efficiency.

SESAR mainstream programme (since 2008 and on-going): leadership in work packages on CBA modelling and performance assessment, evaluating environmental benefits among Solutions' impacts.

ALG's wide understanding of SESAR's governance, programme and funding mechanisms has demonstrated SESAR's contribution to ATM modernisation under a DG MOVE specific contract.

The statistical analysis based on operational data confirms that SESAR Solutions' deployments have led to measurable gains in flight efficiency and reduced airport delays, reflecting the positive environmental impact.

Through its contributions, ALG demonstrates that SESAR innovations are not only strongly defined at concept level but also translated into concrete reductions in fuel consumption and emissions across the network.

[18] SESARJU

f) Enhancing airport efficiency and environmental performance

Airport congestion generates inefficiencies such as delays, long taxi times, and unnecessary fuel burn.

Airport Collaborative Decision Making (A-CDM) addresses these challenges by sharing real-time information and integrating all airport stakeholders (airport operator, ANSP, airlines, ground handlers) into a collaborative, data-driven decision-making framework.

The environmental impact is direct: shorter taxiing and reduced holding times translate into lower fuel consumption and CO_2 emissions. A-CDM helps avoid delays and inefficient use of airport infrastructure by making operations more predictable and organised.

ALG has led and implemented A-CDM projects across main Latin American airports, developing:

- **Operational guidelines.**
- **Data models and integration protocols.**
- **Airport Operations Control Centres (AOCCs) to coordinate performance and sustainability.**

These projects enabled airports to:

- **Reduce fuel burn and emissions during ground operations.**
- **Improve punctuality and operational efficiency.**
- **Align with European and international sustainability standards.**

g) Startical project

Air traffic management over oceanic and remote regions still relies on outdated ground-based systems, creating large gaps in surveillance and communication.

This forces wider separation between aircraft, less direct routing, and higher fuel burn. To address this, Startical—a joint venture of ENAIRE and Indra, with ALG as a strategic partner—proposes a constellation of satellites that will deliver real-time communication and surveillance in underserved airspaces such as the North Atlantic corridor from 2030 onwards.

Startical brings a step change to long-haul efficiency.

By enabling more direct routes, tighter separation, and greater predictability, it optimises trajectories and cuts fuel burn.

The environmental payoff is clear: up to 5 million tonnes of CO_2 savings each year. Economically, these gains could reduce airlines' carbon costs under CORSIA and the EU ETS by around USD 300 million annually.

Thanks to its innovative approach, Startical positions itself as a key enabler of sustainable aviation, supporting the transition to net-zero in global airspace.

ALG's role in the Startical project is broad, covering strategic, technical, and market dimensions. However, in the environmental aspect, ALG carried out an environmental study to assess the system's footprint and potential benefits.

The contribution included three main components: introducing carbon emissions context with reference to international policies and aviation's role, sizing carbon emissions market under CORSIA enforcement while accounting for fleet renewal, new technologies and greener fuels, and evaluating Startical's environmental footprint across the full value chain, quantifying emissions costs and identifying the positive impacts the system could generate.

Thanks to this approach, Startical exemplifies how operational efficiency projects can provide measurable climate benefits today, bridging the gap until breakthrough technologies become fully viable. It stands as a proof point that aviation decarbonisation requires not only fuels and fleets, but also smarter skies.

CONCLUSION

Achieving net-zero carbon emissions by 2050 in the aviation sector will require unprecedented levels of investment and the coordinated contribution of all stakeholders, including States, aircraft manufacturers, fuel suppliers, feedstock producers, airports, Air Navigation Service Providers (ANSPs) and airlines.

No single measure will be enough: meaningful reductions can only be achieved by combining three levers—technological innovation, operational efficiency, and the deployment of alternative fuels.

At the same time, the production of those fuels must also decarbonize, using renewable energy and cleaner industrial processes, in step with the broader transition of the global economy. Only through combined action, sustained investment, and global alignment can aviation reach net zero while maintaining its role as a driver of connectivity and growth.

EMERGING PRIORITIES

- **Global harmonization is critical:** Fragmented regulation risks distorting competition and undermining the effectiveness of climate policies.
- **Scaling SAF is indispensable:** Market forces alone will not deliver the required volumes—government intervention and early long-term agreements are essential to accelerate the deployment.
- **Operational innovation delivers immediate results:** Modernised ATM, Free Route Airspace, and Performance-Based Navigation can provide measurable CO_2 savings today.
- **Competitiveness depends on early adaptation:** Those who invest early and embed decarbonization into their business models will transform compliance into a source of resilience and advantage.

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