



## **Comparing sustainability practices and initiatives for achieving carbon-neutral/more sustainable targets in airfreight**

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Master of Business Administration

Sustainable Aviation Business

Master Thesis

2025

## Abstract

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<b>Degree</b> Master of Sustainable Aviation Business
<b>Report/thesis title</b> Comparing sustainability practices and initiatives for achieving carbon-neutral/more sustainable targets in airfreight
<b>Number of pages and appendix pages</b> 55 + 9
<p>Global warming is increasing the global surface temperatures on an alarming manner. Urgent emission reductions are needed to slow down the progress. Aviation sector contributes about 2% of global CO<sub>2</sub> emissions, but the high-altitude effects amplify the industry climate impact.</p> <p>Air freight is vital to global trade, but has one of the highest carbon intensities in transportation industry. Sustainable aviation era has started and decarbonizing and meeting the industry climate target of reaching net zero emissions by 2050 is of high importance for all air cargo operators.</p> <p>This study examines major policies and regulations guiding air cargo sector towards net zero emissions. Comparative data analysis evaluates how carriers integrate environmental policies into long term strategies and assesses ESG performance through KPI based scoring. By comparing airlines in different regulatory environments, the research identifies the effectiveness of current initiatives and highlights best practises for improving sustainability in the air freight industry.</p> <p>Results show, that while carriers report engagement in all ESG sectors, environmental, social and governance, they are at different stage of involvement. Prioritizing Sustainable Aviation Fuel investments, focusing on innovations and strong reporting framework tend to lead to better environmental results along investing in modern fleet. Key challenges of the industry include limited SAF availability, high cost of SAF, partially overlapping and ever evolving standards and lack of global standardization. Industry needs to accelerate standardization and scalable clean energy solutions to reach net zero targets by 2050.</p>
<b>Keywords</b> Sustainability, Sustainable Aviation Fuel, ESG, air cargo

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## 1 Introduction

Intergovernmental Panel on Climate Change presents evidence that human activities, primarily through greenhouse gas emissions, have caused global warming, with surface temperatures rising 1.1°C above 1850-1900 levels during 2011-2020. This warming has resulted in widespread changes across the atmosphere, oceans, cryosphere, and biosphere, manifesting in severe weather extremes that cause significant losses and damage to natural ecosystems and human communities. The same report warns that without urgent and substantial reductions in emissions, global warming is likely to exceed 1.5°C between 2030 and 2035, amplifying risks and irreversible harm. It emphasizes the need for immediate, large-scale mitigation efforts to secure a safe, livable future and to avoid impacts on vulnerable populations, outlining feasible pathways for both emissions reduction and climate action. (UN IPCC AR6 Synthesis Report, 2023)

The International Civil Aviation Organization, ICAO reports that the aviation sector contributes approximately 2% to global CO<sub>2</sub> emissions, a figure that seems modest in comparison to industrial agriculture (about 10%) and energy production (about 70%). However, aviation's climate impact is elevated due to the high-altitude release of greenhouse gases, leading to a more potent warming effect. Aircraft burn fossil fuels, primarily jet fuel, producing CO<sub>2</sub>, water vapor, nitrogen oxides, and other pollutants, which accelerate global warming. The sector's emissions currently amount to around 880 million tons of CO<sub>2</sub> annually, making aviation the seventh-largest emitter if considered a country. The European Union Aviation Safety Agency, EASA estimates that without intervention, aviation emissions could double or triple by 2050 due to significant projected growth. Moreover, non-CO<sub>2</sub> effects such as the formation of contrail cirrus clouds contribute to industry's net climate forcing (EASA, European Aviation Environmental report 2025). Urgent action is required across technical, operational, and policy domains to mitigate the aviation sector's growing climate footprint and to align with global climate targets.

On a global level China, the United States, and Europe are responsible for the vast majority of global greenhouse gas emissions. These regions collectively account for a significant share of the emissions driving climate change, highlighting their critical role in global mitigation efforts. The transportation sector, including aviation and air freight carriers, is an important component of emissions in these regions and presents a substantial opportunity for reductions.

In the globalized economy, air freight plays a critical role in delivering goods quickly and reliably, with approximately 100,000 flights daily transporting cargo either in passenger aircraft bellies or dedicated freighters. However, air freight has one of the highest carbon footprints among transportation modes, contributing significantly to global greenhouse gas emissions. Reduction of emissions in this sector is essential to meet global climate targets, align with evolving regulatory

frameworks, and satisfy consumer expectations for sustainability. Tools for reducing the carbon footprint of air freight include adopting cleaner and more fuel-efficient technologies, improving operational efficiencies, and transitioning toward sustainable energy sources such as sustainable aviation fuels (SAF), electric, and hydrogen propulsion.

Current era for transportation industry is strongly focused on sustainability since 2020. Operators face regulatory pressure from ICAO and Corsia, trying to comply with industry commitments guided by IATA while navigating towards set industry target of reaching net-zero carbon emissions by 2050. Simultaneously corporate clients require verified emission data and are looking for greener solutions from their partners. Investors alike are looking into environmental practices and search for green finance incentives. IATA has provided net zero 2050 roadmap for airlines as a guideline to navigate through new policies and complex changes in industry standards.

### **1.1 Objectives and research questions**

Objective of this study is to introduce the most important policies, regulations and recommendations on how the air cargo industry can reach net zero CO<sub>2</sub> goal by 2050. Research consists of studying how cargo carriers are incorporating environmental policies onto their long-term strategy and how they fulfill their environmental, operational and social and governance KPIs. ESG KPIs are further rated to form an ESG score to be analyzed. Airlines selected for this study are from different market environments. Aim is to compare, if their regulatory framework effects on their environmental strategy. Effectiveness and outcome of policies is studied to learn if there are best demonstrated practices or suggestions that can be made for the industry of air cargo carriers newly establishing their policies or the ones perfecting their current framework.

Table 1. Overlay matrix

Research question	Theoretical framework	Methodology	Results
RQ1: What kind of regulatory sustainability environment surrounds the air cargo sectors on a global, national, and industry level?	4 5.1 5.2 5.3 5.4 7	8	8 9
RQ2: How do cargo airlines implement sustainability practices within the regulatory framework?	6.1 6.2 6.3 6.4 6.5 6.6	8.1 8.2 8.3 8.4	9 10
RQ3: How effective are current initiatives in contributing to carbon-neutral targets?	5	9 10	9 10

## 1.2 Limitations of the study

Geographical scope of the study is set to Europe and North America, as these regions handle almost 50% of global cargo volumes and are currently home for most SAF production facilities.

Cargo carriers from these regions are considered to be market leaders with environmental efforts and have most consistent regulations in place and allow best access to data collection and policy comparison.

Focus is on set on scope 1 emissions, which tend to be largest part of airline emissions. These are related to mainly jet fuel combustion causing emissions. However, scope 2 and 3 emissions, which are indirect emission resulting mainly of purchased electricity and facilities used by airline are referenced to complete the understanding of the environment and ecosystem the cargo airlines operate within.

The thesis made use of ChatGPT application to support the development and organization of the ideas and the table of contents as well as to format ESG KPI measurement tool. AI generated text

was incorporated in an iterative manner. The author of the thesis has further refined the AI-generated texts to make them error-free, relevant, clear and understandable. The AI applications have been used responsibly, considering data protection and copyright. All sources and data referenced in the thesis were used correctly and originate from verifiable, non-AI-generated materials.

## 2 Airfreight and its environmental impact

Air Freight Market is a network of services and industries involved in transporting goods via air. Network consists of airlines, freight forwarders, airports and logistical offer for air freight movement. This market performs essential function in global alternate, facilitating the rapid motion of goods across international locations and continents. (Business Research Insights)

Airfreight is important, because it enables the fast, reliable, and efficient transportation of goods across long distances and international borders. It supports global trade by connecting markets worldwide and allows businesses to access distant customers quickly. The speed of airfreight makes it ideal for time-sensitive shipments such as perishable goods, e-commerce, pharmaceuticals, and high-value items. It also enhances supply chain efficiency by reducing transit times, enabling just-in-time manufacturing, minimizing inventory costs, and ensuring timely delivery. Airfreight is also very secure, due to strict airport regulations. There is less handling in airfreight and it reduces the need for extensive packaging and warehousing and provides access to remote or otherwise hard-to-reach markets. Overall, airfreight is seen as important part of modern world, driving economic growth, supporting industries, and facilitating global commerce. Global economy depends on the ability to deliver high-quality products at competitive prices to consumers worldwide. (IATA, Value of Air Cargo)

### 2.1 History of Air Cargo Air Mail

First movement of cargo fulfilled the modern-day e-commerce needs for speedy and precise delivery: first cargo only flight took place on 7 November 1910, when a delivery race took place between an express train and a Wright Model B airplane. The cargo consisted of 10 bolts of silk, weighing 91kg. The silk traveled 65 miles/105km from Dayton to a retail store in Columbus, Ohio, for the store's grand opening. It took 57 minutes to move cargo as airfreight, and movement was faster than train. (Grand Aire, The History of air cargo)

In the early 1900's airplanes used to carry rather small cargo. This was due to small size aircraft only. Later the industry evolved onto regular airmail service between Washington D.C. and New York City in 1918. New airlines started in 1920's and as result the air freight industry started. Cargo was primarily high-priority mechanical parts or merchandise including jewelry, high-fashion clothing, movie reels, and pharmaceuticals. These items needed to be received quickly to meet critical deadlines, very much like air cargo today. It was also during these pioneer days, that first legislation for the industry was written. Contract Air Mails Act of 1925, known as Kelly Act, allowed airmail services to be privatized. (Grand Aire, The History of air cargo)

## 2.2 The Upsurge of All-Cargo Flights

When larger planes became available after World War II technological development, cargo operations increased, and several all-cargo companies started operations. The fuselage of the airplane was used to carry everything from frozen foods, miscellaneous perishables, construction equipment, automobile parts, and even complete cars. Pressurized cargo planes were utilized to transport livestock. (Grand Aire, The History of air cargo).

Established passenger carriers began to realize that moving cargo could be a financial opportunity. They started their own cargo departments and began running all-freight flights to compete with the all-cargo airlines. Since the passenger airlines had established facilities and routes, they had lower fixed costs to transport cargo (Grand Aire, The History of air cargo).

Further developing the offer, many passenger airlines created a secondary market by selling their belly capacity and developing extra income through added service. As of today, more than half of all air cargo is transported in the baggage hold of a passenger aircraft (Grand Aire, The History of air cargo).

## 2.3 Air Freight today

Introduction of Boeing 747 transformed the air cargo industry by allowing full pallets to be transported within the cargo hold of the wide-body aircraft. Airline Deregulation Act of 1978 meant that carriers like FedEx, UPS and other full-service, all-cargo airlines were started and allowed to move cargo, contributing greatly to increased volume of air freight (Grand Aire, The History of air cargo). In the 70's one could not imagine, how strong the air freight market development would be in the upcoming 60 years and how much aircraft technology would advance. The modern freighters, being able to accommodate oversized pieces and massive crates move roughly 54% of global cargo flows today.

Today air cargo transports over USD 8 trillion worth of goods, accounting for approximately 33% of world trade by value, but less than 1 % of world trade by volume in 2025 (IATA, Value of Air Cargo). Air freight market is forecasted to grow consistently, ultimately achieving USD 9.4 billion by 2033, at a steady CAGR of 2.4% (Business Research Insights). IATA predicts cargo volumes in 2043 are up to 2.1 times the volumes in 2023.

Air freight has become crucial for transporting clinical resources, private defensive device (PPE), ventilators, and vaccines globally. The pandemic expanded online purchasing, leading to a pointy

increase in call for air freight offerings to fulfill time-sensitive deliveries. The increasing need for vaccine distribution further pushed the importance of temperature-controlled air product (Business Research Insights). Most travelers on a passengers aircraft cannot even imagine the type of goods transported in the hold as air cargo. Commodities moving as air cargo could vary between anything from racehorses, flowers to electronics, aircraft engines or pharmaceuticals to live animals or even cars. IATA estimates roughly \$18.6 billion worth of goods are transported by 100 000 planes globally every day as can be seen in figure 1 (IATA. Value of Air Cargo).

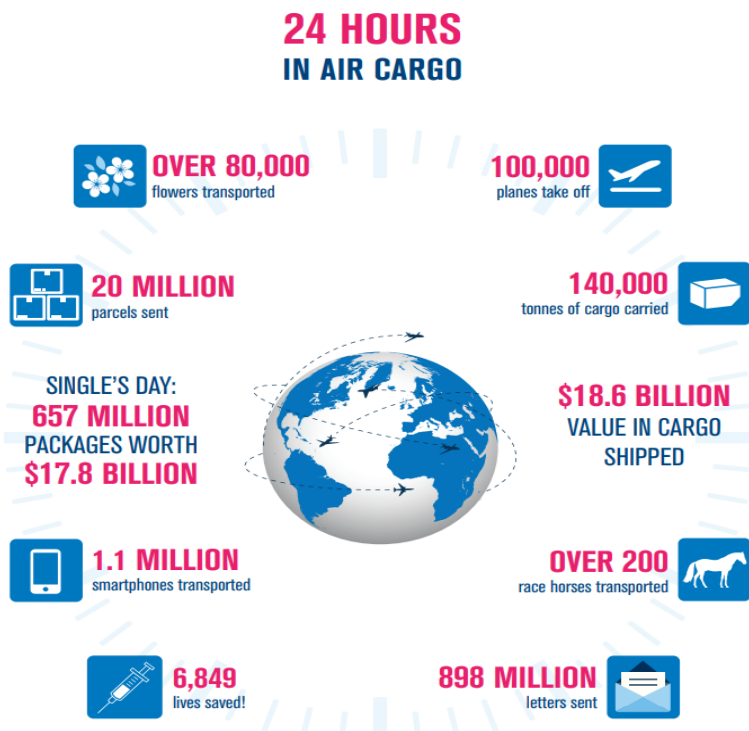


Figure 1. 24 hours in Air Cargo (IATA 2024)

Air cargo demand, measured in cargo ton kilometers (CTK), grew 11.3% in 2024, exceeding previous record from 2021 as pictured in table 2. The market grew in all geographical regions. Asia-Pacific led growth in air cargo demand, with a 14.5% increase in CTK, followed by the Middle East, at 13.0%, and by Latin America, at 12.8%. North America, the world's second-largest market, saw modest growth of CTK of 6.5% YoY. In general, air cargo is experiencing more modest growth in 2025, with YTD data for March 2025 showing a 2.4% increase. (IATA, Annual review 2025)

Table 2. Air Cargo Market in detail 2024 (IATA 2024)

2024 (%YEAR-ON-YEAR)	WORLD SHARE *1	CTK	ACTK	CLF (%-PT) *2	CLF (LEVEL) *3
<b>Total Market</b>	<b>100%</b>	<b>11.3%</b>	<b>7.4%</b>	<b>1.6%</b>	<b>45.9%</b>
Africa	2.0%	8.5%	13.6%	-2.0%	41.8%
Asia Pacific	34.2%	14.5%	11.3%	1.3%	47.2%
Europe	21.5%	11.2%	7.8%	1.6%	53.7%
Latin America	2.9%	12.6%	7.9%	1.5%	36.6%
Middle East	13.6%	13.0%	5.5%	3.1%	46.9%
North America	25.8%	6.6%	3.4%	1.2%	40.3%

(\*1) % of industry CTKs in 2024 (\*2) Year-on-year change in load factor (\*3) Load factor level

Resourcefulness in the face of scarcity defined the air cargo sector in 2024. There was more demand for capacity than offer. Passenger aircraft belly cargo capacity for international flights hit a peak in 2024, carrying 54.6% of all cargo. Since early 2023 more cargo is transported in passenger aircraft than in freighters. Cargo load factors (CLF) reached 45.9% in 2024, up 1.6 percentage points from 2023. Another notable trend was the stabilization of air cargo yields, which dropped only 1.6% and amounted to \$2.47 per kilogram. Challenges in container shipping put extensive upward pressure on ocean shipping rates. Maritime rates did not reach the highs of 2021, but they nevertheless caused a sharp drop in air cargo rates, boosting the competitiveness of air cargo. (IATA, IATA annual review 2025)

## 2.4 Environmental impact

The airfreight industry has a significant environmental impact primarily due to high greenhouse gas emissions. It accounts for about 9% of global transport CO<sub>2</sub> emissions and produces around 10 times more CO<sub>2</sub> per ton-kilometer than sea freight and considerably more than road or rail transport. Aircraft burn fossil fuel releasing CO<sub>2</sub>, nitrogen oxides (NO<sub>x</sub>), sulfur dioxide, soot, and water vapor, which have a warming effect much greater than CO<sub>2</sub> alone due to emissions released at high altitudes. Airfreight also contributes to noise pollution and local air quality issues near airports. (ICCT, Standards to promote airline fuel efficiency, 2020)

Contrails, ice-crystal trails produced by aircraft at high altitudes can trap heat in the atmosphere by behaving similarly to thin cirrus clouds, thereby contributing to global warming. Though they don't emit pollutants directly, their climate impact can be extensive. Despite extensive studies a lot of uncertainty exists in regards of contrails climate effect. In comparison to CO<sub>2</sub> emission effects,

impact of contrails may only last few hours, while CO2 climate impact might last for hundreds of years. (IATA, Aviation contrails and their climate effect)

Compared to other transport modes, airfreight has a much larger carbon footprint. As an example, in figure 2 it can be seen moving 2 kg of cargo for 1000km by air produces 4.42kg of CO2 emissions. Sea transport for the same produces about 30 grams of emissions in comparison (UK government, Greenhouse gas reporting conversion factors). However, there are nuances such as lower-deck cargo on passenger aircraft having a smaller footprint comparable to road transport in some cases. The direct flight paths of planes also contribute to route efficiency.

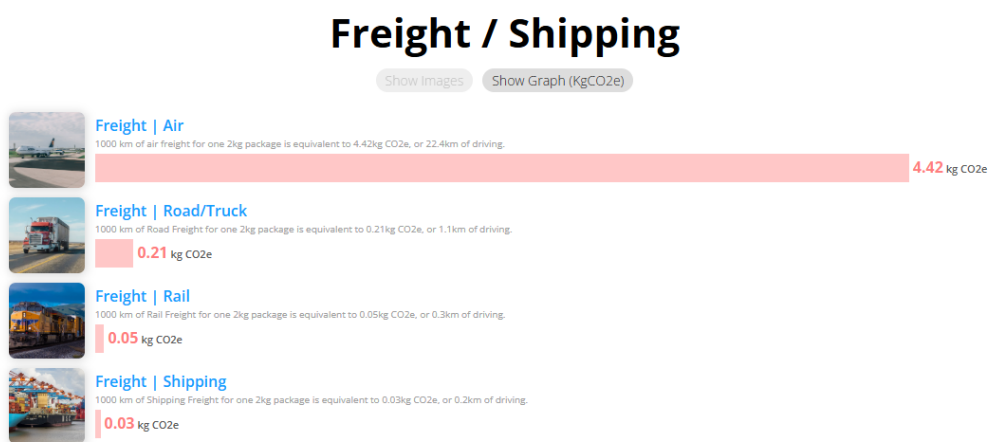


Figure 2. Carbon footprint for 2 kg package for movement of 1000km (UK government s.a.)

Air cargo industry faces pressure to reduce its carbon footprint while maintaining the speed and reliability that the clientele demands. Sustainable aviation fuel is seen as most prominent way to reduce CO2 emissions on a short term, before other technologies are put into use. SAF use can reduce emissions by up to 80% compared to traditional jet fuel (IATA, Value of Air Cargo).

## 3 Geography Analysis

### 3.1 North America

North America is one of the fastest-growing regions in the market and holds the maximum air freight market share. North America's geographical position is an advantage to act as a gateway to both Europe and Asia. It is connected to Latin America as well, facilitating cross-border e-trade and deliver chain operations. Mexico-driven domestic parcel demand and near-shoring of electronics and spares from the South benefits the air freight market. All these combined stresses the importance of the United States within the global air freight market. The United States Air Freight market is deeply incorporated into global supply chains, assisting on-time production methods. As a result, industries like automobile, electronics, and consumer items regularly depend on air freight to make on-time deliveries (Business Research Insights). Bilateral trade levels underpin balanced CTKs, enhancing structural utilization and supporting the long-term health of the air freight market (Mordor Intelligence 2025).

### 3.2 Europe

Europe is on a growth path with air freight volumes due to numerous factors, starting from financial strength and a strong push of e-trade to advance infrastructure and sustainability. Europe is poised for persisted growth inside the air freight Market, fueled via its strategic location, thriving e-trade, strong production sectors, superior infrastructure, and a focal point on sustainability and digital transformation. As those factors continue to conform, Europe's role in international air freight logistics will likely enlarge, reinforcing its position as a global key participant. (Business Research Insights). The challenges European carriers face are related to cost pressure caused by carbon compliance, heavy compliance regulations and growing personnel cost in comparison to especially Middle Eastern competitors.

In another study by Mordor Intelligence, Europe and the Middle East present contrasting outlooks. European carriers face cost pressure from carbon compliance but benefit from a high-value export mix and strong pharmaceutical flows. Middle Eastern hubs exploit geographic proximity among three continents, achieving robust transshipment traffic. Africa and South America remain smaller yet demonstrate opportunity in resource-driven demand and growing e-commerce penetration. (Mordor Intelligence 2025)

### 3.3 Asia

Asia is experiencing a boom inside the air freight market, pushed by numerous elements like rapid economic improvement, increasing e-trade, and a strategic role inside international shipping routes. The area's strong manufacturing base, specifically in international locations like China, India, and Japan, maintains the need for air freight offerings to transport items throughout worldwide supply chains. As one of the largest producer of electronics, equipment, and prescription drugs, Asia is a key participant in international trade. (Business Research Insights)

Asia-Pacific dominated 2024 with 41% revenue and is expected to post a 5.80% CAGR (2025-2030), reflecting dense manufacturing ecosystems, rapid consumer spending growth, and expanding intra-regional express networks. Strategic hubs in Singapore, Hong Kong, and Incheon interlink secondary production centers, boosting connectivity and network redundancy. Government incentives for near-term capacity growth at Indian and Southeast Asian airports further elevate regional significance. (Mordor Intelligence 2025)



Figure 3. Air Freight Market, Growth Rate by Region, 2025-2030 (Mordor Intelligence 2025)

Mordor Intelligence global air freight market report displays international traffic growth in figure 3. It can be stated, that long-haul lanes from Asia-Pacific to North America and Europe are expected to continue generating high load factors and premium yields contributing towards growth. Balancing pure-cargo fleets with belly network to diversify risk will be the key to sustain route economics. Sophisticated revenue management integrating passenger and cargo yields are expected to raise overall profitability. Manufacturing, automotive, e-commerce, high tech, healthcare and perishables will continue to be the drivers of the growth. (Mordor Intelligence, Global Air Freight Market 2025)

## 4 Environmental, Social and Governance, ESG regulations in aviation industry

ESG stands for Environmental, Social, and Governance. It is a framework used to assess an organization's business practices and performance on various sustainability and ethical issues. ESG Spotlight refers to various resources, reports, and series that provide insights and analysis on ESG issues.

Aviation industry being long scrutinized for its carbon footprint, is under heavy pressure to comply with demanding enhanced fuel efficiency, responsible resource use, reduced emissions and alignment with global sustainability goals. With the expected growth in industry boosting future emissions, taking action is more important than ever but very complex at the same time.



Figure 4. United Nations, Sustainable Development Goals (United Nations s.a.)

United Nations 17 Sustainability Development Goals displayed in figure 4, include several targets that are either directly or indirectly related to airline operations and movement of airfreight. Goals for climate action include general targets towards more sustainable transport. UN is also planning to lay out further details of the UN Decade of Sustainable Transport 2026-2035 plan towards the end of the year. Member states will be given an opportunity to showcase their commitment to sustainable transport, share best practices and announce their future activities towards more sustainable aviation future. (United Nations, 17 goals)

Affordable and clean energy target can be related to need for use of cleaner energy sources in the industry, and push for use of new technologies enabling alternative, cleaner energy sources.

Unfortunately, based on recent UN report published in 2025, only 4% of transportation sector energy sources were of renewable origin. Opportunity for less developed countries to partake in production of Sustainable Aviation fuel can be seen as fulfillment of goal number 7.

Need for responsible consumption and production can be seen as target for airfreight, including manufacturers and consumers alike. Companies, especially in developed countries, will need to concentrate on sustainable reporting including emissions, energy efficiency, and CO2 equivalents with growing emphasis on climate related topics including carbon targets. Social reporting related to health and safety and concentration on human rights is encouraged. (United Nations, 17 goals)

Aircraft Value News, 2024 estimates that achieving ESG goals will come at a cost for the industry. Stricter regulations are expected to drive up capital expenditures for both airlines and manufacturers, and smaller carriers might face operational struggles. Getting consumers and enterprises to contribute financially can be challenging, if economics are tight. Despite these risks, the shift toward ESG-aligned aviation offers an opportunity for industry stakeholders to innovate, making air cargo more sustainable for future generations.

The International Air Cargo Association, TIACA conducted industry research in 2025 and especially large businesses report a clear link between their reputation and ESG performance and attractiveness. Sustainability seems to continue high priority for many industry CEOs in air cargo. Attractiveness continues to be important benefit to especially large, European headquartered companies (TIACA, Air Cargo Sustainability Insights, 2025).

## 5 Aviation-Emission Regulations

Balancing economic performance with sustainability is crucial for the future success of reducing emissions in the air freight industry. Achieving this goal requires coordinated collaboration among governments, civil society, and the private sector at local, national, and international levels to promote sustainable and climate-resilient development. This collaboration must embrace inclusive decision-making processes that emphasize risk reduction, equity, and justice, while integrating policies, financing, and actions across different governance levels and sectors. Essential enabling conditions, which differ by region and context, include political commitment, coordinated policies, cooperation, ecosystem stewardship, inclusive governance, diverse knowledge, technological innovation, robust monitoring and evaluation, and increased financial support targeting vulnerable regions, sectors, and communities. International cooperation remains a critical component for meeting the global target of achieving net-zero carbon emissions from international aviation by 2050. This includes the specific target of reducing CO<sub>2</sub> emissions by 5% by 2030 using Sustainable Aviation Fuels (SAF), Low Carbon Aviation Fuels, and other cleaner aviation energy sources. (IPCC, Climate change 2023 Synthesis report)

In the next chapters the most important global and regional including European and American policies are introduced. On a global level IATA Roadmap is explained, as the program aims to support airlines with comprehensive guide to navigate towards greener skies. Table 1 offers an overview of policies grouped by their nature. While global and industry wide regulations apply to all joining parties, regional and national are of a more limited scope. However policies might overlap and it is possible an airline departing from United States to Europe needs to follow different compliance at the origin, than at the destination. For example an aircraft departing from California can benefit from California Low Carbon Fuel Standard by getting credits with use of SAF. At the same time minimum amount of SAF in the tank is mandated by ReFuelEu, due to destination being in Europe.

Table 3. Sustainability regulations and frameworks applying to air cargo

<b>Level</b>	<b>Example</b>	<b>Focus</b>
<b>Global</b>	United Nations 17 Sustainable Development Goals (SDGs)	Provides overarching global framework for sustainable economic growth, environmental protection, and social inclusion.
	CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation)	Requires airlines to monitor CO <sub>2</sub> emissions and offset any growth above 2019 levels through verified carbon credits.
<b>Regional</b>	EU Emissions Trading System (EU ETS)	Market-based mechanism to reduce greenhouse gas emissions by requiring airlines to purchase allowances for their CO <sub>2</sub> output.
	ReFuelEU Aviation	Mandates a gradual increase in the use of Sustainable Aviation Fuel (SAF) for flights to, from, and within Europe.
	EU Corporate Sustainability Due Diligence Directive (CSDDD)	Requires companies to uphold human and labor rights and to mitigate adverse environmental impacts, including climate change.
	EU Corporate Sustainability Reporting Directive (CSRD)	Standardizes sustainability disclosure and reporting requirements across the EU.
	California Low Carbon Fuel Standard (LCFS)	Provides credits to incentivize the production, sale, and use of low-carbon and sustainable aviation fuels in California.
<b>National</b>	U.S. Aviation Climate Action Plan	Sets the objective to achieve net-zero greenhouse gas emissions from U.S. aviation by 2050.
	U.S. Renewable Fuel Standard (RFS) and SAF Initiative	Mandates annual minimum volumes of renewable fuels, including SAF, to reduce dependence on fossil-based jet fuel.
	U.S. Sustainable Skies Act	Offers tax incentives and financial support to expand SAF production and adoption.
<b>Industry</b>	IATA Net Zero Carbon Roadmap 2050	Provides industry-wide guidance, tools, and milestones for airlines to achieve net-zero emissions by 2050.

## 5.1 IATA view on SAF policy approaches

The International Air Transport Association (IATA) advocates policy frameworks that promote the commercial use of Sustainable Aviation Fuel (SAF). IATA's preference is for positive policy measures, prioritizing financial incentives and risk mitigation over regulatory mandates. The policy focuses on using funds to create incentives or direct financial support to SAF projects without strict regulations. IATA favors policy, that helps SAF production compete fairly with renewable fuels used in ground transportation. IATA promotes book & claim SAF accounting system, to open more supply options for airlines and to allow SAF to be delivered into fuel systems where logistics are optimal. (IATA, US and EU SAF policies). Examples of policies include:

- Carbon intensity reduction mechanisms with opt-in provisions: policies that mandate reductions in carbon intensity while allowing aviation to participate in incentive programs designed for ground transportation fuels, thereby leveling the competitive landscape.
- Regulatory incentives with energy multipliers: the introduction of SAF-specific regulatory incentives, such as energy multipliers, to enhance the economic attractiveness of SAF production.
- Capital support and loan guarantees: financial mechanisms, including capital grants and loan guarantees, to reduce the upfront costs and financial risks associated with SAF projects.
- Feedstock subsidies and support mechanisms: subsidies or support programs targeting SAF feedstocks to lower production costs and improve supply chain reliability.
- Tax relief and exemptions: tax policies, such as exemptions or reductions, to alleviate the financial burden on SAF producers and encourage market competitiveness.
- Financial market instruments: the use of green bond mechanisms and debt guarantees to facilitate access to capital for SAF projects, promoting investment in sustainable fuel infrastructure.
- Accounting policy reforms: implementation of accelerated amortization schedules to improve the financial feasibility of SAF production facilities.
- Research and development (R&D) support: public funding for R&D programs to drive innovation in SAF production technologies and processes, reducing long-term costs.

These mechanisms collectively aim to align SAF production with the economic incentives available to other renewable fuel sectors, fostering a more equitable market environment. (IATA, US and EU SAF policies)

## 5.2 Carbon Offsetting and Reduction Scheme for International Aviation, CORSIA

CORSIA is the very first global market-based scheme that applies to international aviation section. The international standards for the implementation of CORSIA were adopted as an Annex to the Chicago Convention, and they apply to all of ICAO's 193 member States from 1 January 2019

onwards. It complements other aviation in-sector emissions reductions efforts such as technological innovations, operational improvements and sustainable aviation fuels to meet the ICAO aspirational goal of carbon neutral growth. Each sector complementing each other is contributing towards planned carbon neutral future as displayed in figure 5. (ICAO, Carbon Offsetting and Reduction Scheme for International Aviation)

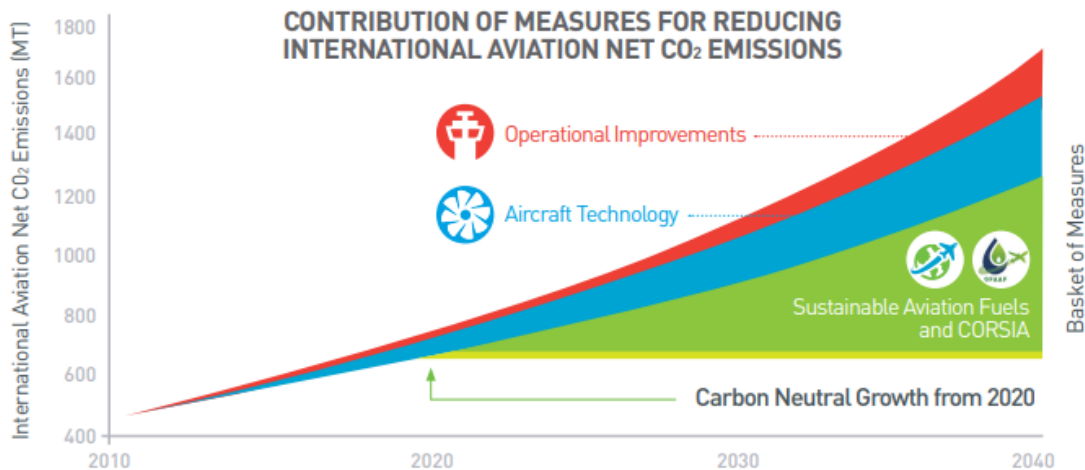


Figure 5. ICAO's Basket of measures to attain global sustainability goals (ICAO s.a)

CORSIA requires aircraft operators to monitor their emissions from international flights and offset any growth above the 2019 emissions baseline. Starting in 2025, and then every three years, operators will have to cancel enough emissions units to match their offsetting obligation for the most recent 3-year compliance period. Offsetting is done by purchasing carbon credits or using approved sustainable aviation fuels (IATA, Offsetting CO<sub>2</sub> Emissions with CORSIA). The type of offset used to achieve CO<sub>2</sub> reductions may bring other benefits like social, environmental, and economic benefits. These offsets can be project activities like renewable energy projects and can be purchased through specialized offset providers or carbon brokers. ICAO Council reviews and approves a list of programs that can supply CORSIA Eligible Emissions Units, EEU's. Council has quality control party, that oversee the programs comply with set CO<sub>2</sub> reductions (ICAO, Carbon Offsetting and Reduction Scheme for International Aviation).

CORSIA affects all air operators and private operators with international flights that result in 10,000+ tons of carbon dioxide emissions, or roughly the equivalent of 3,160 tons of consumed fuel, each year (ICAO, Carbon Offsetting and Reduction Scheme for International Aviation). Operators must keep track of their fuel use for each individual flight to calculate their CO<sub>2</sub> emissions. They will have to apply one of the five approved fuel-use monitoring methods. In certain circumstances, however, operators may be eligible to use simplified monitoring and estimate their

emissions using the CO<sub>2</sub> Estimation and Reporting Tool (CERT), developed by ICAO as part of CORSIA. All operators, irrespective of their nationality, must monitor, report, and verify (MRV) CO<sub>2</sub> emissions from all their international flights to their national authority “administrating authority” on an annual basis (IATA, Offsetting CO<sub>2</sub> Emissions with CORSIA).

CORSIA only applies to international flights, which take off in one state and land in another. Domestic flights, i.e. flights between two aerodromes located in the same state, are not included in the scope of CORSIA. (IATA, Offsetting CO<sub>2</sub> Emissions with CORSIA)

CORSIA participation began with a pilot phase from 2021 to 2023, which was voluntary, followed by the first phase from 2024 to 2026, also voluntary. From 2027 onwards, participation becomes mandatory for most countries based on their 2018 aviation activity data, though exemptions exist for least developed countries, small island developing states, landlocked developing countries, and countries with minimal international aviation activity. From 2021 until 2026 only flights between States that volunteer to participate in CORSIA will be subject to offsetting requirements. From 2027 the program will be expanded to include all international flights, with few exceptions left. (IATA, Offsetting CO<sub>2</sub> Emissions with CORSIA)

Few countries like Vietnam have announced formal commitments to join CORSIA starting in 2026. However, major countries such as China, India, and Brazil have not yet committed to participating as can be seen in figure 6. Considering these regions are expected to have biggest future traffic growth, it would be very important to see them participate in the future. In the name of fair market competition and common goals, the industry is looking forward to their participation. (IATA, Offsetting CO<sub>2</sub> Emissions with CORSIA)

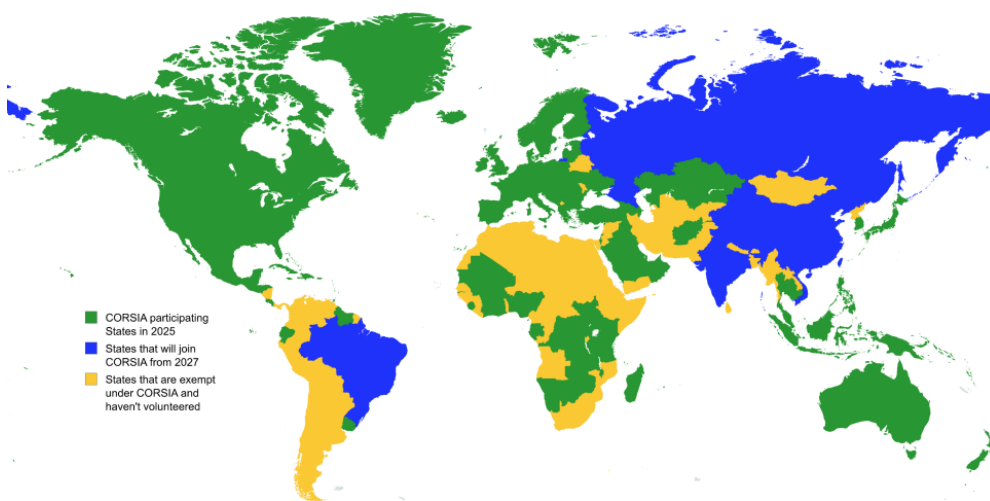


Figure 6. IATA state of global CORSIA participation (IATA s.a.)

### **5.3 European Policies**

Europe is currently leading the way with focus on regulatory and compliance-based aviation climate model. EU's integrated approach linking emissions trading, SAF mandates with comprehensive reporting standards makes it a global model for advancing sustainable air freight standards.

#### **5.3.1 EU Emissions Trading System**

EU Emissions Trading System, EU ETS is built to act as market-based mechanism to reduce greenhouse gas emissions from various sectors, including aviation. Airlines need to monitor, report and verify their CO<sub>2</sub> emissions. Each airline has an allocation of carbon allowances, that is designed to be less than average materialized rate of the specific airline. If airline exceeds the allocation, they can purchase additional allowances from the market. In a secondary market airlines can also sell allowances to competitors or bank their unused allowances for future. Idea of EU ETS is to encourage airlines to reduce their emissions. The cap will reduce every year by 4.3% from 2024 to 2027 and from there onwards by 4.4% annually. EU ETS covers all passenger and cargo flights that operate from EU airport. (European Commission, Reducing emissions from aviation)

#### **5.3.2 ReFuelEU Aviation**

The European Commission published a package of legislative proposals branded "Fit for 55" in July 2021. ReFuelEU goal is to increase production and usage of SAF. The proposal includes a blending mandate imposed on aviation fuel suppliers, with the obligation for the suppliers to ensure that all aviation fuel supplied to aircraft operators at European Union airports contains a minimum share of SAF, including a minimum share of synthetic fuel. (IATA, US and EU SAF policies)

The mandate started in 2025 with a minimum volume of SAF at 2%. There will be an increase every five years with a minimum volume of 63% needed in 2050, of which 28% would consist of synthetic aviation fuels. A sub-mandate for synthetic e-fuels, starting at 0.7% in 2030 and increasing to 35% in 2050, underlines their significant potential for emissions reductions. All SAF supplied under the ReFuelEU Aviation needs to comply with the sustainability and greenhouse gas emissions saving criteria as set out in the Renewable Energy Directive, RED. (IATA, US and EU SAF policies)

ReFuelEU mandates every airline departing from EU airports to uplift jet fuel prior to departure, no matter where the airline is from. The amount of jet fuel uplifted must correspond to the volume of jet fuel necessary to operate the planned flight, regardless of the destination. The yearly quantity of aviation fuel uplifted by a given aircraft operator at a given EU airport shall be at least 90% of the

yearly aviation fuel required. The legislative proposal also associates with reporting obligations of aircraft operators to the European Union Aviation Safety Agency. (IATA, US and EU SAF policies)

ReFuelEU has been criticized by European airlines due to several reasons. Mandate is seen as bureaucratic, SAF availability is still below need and it is more expensive than jet fuel, airport infrastructure is not ready throughout EU yet and the directive puts EU airlines in unfair competition against non-EU airlines.

### **5.3.3 The European Union's corporate sustainability due diligence directive**

The European Union's corporate sustainability due diligence directive (CSDDD) was adopted in 2024. The landmark EU corporate supply-chain legislation law mandates companies to better protect human rights and labor rights and work towards healthier environment for present and future generations, including climate change mitigation. The law aims to increase trust in businesses allowing companies to be transparent on their ESG strategy and building trust through transparency. Fragmented national rules on corporate, sustainability-related obligations have made it challenging to get reliable information on business partner's operations. Harmonized rules create framework and are built to create legal certainty and level playing field for all. For developed countries the directive offers better protection of human rights and environment as well as improved sustainability-related standards. (European Union, Corporate sustainability due diligence)

All companies with 1000 or more employees and above 450 million euros in turnover are subject to the law. Environmental issues within supply chains might lead to fines up to 5% of global turnover.

CSDDD has become one of the most politically contested parts of Europe's green agenda, and Brussels is now negotiating changes to simplify the rules for European companies.

### **5.3.4 The European Union's corporate Sustainability Reporting directive**

The European Union's corporate Sustainability Reporting directive, CSRD aims to standardize sustainability reporting across the EU, requiring companies to disclose their environment and social impacts in a transparent way, including reporting on human rights, company boards and human rights as well as anti-corruption measures. For airlines the directive means transparency reporting on the emissions, energy consumption and waste management. While many airlines have been blamed for greenwashing efforts, the transparency could offer some welcome standardization for the industry. The directive applies to European airlines, among other companies having a balance sheet of over 25 million euros or employing more than 250 people. Foreign enterprises having a subsidiary or branch in the EU need to report, if generating a turnover of more than 150 million euros. (European Union, Eur Lex, Access to European Union law)

With increasing standardized reporting requirements, it is expected the airlines demonstrate transparency in their ESG policies and responsible practices and can avoid potential penalties and reputational risks with non-compliance. (European Union, Eur Lex, Access to European Union law)

While first phase of CSRD started on January 1<sup>st</sup>, 2024, the directive has seen a lot of criticism, and it remains to be seen if the directive will be eased by the EU as many companies have pleaded for more free competition and less bureaucratic reporting to ensure competitiveness of European companies.

## **5.4 The United States Policies**

While sustainability targets in United States are very similar to European Union, U.S. approaches aviation sustainability differently. Policies are a combination of federal initiatives, market-based measures, and industry-led programs, rather than a single unified mandatory policy framework like in the European Union. U.S. policy emphasizes innovation, fuel efficiency, and the development of sustainable aviation fuels (SAF) as key pathways to decarbonization.

### **5.4.1 United States Aviation Climate Action Plan**

On November 9, 2021, the Federal Aviation Administration (FAA) released the United States 2021 Aviation Climate Action Plan. This government-wide initiative sets objective to achieve net-zero life cycle greenhouse gas (GHG) emissions from aviation within the United States by 2050. The plan aims to prevent irreversible and potentially catastrophic impacts of climate change through this targeted reduction. (United States 2021 Climate Action Plan)

Climate Action plan lists following actions as pathway to reduce CHG to net-zero level:

- The introduction of new, more efficient aircraft by airlines into their operational fleet and retirement of older, less efficient aircraft.
- Development of new, more energy efficient aircraft and engine technologies by the original equipment manufacturers (OEMs).
- Improvements in aircraft operations throughout the National Airspace System (NAS) by the U.S. Government (USG) and by airlines flying more optimal trajectories for reduced fuel use and contrail impacts.
- Production of Sustainable Aviation Fuels (SAF) by the energy sector.
- Electrification and potentially hydrogen as solutions for short-haul aviation.

- Advancements in airport operations across the United States.
- International initiatives such as the airplane CO2 standard and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).
- Domestic policies and measures to help meet emissions targets.
- Support for research into climate science related to aviation impacts

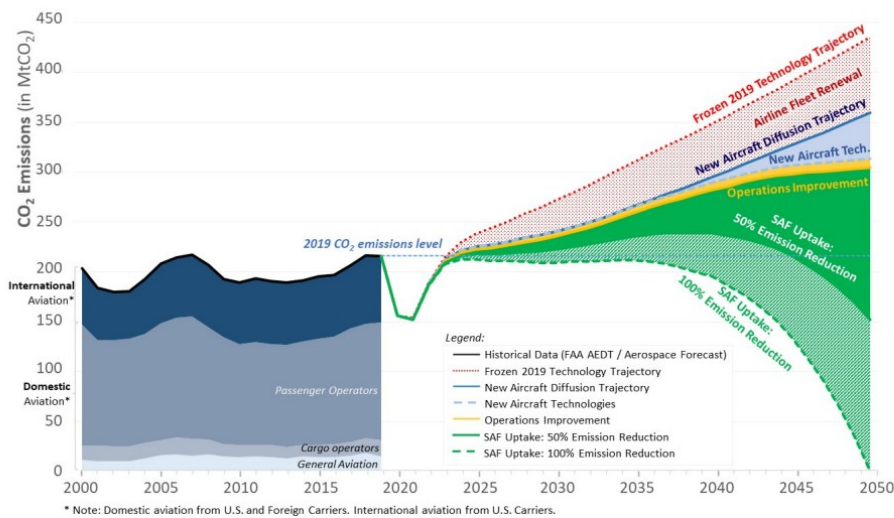


Figure 7. Analysis of U.S future domestic and international aviation CO2 emissions (Congress of United States 2021)

It is notable the Aviation Climate Action Plan measurements are very similar to ICAO's Basket of measures to attain global sustainability goals. However, there are 2 trajectories for the usage of SAF. One based on 50% reduction in life cycle emissions leading no rough net zero emissions goal by 2050. It is noteworthy to mention with the most optimized SAF emission reduction of 100%, the NET zero emissions projection could be even below 2019 level.

In the near term, the plan targets greenhouse gas (GHG) reductions through improvements in aircraft efficiency and increased use of sustainable drop-in jet fuels. Long-term strategies emphasize the development of advanced technologies, including cryogenic hydrogen-fueled, electric, and electric-hybrid aircraft; however, these innovations are not expected to significantly impact GHG emissions until after 2050. Achieving net-zero GHG emissions from aviation by 2050 will require substantial restructuring of the national aviation and energy infrastructure, incurring significant costs. Although this goal is ambitious, its feasibility improves when decisions are driven by

scientific evidence and data. Additionally, the plan highlights that these efforts aim to stimulate economic growth and job creation in the United States. (United States 2021 Climate Action Plan)

Scope of measurement encompasses domestic aviation, flights departing and arriving within United States and its territories including US and non US operators. (United States 2021 Climate Action Plan)

An update to plan was published in 2024, reflecting differences in actual plan and measured results by 2024 as seen in figure 8. It was notable that the aviation sector had recovered from Covid-19 and offered capacity and available Ton Kilometers (ATK) was 9% higher than projected for 2022. Combustion Co2 emissions were +8% higher than forecasted due to same reasons. However, the CO2 intensity of the US Aviation sector was approximately 0.9% than projected in the action plan mainly due to efforts in fleet renewal, aircraft technology and fleet renewal. SAF investments yielded an eight-fold increase in the volume used by U.S operators. This is seen as encouraging trend in SAF development, production and uptake. (United States 2024 Climate Action Plan)

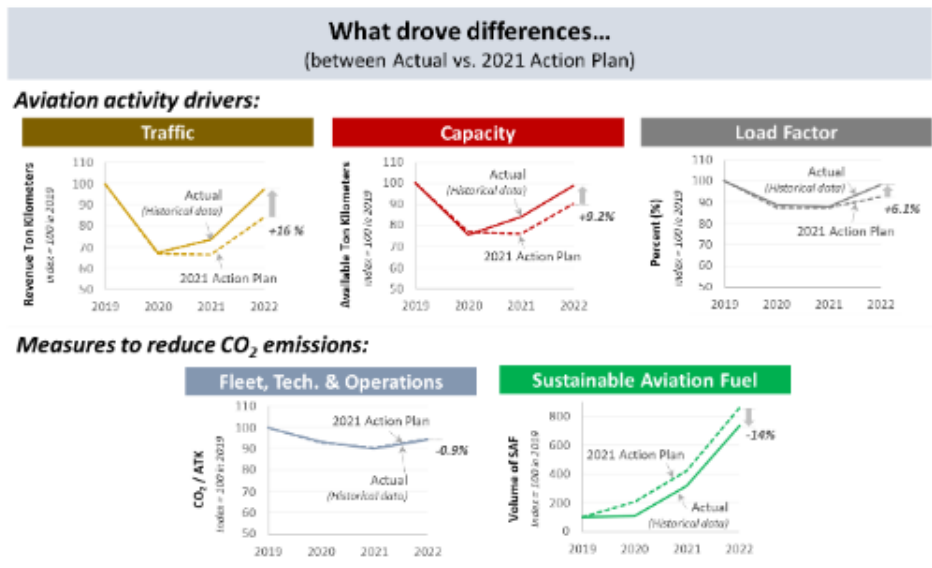


Figure 8. Factors influencing the evolution of CO<sub>2</sub> emissions from the U.S. aviation sector between 2021 and 2024 (Congress of United States 2024)

#### **5.4.2 California Low Carbon Fuel Standard**

The California Low Carbon Fuel Standard, CA-LCFS is a policy framework designed to reduce greenhouse gas (GHG) emissions in the transportation sector by implementing a system of carbon intensity reduction, assigning value to carbon reductions achieved through renewable fuels, such as sustainable aviation fuel (SAF). Updated in 2019 to include SAF as an eligible fuel for generating credits, the CA-LCFS quantifies the GHG benefits of SAF using life-cycle assessment modeling to calculate avoided emissions compared to conventional jet fuel. These credits incentivize SAF production by allowing their sale to other obligated parties under the CA-LCFS, thereby encouraging the broader adoption and production of sustainable aviation fuel. (California Air Resources Board, Low Carbon Fuel Standard)

Individual states such as Oregon, Washington, and the province of British Columbia have recently introduced their own LCFS legislation to establish state markets and have aligned their policies with California to reduce GHG emissions and promote clean energy along the entire western corridor of the United States and Canada through the Pacific Coast Collaborative (PCC) agreement. (California Air Resources Board, Low Carbon Fuel Standard)

#### **5.4.3 The U.S. Renewable Fuel Standard and SAF Initiative**

The U.S. Renewable Fuel Standard, RFS was created by the Energy Policy Act of 2005 and was later updated through the Energy Independence and Security Act of 2007. This regulation targets renewable fuel for ground transportation by mandating a minimum annual volume that increases over time. The approach aims to enhance the competitiveness of Sustainable Aviation Fuel (SAF) relative to renewable diesel, without imposing a direct mandate for SAF use. (United States Environmental Protection Agency, Renewable Fuel Standard)

The Sustainable Aviation Fuel (SAF) Initiative, formerly the SAF Grand Challenge, represents an effort by the U.S. Department of Energy, Department of Transportation, Department of Agriculture, and other federal agencies to develop a comprehensive strategy for scaling up innovative technologies to enhance the production of affordable, domestically produced sustainable aviation fuel (SAF). This initiative aims to reduce costs, improve sustainability, expand production, create export opportunities, increase fuel choices, support American farmers, and lower energy costs, with specific targets of achieving 3 billion gallons of annual domestic SAF production by 2030, with at least a 50% reduction in life-cycle greenhouse gas emissions compared to conventional fuel, and

meeting 100% of projected aviation jet fuel demand, equivalent to 35 billion gallons annually, by 2050. (Biomass Research & Development, Sustainable Aviation Fuel Initiative)

As an addition to SAF Grand Challenge president Biden announced Inflation Reduction Act, IRA in 2022, that allocates resources towards clean energy initiatives. One of the provisions is to support SAF usage in aviation sector. The IRA provides airlines with incentives and subsidies for SAF production. Airlines can receive tax credits ranging from \$1.25 to \$1.75 per gallon for using SAF, that achieves at least 50% reduction in lifecycle CHG. This proactive approach helps airlines to reduce their fuel cost while supporting their environmental goals. Act also includes funding through loan guarantee programs and grants to support innovations and clean technology deployment. (USDOT, SAF Grand Challenge Roadmap)

#### **5.4.4 The U.S. Sustainable Skies Act**

The Sustainable Skies Act was introduced by US. Congress in May 2021. Idea is to incentivize the production and use of SAF. A credit of \$1.50USD per gallon is available for blenders that supply SAF with a demonstrated 50% or greater lifecycle GHG savings. Through higher GHG achievement an even higher credit is available. All SAF must meet ICAO sustainability criteria to meet the transparency criteria. Additionally, the Act includes provisions for grants to expand SAF production facilities, further enhancing supply availability and infrastructure in the U.S. Idea is to produce 3 billion gallons of SAF per year by 2030. This creates economic opportunities and supports job growth in the sustainable fuels sector. Ultimately, the Sustainable Skies Act helps airlines accelerate the transition to cleaner fuels while maintaining economic competitiveness and aligning with climate goals. When blenders get a tax credit they can sell SAF to airlines at lower cost. (Congress of United States, Sustainable Skies Act)

## 6 Airline and Cargo Carrier Initiatives

### 6.1 SAF

Use of Sustainable Aviation Fuel is seen as the best solution in the short and midterm to reduce air cargo industry emissions by 2050. IATA states in their Developing Sustainable Aviation fuel report, that SAF is a liquid fuel currently used in commercial aviation which reduces CO<sub>2</sub> emissions by up to 80%. SAF can be produced from several sources, feed stock including waste oil and fats, green and municipal waste and non-food crops. Benefit of SAF is that it is drop-in and can be blended into existing fuel infrastructure and is compatible with current engines used. Globally various measures have been put in place to support the achievement of European, American and ICAO goals on SAF, including a European Clearing House, financial incentives, research programs and international cooperation.

In 2023, the ICAO CAAF/3 conference agreed on a global vision to reduce CO<sub>2</sub> emissions from international aviation by 5% in 2030 with SAF, low-carbon aviation fuels and other aviation cleaner energies. However, as of 2024, SAF production represented only 0.53% of global jet fuel use and significant expansion of production capacity is required to meet ambitious future mandates and goals. In 2019, less than 200,000 tons of SAF were produced globally, a tiny fraction of the roughly 300 million tons of jet fuel used by commercial airlines. If planned SAF projects materialize in the next few years, production could scale to at least four million tons—roughly 1 percent of global jet fuel demand in 2030. (IATA, Annual review 2025)

Nine types of biofuel methods to produce SAF have been approved for use, and there are ongoing efforts to increase blending limits and support the use of 100% drop-in SAF by 2030. Currently allowed blend is max. 50%, while tests have been conducted using higher blend. All SAF must meet international standards to ensure the safety and performance of aviation fuel. SAF has the potential to offer significant CO<sub>2</sub> and nonCO<sub>2</sub> emissions reductions on a lifecycle basis compared to conventional jet fuels, primarily achieved during the production process using sustainable feedstock. Several factors such as land use changes can negatively impact on the overall lifecycle emissions though. (IATA, Annual review 2025)

Research shows SAF has non-CO<sub>2</sub> related environmental impacts. SAF varies in its hydrocarbon composition relative to conventional A1; further, SAF in general has zero fuel sulfur content. Measurements have consistently shown that SAF use reduces non-volatile particulate matter like soot or black carbon and sulfur dioxide emissions. The research on these quantities and on how these emissions affect air quality and climate is ongoing. Of particular interest is the effect SAF

combustion will have on contrails and aviation-induced cloudiness. Preliminary work shows that SAF use will change the properties of contrails and aviation-induced cloudiness, and these changes could result in a net climate benefit. However, additional work is needed before conclusions can be reached on this subject. (USDOT, SAF Grand Challenge Roadmap)

Production of SAF can have side effects: the upscaling of SAF has generated concerns about potential fraudulent behavior where products labeled as meeting sustainability requirements are not compliant in search of a quick win (EASA, European Aviation Environmental report 2025). USDOT voices a concern in regards of fuel import/export tariffs and how the countervailing nature of these policies affects market behavior. It is important to also review and consider overseas policies. For example, the development of low-carbon fuel standards in Canada and the development of SAF mandates in Europe could have an impact on U.S. feedstocks and markets for SAF. (USDOT, SAF Grand Challenge Roadmap)

Airlines have signed sustainable aviation fuel (SAF) offtake agreements as displayed in figure 9. SAF offtake agreement is an agreement between a supplier and a buyer to purchase a volume of SAF produced by a plant, either established or under construction. The industry signed 124 intake agreements between 2022 and 2025 out of which 86 binding and 30 nonbinding purchase commitments. Hydro processed esters and fatty acids (HEFA) and HEFA coprocessing dominate offtake agreements, accounting for 64% of the total. Although SAF production doubled in 2024 compared with 2023, the scale-up is insufficient to satisfy demand. In 2024, SAF supply represented a mere 0.3% of all air transport fuel consumption (IATA, Annual review 2025). Considering the mandatory ReFuelEu SAF order starting in 2025, it will be important that supply meets or exceeds demand.

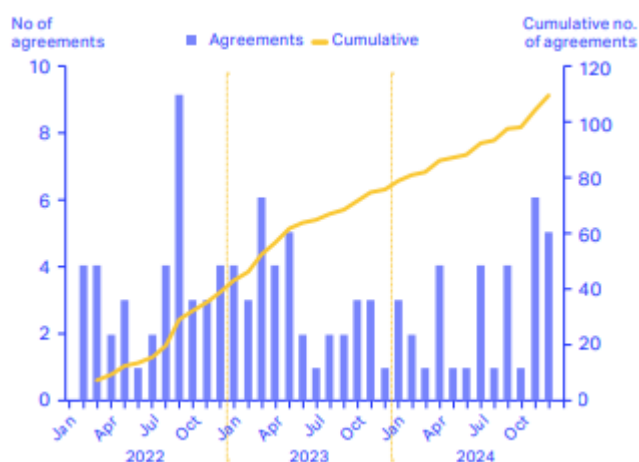


Figure 9. Sustainable aviation fuel (SAF) offtake agreements as of Dec24 (IATA 2025)

IATA estimates that a million tons of SAF was produced in 2024 and that it sold at an average price of \$2,316 per ton. This price is 3.1 times higher than that for conventional aviation fuel and added \$1.6 billion to airlines' combined fuel bill in 2024. EASA generally states SAF is 3 to 10 times more expensive than conventional fuel. In IATA's estimate, SAF will increase to 0.7% of airlines' total fuel consumption in 2025 and will add \$4.4 billion to the industry's fuel costs, assuming prevailing prices (IATA Sustainability & Economics, IATA Annual Review 2025). Considering airline industry including air freight carriers operates on small margins in average, the high price of SAF can be seen as an economic challenge, especially for smaller airlines. Jet fuel cost is a major cost item in airline tables up to 25%, leading to elevated influence on profitability.

## **6.2 Fleet modernization fuel-efficient aircraft**

Latest generation aircraft Boeing 787 and Airbus 350 come with advantages with reduced fuel consumption. B777 freighters are considered the most efficient freighter aircraft in the market, while the first freighter version of A350 is currently being built in Europe. Each new generation of aircraft burns roughly 15% less fuel per passenger kilometer than the aircraft it replaces, some aircraft manufacturers advertising even steeper savings, up to 25%. Key technologies include more fuel-efficient next generation engines, improved aerodynamics, lightweight materials such as advanced composites, plus advanced systems and integrated design. Looking at the historical data, new aircraft fuel burn has fallen by 1.3% per year since 1960s. Recently, the rate of improvement has been declining due to the prevalence of cheaper "re-engined" aircraft, such as the Boeing 737 MAX and a lack of "clean sheet" designs like the Boeing 787 Dreamliner and airlines performing retrofits instead of investing in new planes. (International Council on Clean Transportation, Standards to promote airline fuel efficiency, 2020)

There has been only limited number of new certified large transport aircraft and engine types over the last few years with marginal environmental improvements. Ensuring technological, industrial and certification readiness of new concept aircraft and engines to meet the planned in-service schedule and use of 100% SAF in European Aviation is one of the key targets of EASA. While deliveries of the latest generation of aircraft continue to penetrate the European fleet, the industry is challenged with long lead times for aircraft deliveries due to challenges in supply chain and legal issues with aircraft certification. These factors affect airline's investment decisions. (EASA, European Aviation Environmental report 2025)

While fleet modernization brings benefits on the environmental side, it also involves significant capital investment. Mordor Intelligence study 2025 reports high sustainability surcharges raise shipper prices, potentially diverting low-yield cargo to ocean transport and dampening certain routes within the air freight market. (Mordor Intelligence, Global Air Freight Market 2025)

### 6.3 Technological advancement

Technological advancements are related to mainly modern type of short- and long-haul aircraft designs. There are roughly 700 projects ongoing globally.

Maybe the most prominent future aircraft type is the electric plane. Electric aircraft could reduce both emissions and noise pollution. Disadvantage of electric powered flying is the heavy battery packs that contain less energy per kg than jet fuel. Even the best batteries have a specific energy of only 250 watt-hours per kilogram, but we need to get closer to 800 to really start flying, and that is still nothing compared to jet fuel's specific energy, which is nearly 12,000 watt-hours per kilogram. The sourcing of lithium battery materials is also controversial and currently the airports do not have any charging stations or storage facilities to accommodate possibly several types of battery sets. Certification process for new aircraft type is also long and challenging. Currently the electric planes are expected to enter commercial service in 2040 the earliest. (EASA, European Aviation Environmental report 2025)

Hydrogen-powered fuel cells might be another option to work alongside environmental commitments. They work by combining hydrogen and oxygen to produce a reaction, a by-product of which is electricity. Combustion product is water. The abundance of hydrogen in our atmosphere makes the proposal attractive. However, issues on supply and cost need to be addressed. Hydrogen has a very low boiling point of  $-252.8^{\circ}\text{C}$  leading to huge energy demand. It is also difficult to store and handle. As with electric option, the airports are not set up to serve hydrogen powered aircraft. Some legal challenges exist besides getting hydrogen certified, instrument flight rules require planes to be able to fly to alternative airports and 45 minutes beyond that. Flying longer distance alone is a problem, not to mention meeting the minimum targets (EASA, European Aviation Environmental report 2025). Airbus is currently working on ZeroE hydrogen powered combining efficiency and latest technology (Airbus Pioneering technology for future aircraft). While hydrogen powered aircraft could be used for short haul flights, there might be reductions in payload and currently freighter options are not in development.

Plane manufacturers are consistently evolving to help air travel be more efficient. Examples include Boeing's ecoDemonstrator program, that tests and implements technologies aimed at improving fuel efficiency and reducing emissions. In 2024, the program evaluated 36 technologies, including the use of sustainable aviation fuel blends, single-engine taxiing, and advanced flight path optimization – an example of a technology that is benefiting airlines now (Boeing, World Air Cargo forecast 2024-2043). Looking ahead, United's and Delta's investments in JetZero's "blended-wing body" aircraft, known as the Z4, integrates the wings and fuselage into a single,

wide airframe, enhancing aerodynamic efficiency and potentially reducing fuel consumption by up to 50 percent per passenger mile compared to traditional aircraft. These could be used in commercial flights as soon as 2027 (JetZero). An advantage of JetZero plan is, it is designed to serve as a freighter as well, and the announced 5 000 nautical miles range is competitive with the current, B77F freighter range. JetZero seems to be the most prominent option for long range larger capacity planes. While Airbus is actively working on a single aisle 100% SAF powered aircraft type, that would reduce the current fuel burn level by 20-30%, the single aisle type of aircraft will not directly support cargo industry volumes (Airbus, Airbus Summit 2025 Pioneering technology for future aircraft). Waypoint 2050 report estimates that for long haul operations, that currently produce 30% of industry emissions, there might not be technological alternatives in use by 2050. SAF would be the best option to reduce emissions in this sector (Air Transport Action Group, Waypoint 2050).

If airlines are investing in new aircraft, where lot of capita is engaged, they may have less ability to also invest heavily in sustainable aviation fuel scale-up simultaneously.

#### **6.4 Carbon offsetting schemes**

Offsetting is an action by a company or individual to compensate for their emissions by financing a reduction in emissions elsewhere. It can mean to balance, cancel or neutralize. Such offsets can be sourced from various types of project activities, including wind energy, use of clean cooking stoves, methane capture, and other emission reduction projects. Many projects are designed to support the UN Sustainable Development Goals. Carbon offsetting is based on airline voluntary commitment, where passenger or cargo shippers decide to reduce their own footprint. Therefore, offsetting credits cannot be used claim toward mandatory scheme like Corsia and double selling of credits should be avoided. (IATA, Voluntary carbon offsetting)

Critics of carbon offset programs state that they may lack verification and transparency, raising concerns about whether the promised carbon reductions are materializing. Many airlines have been accused of greenwashing in this context. Research by Guardian claims, that more than 90 percent of rainforest-based carbon offsets are “useless,” offering no actual benefit to the planet. Many projects provide a delayed impact, particularly tree planting, which can take decades to sequester the amount of carbon equivalent to the emissions from a single flight. While offsets can play a role in broader climate strategies, they should not be relied upon as the primary solution. Reducing emissions at the source should be the main goal instead. Another argument against carbon removal is that it simply allows polluters to continue polluting with the promise of cleaning it up later. (Matador Network, Air Travel Pollutes Relentlessly. Is Carbon Removal Part of the Solution?)

## 6.5 Load Optimization for Air Freight

When effectively optimizing cargo loads, this can increase the capacity of goods an aircraft can hold and maximize the space available, ultimately reducing the number of flights required and increasing the load factor. Use of lighter, innovative materials for building pallets for airfreight or using lighter support materials to build the cargo can help fly lighter with less emissions and more efficiently. (ICCT Standards to promote airline fuel efficiency 2020)

Airlines that excel in this area not only enhance profitability but also minimize their per-ton emissions. Reportedly, a well-managed load can result in a 25% reduction in emissions per cargo unit transported. Collaborative efforts among various stakeholders are being prioritized to improve overall industry performance. Many air cargo operators report using AI driven tools including algorithms to plan for cargo arrangements on pallets, accounting for stacking rules and fully optimizing the volume/weight utilization of the contour. (ICCT Standards to promote airline fuel efficiency 2020)

Using lighter cargo containers made of high-tech, fire-resistant composite materials such as MACROLite and Kevlar can help airlines to reduce emissions and carry more cargo. Airlines can invest in modern cargo nets made of advanced materials like dyneema, allowing up to 10kg weight reduction per net in comparison to more traditional materials. (Air Transport Action Group, Waypoint 2050)

## 6.6 Optimizing Air Freight Routes

Airlines are using advanced routing and flight planning techniques to find the most direct, elevation optimized and accurate routes to minimize fuel consumption and reduce emissions. Artificial intelligence is used to predict weather, air traffic and fuel consumption. Doing so considers factors such as wind patterns, air traffic congestion and the performance capabilities of aircraft. Reducing “circuitry” by avoiding unnecessary layovers and routing flights more directly can also reduce fuel burn. Operational improvements can provide fuel efficiency gains of around 0.5% per year. (ICCT, Standards to promote airline fuel efficiency)

## 7 IATA Net Zero Roadmap

IATA's five Net Zero Roadmap is set to give guidance to airlines, identifying tools and milestones on the part to net zero 2050. Goal is to offer support to airlines navigating through development and requirements within the industry. The dynamic roadmaps chart a possible course towards net zero for the aviation industry, by leveraging all the possible technological, infrastructural, operational, financial, and policy levers in an integrated way. Furthermore, the roadmaps are scenario dependent, and the scenarios defined today might differ from the pathway the sector will follow, as this will be influenced by the ever-advancing research in all the five areas that the roadmaps address: aircraft technology, energy infrastructure, operations, finance, and policy. Figure 10 depicts how the five Roadmaps cover the three levers to reduce, neutralize or eliminate emissions, and how each plan collaborates and interacts with each other. (IATA, The Net Zero Roadmaps)

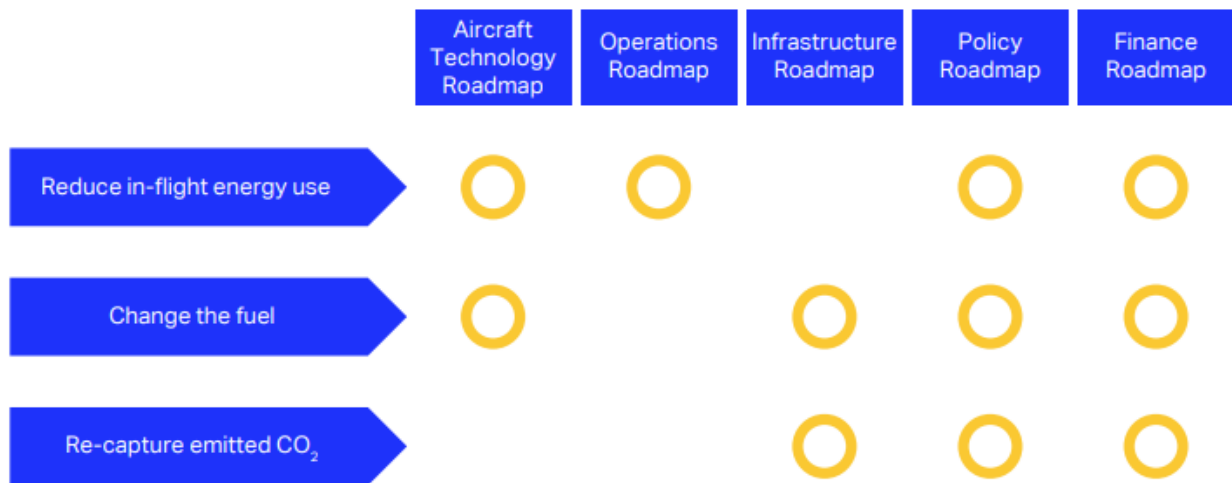


Figure 10. IATA The five net zero roadmaps and the areas which they contribute to (IATA 2024)

### 7.1 The Aircraft Technology Roadmap

It is a fact, that most aviation sector emissions are a result of fuel burn and the Aircraft Technology Roadmap addresses the issue on how new aircraft and engine technologies can deliver more efficient aircraft which use less energy. There are estimates that jet fueled aircraft could still gain 15-20% in terms of efficiency compared to the best technology available today as confirmed by research by Boeing as well. Efficiency improvements through new aircraft technology could cut aviation in-flight energy needs by 7-10% by 2050. The idea is for next generation aircraft to be able to operate on 100% Sustainable Aviation Fuel. (IATA, The Net Zero Roadmaps)

Other futuristic development plans conclude revolutionary aircraft which will be operated with hydrogen or batteries, fully eliminating carbon emissions from their operations. These aircraft could avoid an extra 35-125 Mt of CO<sub>2</sub> by 2050. While many projects are ongoing, it remains to be seen when the first planes enter the market, how far they can fly, and how many passengers they can carry on board. Projects from developing new technologies can be lengthy starting from investing and demonstrator programs, including new engines, aerodynamics, aircraft structures and flight systems. Before new aircraft enter the market, they need to be demonstrated in full scale, before they can enter service. Right now the influence of revolutionary aircraft types operating in the market and their share of emission reduction rate is questionable. (IATA, The net zero roadmaps)

## **7.2 The Energy and New Fuels Infrastructure Roadmap**

The next generation aircraft will depend heavily on SAF infrastructure and airports will need to be equipped for feedstock collection, refining, and blending, to replace conventional aviation fuels. Central scenarios project that SAF will account for 80-90% of aviation fuel consumption by 2050, thereby cutting aviation emissions by 62%. According to IATA's analysis, meeting this demand will require between 5,000 and 7,000 biorefineries globally by 2050. Most SAF production pathways will also rely heavily on hydrogen, with the sector potentially demanding nearly 100 million tons of hydrogen by 2050. A smaller portion of this hydrogen, between 4-14 million tons, will be used in pure form to power zero-carbon hydrogen aircraft. Hydrogen-powered aircraft will necessitate additional airport infrastructure, including fuel storage, distribution systems, new ground procedures, and supporting equipment. Carbon capture facilities will also be critical to extract more than 700 million tons of CO<sub>2</sub> from the atmosphere, both to reduce residual emissions and to supply carbon for synthetic SAF production. Renewable energy will be a common nominator for all these solutions, enabling the manufacture of zero-carbon fuels on the ground to meet the in-flight energy demands of future aviation. (IATA, The net zero roadmaps)

## **7.3 The Operations Roadmap**

Air Traffic Management, ATM is a critical part of national infrastructure, and it is important part of sustainable civil aviation strategy. Effective sustainability in ATM means coordinating investment and alignment among shareholders: airlines, airports and air navigation service providers. Airspace is becoming increasingly scarce and shared resource, making managing it efficiently essential. Current ATM system is not optimal and leads to unnecessary fuel consumption and emissions. While reductions in ATM alone will reduce all industry CO<sub>2</sub> emissions, the near-term opportunities for enhanced efficiency are there. (IATA, The net zero roadmaps). While airlines can try to influence and co-ordinate with ATC regulations, the field is still not completely within their influence zone.

The Operations Roadmaps suggest following approaches to accelerate the implementation of the different elements included in the roadmap:

- Use of local and regional projects as proof of concept for the development of global standards and highlighting benefits and costs.
- Environment and performance benchmarking to measure progress and showcase best practices for implementation towards Trajectory Based Operations (TBO).
- Regional and local consortia for implementation which ensure that the needs of airspace users are considered in the planning and implementation phase (IATA, The net zero roadmaps)

#### **7.4 The Finance Roadmap**

The Finance Roadmap shares a number for investments needed to reach net zero CO<sub>2</sub> emissions by 2050, and the costs involved to airlines in procuring the new solutions. Substantial investments in new bio-refineries will be needed. These facilities will produce biofuels benefiting multiple industries beside aviation. Policymakers would need to drive the energy transition.

Key points of finance roadmap include:

- Required average annual investments: to reach net zero by 2050, the annual average capex needed to build the new facilities over the 30-year period is about USD128 billion per year, in a best-case scenario, significantly less than the estimated total sum of investments in the solar and wind energy markets at USD280 billion per annum between 2004 and 2022. Success would be facilitated by governments redirecting subsidies away from fossil fuels and toward renewable energy production, of which SAF is just one type of product.
- Annual transition cost, meaning the cost that comes on top of that of jet fuel as a result of procuring SAF, hydrogen, and other key levers, is estimated at USD1.4 billion in 2025. In 2050, the transition cost could be as high as USD744 billion, based on IATA's analysis. These numbers highlight the need for speed and scale in bringing solutions to market so that net zero CO<sub>2</sub> emissions can be achieved.

#### **7.5 The Policy Roadmap**

The IATA Policy Roadmap for achieving net-zero CO<sub>2</sub> emissions by 2050 outlines a strategic, phased approach for the aviation industry's decarbonization. It emphasizes that reaching net zero

requires coordinated policy, investment, and technological advances supported by strong government collaboration. The roadmap is organized across three time horizons: immediate (to 2025), medium-term (2026-2030), and long-term (2031-2050) objectives.

- Immediate action is needed to unlock the carbon offsetting and reduction scheme for international aviation (CORSIA) Eligible Emissions Units (EEUs) and prioritizing SAF in the product mix at refineries.
- Strategic policy sequencing combining technology-push and demand-pull measures will be critical. Moreover, governments must foster global, liquid, and transparent markets for cleaner aviation energy.
- Transformative collaboration between governments, the aviation sector, and across all sectors to remove existing barriers and promote investment in new technologies, SAF, and infrastructure. This recognizes that air transport's decarbonization is part of the broader global energy transition. The creation of a global SAF accounting framework is also essential to ensure transparency and prevent double counting of SAF's environmental benefits. Addressing the current fragmentation in certification processes for SAF and carbon offsets should be part of that endeavor as well (IATA, The net zero roadmaps)

The net zero roadmaps emphasize the fact there is no single solution to bring the industry to reach Net Zero CO<sub>2</sub> emissions by 2050. Optimal scenario is shown in the colored bars in figure 11, while the black lines depict the potential range of outcomes, depending notably on the extent and pacing of financing and policy support. In all the scenarios modeled, even the most optimized one with SAF replacing traditional jet fuel, there will be residual emissions which will need to be removed using carbon capture. (IATA, The net zero roadmaps)

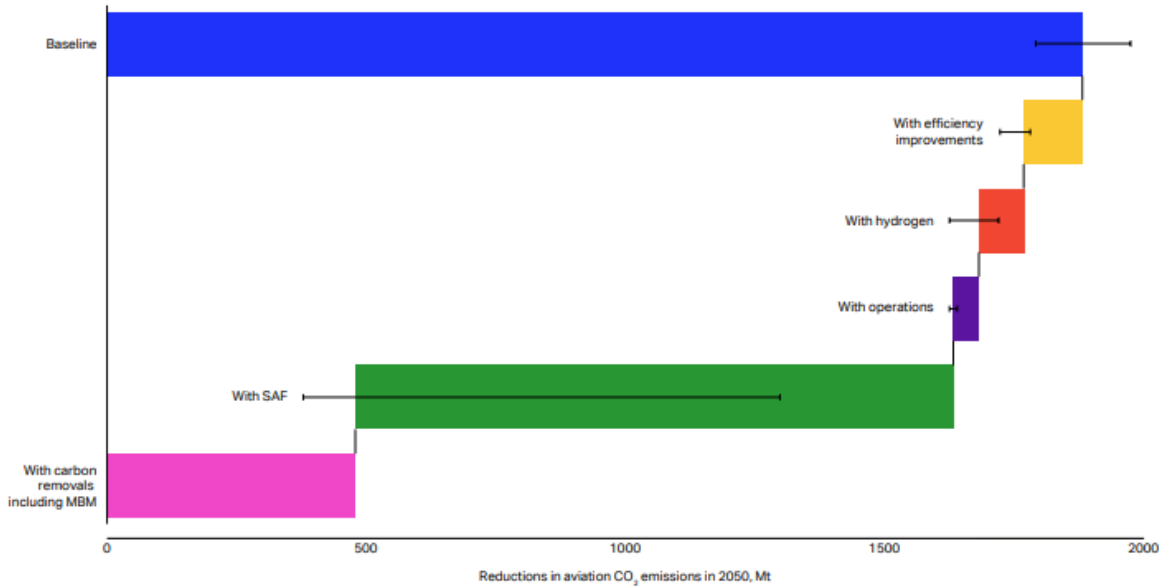


Figure 11. Reduction in aviation CO<sub>2</sub> emission in 2050 achieved through the different levels of action (IATA 2024)

Studying and understanding environmental policies in air cargo industry can be seen as complex tasks. Policies are still forming, and some can overlap or have varying economic impacts depending on airline home base. However, having IATA roadmap as guidance reaching toward to benefits of following environmental practices can act as guidance to international cargo carriers. Moving on to research part of the study, we can learn more on how the airlines are implementing policies into their strategy and how the efforts reflect.

## 8 Research design

This study evaluates the sustainability performance of four major cargo airlines using a structured ESG framework. The analysis consolidates operational, environmental, social, and governance indicators into a standardized set of key performance measures that enable cross-company comparison. By categorizing each KPI into widely recognized ESG domains and focusing on quantifiable, publicly disclosed metrics, the study provides an evidence-based assessment of how airlines differ in emissions intensity, renewable energy adoption, sustainable aviation fuel deployment, and compliance with global regulatory regimes. The academic objective is to determine the extent to which the selected airlines demonstrate measurable progress toward low-carbon and responsible air cargo operations.

The study uses quantitative methods to test relationships between operational variables and sustainability performance, such as how fleet modernization, SAF blending levels, or load-factor optimization influence emissions. By applying comparative analysis, the research provides objective insights into the current state of air cargo sustainability.

### Case selection

Four airlines were chosen for the study from North American and European market, all representing different stage of commitment to sustainable practices.

Airline A – Atlas Air, United States. Freighter aircraft only operator.

Airline B - Lufthansa Cargo, Germany. Combination freighter and passenger aircraft operator.

Airline C – Turkish Cargo, Turkey. Combination freighter and passenger aircraft operator.

Airline D – United Cargo, United States. Passenger aircraft only operator.

All airlines operate a dedicated cargo division and publish regular sustainability reports with environmental data for research purposes. Airlines have committed to SAF implementation, operational efficiency and carbon reduction. In their home markets airlines are subject to national rules and regulations as listed earlier in this study.

## 8.1 Atlas Air

Atlas Air is an American cargo airline and passenger charter operator based in White Plains, New York. Fleet consists of 113 aircraft and Atlas is the biggest single Boeing 747 freighter operator globally with 60 aircraft in their fleet. Atlas operates to 330 airports in 80 countries. In 2024, Atlas expanded their fleet with three additional Boeing B747-8 freighters. The 747-8F remains one of the most capable and environmentally responsible freighters, offering a 20% higher payload capacity and a 16% reduction in fuel consumption compared to previous 747 models. Atlas also added two new Boeing 777s and acquired four 747-400Fs in 2024, further advancing flight operations efficiency. (Atlas Air Worldwide. 2024 Sustainability report)

Atlas formalized “One Atlas” strategy in 2024: a framework guiding a mission to power customers supply chains. The strategy consists of four pillars: winning the market, delivering excellent performance, living a thriving culture that attracts and retains top talent and making sustainability a competitive advantage. (Atlas Air Worldwide. 2024 Sustainability report)

Atlas supports IATA’s goal to achieve net zero carbon emissions by 2050. Atlas has also set its own Scope 1 emissions reduction goal for 2035, to achieve a 20% reduction in CO2 to baseline of 2021 through a combination of increased SAF use, operational efficiencies and the implementation of innovations designed to reduce fuel burn among its fleet of freighters. Other goals include increasing SAF availability to U.S. aircraft operations to 3 billion gallons by 2030 and managing other environmental impacts, such as aircraft noise and local air quality. (Atlas Air Worldwide. 2024 Sustainability report)

Atlas Air piloted with SAF offer for Inditex in 2024, being the first cargo airline to regularly use SAF in Spain. This agreement with Repsol helps Atlas to prepare to meet ReFuelEU standards. Atlas Air states they offer real-time emissions and fuel data for sustainability reporting. However, Atlas does not enclose any numbers of utilized SAF in their reports, neither are any other offtake agreements listed with ICAO. Airline mentions they are working with customers and fuel suppliers to understand the changes and how to account for the emissions reductions associated with both mandated and voluntary SAF. The airline reports they will join IATA CO2 connect initiative, so more transparency and standardization on reporting is expected. Carbon offset is mentioned, but no details of projects are publicly available. Atlas’ policy is to seek tax credits, grants and loan guarantees at the federal and state levels of government to increase production. These efforts focus on tax incentives such as blenders tax credit and other policies to make SAF commercially viable and give producers more market certainty. (Atlas Air Worldwide. 2024 Sustainability report)

## 8.2 Lufthansa Cargo

Lufthansa Cargo is a German cargo airline and subsidiary of Lufthansa group with headquarters in Frankfurt, Germany. Company serves roughly 300 destinations across over 100 countries.

Lufthansa Cargo utilizes the belly capacities of group airlines including Lufthansa, Austrian Airlines and Brussels Airlines. They have 18 Boeing 777 freighters and operate 4 Airbus 321 freighters mainly serving intra-European routes. It has ordered a further seven Boeing 777-8Fs with upcoming technology and expects to receive these by 2030. (Lufthansa Group, Annual report 2024)

Lufthansa Group has published yearly Sustainability report since 2019. The group defines its purpose as “Connecting people, cultures and economies in a sustainable way” as in figure 12.



Figure 12. Purpose of Lufthansa Group (Lufthansa 2025)

Sustainability goal is to cut carbon emissions in half by 2030 compared to 2018 and to be carbon neutral by 2050. This is in line with Paris agreement and targets are validated by SBTi in 2022 (Lufthansa Cargo, Sustainability at Lufthansa Cargo)

Group states:

“The Company invests in a variety of technologies to support its transition to a sustainable economy — focusing on improving its fuel efficiency, and reducing energy consumption and carbon emissions from aircraft operations. Primarily this includes actions on the fields of fleet modernization, the use of sustainable fuels and efficiency in flight operation” (Lufthansa Cargo, Sustainability at Lufthansa Cargo).

Lufthansa group has currently 5 offtake agreements in place and cargo customers are offered an opportunity to contribute to SAF usage on their single shipment movement, or to purchase SAF in bulk. Projects are either nature or technology based and project details are published on Lufthansa Group website including accreditations. Carbon offsetting projects are offered as a single way of contribution or to complement SAF emission reductions. Lufthansa Cargo states 100% emission reduction can be achieved by combining usage of SAF with carbon emission removal project. Sustainability offer to customers is clearly communicated on their website, Lufthansa Cargo being the only operator in the study with public offer. (Lufthansa Cargo, Sustainability at Lufthansa Cargo)

Lufthansa Cargo pursues a circular economy concept aimed at avoiding and reducing the use of resources as well as conserving resources. This includes loading aids and equipment that are indispensable in the airfreight transport sector. These are mainly items designed for multiple use that only become waste once they are no longer repairable or reach their date of expiry according to international airfreight regulations. Some loading equipment is disposable by nature or on account of product-specific requirements. For both material categories – reusable items such as straps, nets and boards and single-use items such as plastic film – Lufthansa Cargo has developed strategies for keeping items in economic circulation for longer. These are based on the following principles: increasing recycling rates by substituting materials, introducing closed-loop systems and conserving resources, increasing resource efficiency by reducing the materials used, maximizing reusability within the framework of existing regulations and implementing upcycling projects with individual materials. The primary aim of using lightweight containers made of fiber-reinforced composites instead of aluminum containers is to save on kerosene and, with that, reduce carbon emissions. Lufthansa Cargo and its subsidiaries are also committed to using loading aids for as long as possible. To this end, they focus on optimizing the useful life of lightweight containers, taking into consideration International Air Transport Association (IATA) regulations as well as programs for the construction and careful use of certified containers and pallets. Lufthansa Cargo sets out circular economy requirements in its contracts with suppliers. (Lufthansa Cargo, Sustainability at Lufthansa Cargo)

### **8.3 Turkish Cargo**

Turkish Cargo has been conducting air cargo operations since 1933 as part of Turkish Airlines with home base is Istanbul, Turkey. Company fleet consists of 446 passenger aircraft and 23 freighters, serving 340 destinations globally. Turkish Cargo aims to double cargo tonnage by 2033. Growth is supported by opening of the Mega Hub SMARTIST. The hub, that is still in process of being completed, is going to be world's biggest logistics center and will have cargo sorting capacity of 4.5 million tons annually. (Turkish Airlines, Turkish Airlines Annual Report 2024)

Turkish Airlines carries out its operations by adopting a sustainability strategy aimed at reducing carbon emissions and minimizing environmental impacts. Fuel efficiency studies focusing on reducing emissions are at the core of this strategy. Improving fleet by investing in fuel-efficient aircraft, engine upgrades and utilizing the latest technology are stated as key focus. Since 2008, more than 100 operational optimization projects and aircraft configuration projects have been successfully implemented to reduce the carbon footprint. In 2023, these efforts saved 75,148 tons of fuel and prevented 236,751 tons of carbon emissions from being released into the atmosphere. The total fuel savings achieved since 2008 amount to 748,496 tons, with prevented carbon emissions reaching 2,357,764 tons. (Turkish Airlines, Turkish Airlines 2024 Sustainability report)

In 2024, the share of fuel-efficient next-generation aircraft in Turkish Airlines' fleet increased to 34%, up from 31% in 2023. The Company targets at least 90% of its fleet to consist of next-generation aircraft by 2033. Turkish Cargo has signed purchase agreement for four B777F freighters. (Turkish Airlines, Turkish Airlines 2024 Sustainability report)

Turkish Airlines does not report the amount of SAF they have purchased, neither do they have any published offtake agreements recorded with IATA. While the website clearly states they promote use of SAF, there are no public details available about what options clients have to contribute. Turkish offer seems to support both SAF contribution combined with projects. Turkish Cargo website has an online emission calculator, based on IATA CO2 emissions measurement methodology.

#### **8.4 United Cargo**

United Cargo is air freight carrier based in Houston, Texas operating under United Airlines. United utilizes cargo capacity of an average of 5100 passenger flights a day to 374 airports across six continents. United operates over 1000 aircraft together with subsidiaries and is considered one of the largest aircraft operators globally. United operates passenger aircraft only but has few freighters operating on lease basis. (United Airlines, 2024 United Airlines Corporate Impact Report)

United Cargo mission is:

“United Cargo is committed to award-winning customer service with industry-leading operational and on-time performance. We believe that making United a great place to work will result in employees who are more committed than ever to delighting our customers.”

While their mission does not include sustainability statement the company aims to be carbon neutral by 2050 and is committed to industry targets. United has adopted a mid-term target of reducing its carbon emissions intensity by 50% by 2035 from a 2019 baseline to meet their goal. This intensity was validated by Science Based Targets initiative (SBTi) in May 2023. United has defined 4 sustainability pillars as seen in figure 13 concentrating on fuel efficiency, use of SAF, use of

innovations to thrive for lesser environmental footprint and collaboration with partners like airports and policy leaders. (United Airlines, 2024 United Airlines Corporate Impact Report)



Figure 13. United Airline sustainability 4 pillars (United Airlines 2024)

United's goal of achieving net zero GHG emissions by 2050 does not rely on the use of voluntary, traditional carbon offsets and will therefore focus efforts on reducing compliance burdens through maximizing fuel efficiency and working with strategic partners to scale, employ and commercialize the use of SAF. United has established a portfolio of investments and certain SAF purchase agreements, tied to technologies that could support sustainable aviation and emissions mitigation efforts, most recently broadening our investment potential through the establishment of the Sustainable Flight Fund. United's overall absolute emissions have increased in 2024 and are expected to increase in the short-term due to growth and limited supply of sustainable alternatives such as SAF. However, emissions intensity decreased in 2024 by 1.4% compared to 2023 in part due to our use of newer, more energy-efficient planes and increased load factors as demand for travel has increased. (United Airlines, 2024 United Airlines Corporate Impact Report)

United Airlines is leading the way with SAF usage and growth in comparison to earlier years. United was first US airline to start using SAF at an International Airport in Amsterdam in 2022. In addition, in February 2023 the Invest in Illinois Act was signed into law. This law includes a SAF purchase tax credit for SAF sold to or used by an air carrier in Illinois, USA. In 2024, United was the first airline to take advantage of the Illinois tax incentive and brought the first deliveries of blended SAF to its operations at Chicago O'Hare International Airport. Other current agreements with Neste and World Energy allow use of SAF in Los Angeles and recently added Houston, Newark and Washington DC with total 8 SAF offtake agreements in place. With 0.3% SAF use United is the only studied airline that matches the IATAs reported global SAF availability percentage in 2024. United has former Eco-skies Alliance, a program that allows corporate customers find ways to reduce their environmental impact. Details of the program are not publicly available, but contracts are available on annual and multi-year basis. United also states to concentrate on supporting

SAF use and does not offer any offsetting alternatives. (United Airlines, 2024 United Airlines Corporate Impact Report)

United Airlines Ventures was established in 2021 and focuses on investing in startups developing technologies in aerospace, next-generation air traffic control and aviation infrastructure, energy transition and AI-driven travel innovation. Investments vary from developing modern aircraft to developing hydrogen for industrial scale or investing in carbon capture technology. (United Cargo, Sustainable solutions)

Under United's direct control Operational United has established its Fuel Council to implement operational measures that enable more efficient and direct flight and also reduce GHG emissions. These are measures within our operational control, like reducing the use of the auxiliary power unit (APU) in favor of lower-emission solutions like electric power at the gate. Additional opportunities include optimizing extra planned fuel, optimizing payload weight of our aircraft, single-engine taxiing and improving the drag efficiency of our aircraft. (United Airlines, 2024 United Airlines Corporate Impact Report)

## 9 Key Metrics for Measuring Sustainability

Understanding the impact of air cargo on the environment requires a multifaceted approach. Various indicators help assess how cargo airline practices can be optimized for ecological responsibility. These measures are crucial for identifying areas of improvement. They allow companies to track progress over time and make informed decisions. Studying airline environmental and financial reports and comparing their social, environmental and operational Key Performance Indicators, KPIs will reflect how effectively each operator is moving towards their target.

Quantitative data analyze method is best suited to collect and analyze published documents, identify patterns and to provide statistical data in a format of ESG KPI score. This allows an objective, broad spectrum comparison of complex data and offers more holistic assessment than qualitative data method alone (Williams et al. 2024, 3-5).

Study uses modified chart following IATA guidelines for airline sustainable reporting for analysis purposes (IATA, Beginners Guide to Airline Sustainability Reporting Handbook). Data is extracted from sustainability and annual reports published online by studied airlines in 2024, and further weighted to format a ESG score based on KPIs.

KPIs are categorized under ESG categories

### 1. Environmental

#### **Emissions and Carbon Intensity**

- CO<sub>2</sub> emissions per RTK
- CO<sub>2</sub> saved from SAF
- Fossil fuel to SAF ratio
- Carbon offset volumes

#### **Energy and Fuel Transition**

- Share of renewable energy use
- Total SAF consumption

#### **Circularity and Resource Efficiency**

- Recycling rate

#### **Environmental Externalities**

- Share of fleet meeting ICAO noise standards

### 2. Social

### Workforce Inclusion and Diversity

- Diversity and inclusion initiatives

### Community and Humanitarian Engagement

- Humanitarian missions

## 3. Governance

### Regulatory Compliance and Policy Alignment

- Compliance with CORSIA, ETS, ReFuelEU, CSRD, RFS, SAF mandates

### Strategic Alignment with Global Frameworks

- UN SDG alignment

Table 5. Airline Sustainability KPIs Classified by ESG Category

ESG Category	KPI	Atlas Air	Lufthansa Cargo	Turkish Airlines	United Airlines
<b>Environmental</b>	CO <sub>2</sub> emissions per tonne-kilometer (g/RTK)	absence of disclosure	690g (836 in 2023)	519g (622 in 2023)	absence of disclosure
	Percentage of energy consumption from renewable sources	absence of disclosure	0.40%	19.70%	0.30%
	Total SAF consumption	absence of disclosure	400 metric tons	absence of disclosure	4,300 metric tons / 13.6 million gallons (7.3M gallons 2023)

ESG Category	KPI	Atlas Air	Lufthansa Cargo	Turkish Airlines	United Airlines
	CO <sub>2</sub> saved with SAF usage (metric tons)	absence of disclosure	71,952	221,334	123,174
	Rates of fossil fuel / SAF	0.05%	0.20%	absence of disclosure	0.30%
	Carbon offsets	absence of disclosure	531T group, 75T employee trips	12,577T	Not a focus
	Recycling rate	absence of disclosure	38% cargo (target 40% by 2025)	absence of disclosure	18.60%
	Aircraft noise (% of fleet meeting ICAO 2024 noise regulations)	absence of disclosure	99.60%	absence of disclosure	absence of disclosure
<b>Social</b>	Humanitarian efforts	Yes	Yes	Yes	Yes
	Diversity and inclusion initiatives	Women's network, LGBTQ, disabled veterans	Women leadership, DEI	Women leadership	Women leadership

ESG Category	KPI	Atlas Air	Lufthansa Cargo	Turkish Airlines	United Airlines
<b>Governance</b>	Compliance with international/regional policies	CORSIA, U.S. Renewable Fuel Standard & SAF incentives, ReFuelEU (EU flights only)	CORSIA, ReFuelEU, EU ETS, CSRD, CSDDD	CORSIA, ReFuelEU, EU ETS, CSRD, CSDDD	CORSIA, U.S. Renewable Fuel Standard & SAF incentives, ReFuelEU (EU flights only)
	Alignment with UN Sustainable Development Goals	Yes	Yes	Yes	Not reported but supporting policies available

KPIs are broken down to help define weights for each category to work on scoring the airlines on their performance.

#### Environmental (50%)

- CO<sub>2</sub> emissions per RTK: 30%
- SAF usage: 40%
- Renewable energy: 20%
- Recycling rate: 10%

#### Social (25%)

- Humanitarian efforts: 40%
- Diversity & inclusion: 60%

#### Governance (25%)

- Compliance with regulations: 60%
- SDG alignment: 40%

For each category a calculation is completed.

$$\text{Category Score} = \sum (\text{Normalized KPI} \times \text{KPI Weight})$$

Then, combining categories using their weights:

$$\text{Overall ESG Score} = (E \times wE) + (S \times wS) + (G \times wG)$$

Normalized KPI scores 0-100 points

- CO<sub>2</sub> emissions per RTK: Lower is better → 100 points = best performer
- SAF usage / Renewable energy / Recycling / D&I / Compliance / SDG alignment: Higher is better → 100 points = best performer

Table 6. KPI score per airline

KPI	Atlas Air	Lufthansa	Turkish	United
CO <sub>2</sub> per RTK	N/A → 50	100	80	N/A → 50
SAF usage	40	60	40	100
Renewable energy	N/A → 5	10	100	5
Recycling rate	N/A → 18	38	N/A → 18	18
Humanitarian efforts	100	100	100	100
Diversity & inclusion	80	100	60	70
Compliance	90	100	100	90
SDG alignment	100	100	100	50

*N/A values are estimated conservatively at lowest competitor performance*

Table 7. ESG score per airline

Airline	Environmental (50%)	Social (25%)	Governance (25%)	Overall ESG Score
Atlas Air	37.8	88.0	94.0	<b>64.4</b>
Lufthansa Cargo	63.8	100.0	100.0	<b>81.9</b>
Turkish Airlines	65.8	76.0	100.0	<b>76.9</b>
United Airlines	52.8	82.0	74.0	<b>65.4</b>

Lufthansa Cargo is the top performer overall, driven by strong governance and social metrics as well as overall strong performance in all KPI parameters. Turkish Airlines performs well environmentally and in governance but trails slightly in social indicators. Atlas Air and United Airlines have moderate social and governance results but lag in environmental performance.

Lufthansa Cargo achieved the highest overall ESG score (79.9), driven by balanced and steady performance across all three sustainability dimensions. Its leadership in governance (100) reflects strong compliance with international sustainability frameworks such as CORSIA, the EU ETS, and the Corporate Sustainability Reporting Directive (CSRD). Additionally, the airline's comprehensive ESG reporting and consistent environmental performance indicate an advanced stage of integration of sustainability into corporate strategy.

Turkish Airlines Cargo ranked second (74.9), supported by excellent governance (100) and a relatively high environmental score (61.8). The airline's performance reflects a strong commitment to regulatory alignment and fleet modernization but slightly weaker results in the social category (76), suggesting that social initiatives such as diversity and inclusion may not be as advanced as those of European competitors.

United Cargo scored 67.9 overall, showing improvements under the revised weighting due to its extensive SAF adoption, the highest among the sample. However, the carrier's lower governance score (74) and moderate environmental performance in other areas like renewable energy use and recycling reduce its overall competitiveness. The results indicate that while United is progressing in fuel transition, broader environmental and governance integration remain areas for development.

Atlas Air, with an overall ESG score of 64.4, lags its peers. Its relatively strong governance and social results are offset by low environmental performance (37.8), particularly limited renewable

energy use and minimal SAF deployment. This imbalance underscores the challenges faced by non-European carriers in meeting increasingly stringent sustainability standards and reporting expectations. It seems Atlas Air is in the early stages of implementing sustainable strategies and some of the initiatives are customer driven, rather than part of corporate identity.

Overall, the comparative results highlight significant regional and strategic differences in air cargo sustainability performance. European carriers demonstrate stronger environmental governance alignment and reporting consistency, while U.S. carriers exhibit more fragmented but improving approaches. The findings also reinforce the importance of weighting environmental KPIs, especially SAF usage and CO<sub>2</sub> intensity, when evaluating progress toward decarbonization in the airfreight industry.

## 10 Conclusion

Analysis of the ESG-related KPIs across Atlas Air, Lufthansa Cargo, Turkish Airlines, and United Airlines reveals distinct differences in sustainability performance. Environmentally, Turkish Airlines demonstrates the lowest CO<sub>2</sub> emissions per ton-kilometer and the highest share of renewable energy usage, indicating strong operational efficiency and renewable integration. United Airlines leads in SAF usage, reflecting a significant commitment to reducing lifecycle emissions, while Lufthansa Cargo excels in noise compliance, with nearly its entire fleet meeting ICAO 2024 standards. Across social indicators, all airlines report engagement in humanitarian efforts and initiatives supporting diversity and inclusion, although the scope and implementation of programs vary. In terms of governance, all carriers comply with key international and regional regulations such as CORSIA and the EU ETS, and most align their policies with broader UN Sustainable Development Goals. Overall, while each airline demonstrates leadership in specific areas, the analysis underscores the ongoing challenges of scaling renewable energy adoption, increasing SAF utilization, and standardizing social initiatives, highlighting opportunities for further improvement in achieving comprehensive sustainability performance.

The study demonstrates that airlines with a strong focus on growing SAF usage and innovations and environmental opportunities would have better environmental performance. Similarly, companies addressing well formatted reporting pattern perform more competently in the evaluations, even though a strong reporting pattern is not a guarantee of high performance. On the other hand, the study shows, that the carbon offsetting scheme represents the lower priority overall. Further research findings are the lack of standardization in the sustainability reports from the airlines and the lack of transparency among the rating agencies. Regulatory frameworks create multilayered pressure and strategic opportunity for airlines. With uncertainties and differentiating policies it can be challenging to navigate the greener air cargo era.

U.S. aviation sustainability policy can be seen as decentralized, incentive-based, and innovation-driven, focusing on technological development and fuel transformation rather than strict emissions regulation. American carriers have more economical opportunity to purchase subsidized SAF. Incentives in the market investment scenario through U.S. Renewable Fuel Standard and SAF Initiative allow US carriers to create a positive cycle of purchase and investment in SAF and new aircraft investments.

This contrasts with the EU's regulatory and compliance-based model, while both regions share the same long-term goal of carbon-neutral aviation by 2050. Mandatory ReFuelEU SAF mandates seem to be setting European airlines to more challenging position due to high SAF prices driving

up the cost of fuel. Cost and availability of SAF will need to come down and further financial incentives will need to be available to European operators.

Sustainability seems to be deeper routed in the European airlines DNA and this reflects in well-defined strategy and targets, with many innovations in the materials and technologies used like lighter materials and set detailed targets for recycling. Overall is it advisable to implement sustainable practices throughout the operations, whether in the air or on the ground to gain best possible results. Performing a little bit in all ESG areas can lead to stronger results than only focusing on one KPI.

Operators focusing on IATA's roadmap combining new energy and aircraft technology advancement map seem to have most success in results. However, investing in both SAF and newest model aircraft can be costly for airlines. However it is clear ESG is no longer optional and it is the license to operate in the modern economy and a roadmap for a sustainable future. Air cargo carriers cannot ignore embedding ESG into their operations today. By doing so they can attract conscious investors, top talent, and loyal customers who value integrity and responsibility. Reputation loss, regulatory risks, and missed opportunities in a rapidly evolving market could be the cost of ignoring the current industry requirements. By focusing on ESG KPIs, air cargo practitioners and policymakers can better prepare for future disruptions and demonstrate their commitment to long-term sustainability. Air cargo carriers have established targets to reduce their emissions by 50% by 2030. However, ongoing challenges including regulatory compliance, limited availability of sustainable aviation fuel and its high cost raise uncertainties about whether these goals will ultimately be achieved. Airlines will need to speed up their act in order to keep up with the sustainable aviation era.

While increased funding can accelerate progress in sustainability, advances are ultimately constrained by technological, material, and political limitations. As the aviation sector works to decarbonize its energy systems and develop new technologies, other sectors of the global economy are simultaneously pursuing decarbonization. Redirecting existing fossil fuel subsidies toward low-carbon energy could help accelerate this transition. While it is not fully within air cargo operators influence to define politics, liaising with the policy makers and combining forces with peer airlines can be helpful.

In conclusion, pinpointing the differences in carbon emissions reveals a complex landscape where commitment to environmental responsibility varies dramatically. By focusing on fleet modernization, operational efficiency, and collaborative strategies, significant advancements can be made toward reducing ecological footprints. The choice of providers significantly influences overall emissions, underscoring the importance of informed decisions in the logistics sector.

Most growth in future air cargo is expected in Asia, where sustainability practices might not be established standard like in this study. It would be of importance to have all air cargo carriers to participate in programs such as CORSIA to have more standardized global rules and allow equal competition on a global basis.

## 11 Summary and reflection

The aim of this study was to conduct a comparative analysis of sustainability practices among air cargo operators across the Atlantic, with the purpose of evaluating my own preconceptions regarding European and American companies' management of sustainability programs in relation to the global and local standards. A detailed exploration into the corporate significance of Environmental, Social, and Governance criteria, alongside an in-depth examination of the regulatory frameworks governing air cargo operators, prompted consideration of how deeply sustainability policies can be embedded within airline organizational cultures. On an initial appraisal, sustainability may appear as a superficial concern and subordinate to profit maximization for shareholders, potentially overshadowing the responsibilities of corporations as ethical entities and employers. Nonetheless, a review of recent environmental reports highlights that sustainability encompasses a broad spectrum of initiatives: from goodwill projects aimed at societal contributions, to innovative technological advancements such as Lufthansa's Aeroshark and United Airlines' investment in futuristic JetZero aircraft. Each initiative, irrespective of scale, whether flying lighter or using AI for weather and routing predictions, contributes cumulatively towards a greener air cargo future. Treating ESG as a competitive asset rather than a compliance requirement is recommended mindset for any operator. Furthermore, this inquiry prompted an interest in investigating how varying political climates across regions influence the formulation and evolution of sustainability policies. Reading the news of upcoming SAF policies like Singapore's Sustainable Aviation fuel levy now have a deeper meaning, this means the world is taking steps towards greener standardization.

The results show that European air cargo operators exhibit greater maturity in sustainability governance and disclosure, driven by stricter regulatory frameworks such as the EU ETS and CSRD. In contrast, U.S. and global carriers are progressing more unevenly, often emphasizing operational efficiency and SAF development over comprehensive ESG integration. The study concludes that achieving carbon-neutral air cargo operations will require not only technological and fuel innovations but also harmonized global reporting standards, increased transparency, and cross-sectoral policy support to accelerate decarbonization across the industry.

All cargo operators, regardless of their size, should actively explore opportunities related to sustainable aviation fuel. Airlines should establish substantial and ambitious SAF offtake agreements at an early stage to secure supply commitments. Collaboration with plane manufacturers and research institutions supports the SAFsage. Advocacy efforts must be undertaken to engage governmental bodies and the financial sector to support and facilitate the scaling up of SAF production and incentives. Additionally, it is essential to have key commercial customers purchasing

sustainable aviation fuel or contribute to carbon reduction program to foster support and participation in sustainability initiatives within the transportation chain.

Data gaps emerged due to variability in disclosure standards across studied airlines. European carriers typically report more comprehensive ESG indicators because of regulatory requirements, while airlines from other regions often provide only partial or high-level data. This inconsistency in data affects the capability to produce a fully comparable and reliable cross-case analysis. It is advisable to set measurable targets for ESG to have stronger strategy instead of symbolic program in place.

Qualitative component based on interviews on viewing strategic policies and possible stated successes as well as challenges was initially planned to be part of the study. Due to time constraints this did not materialize. A lot more effort and time could have been spent on this study to make it more comprehensive. For subsequent research, it would be beneficial to extend the scope to include airlines operating in regions with less stringent regulatory environments and emerging markets to provide additional perspectives on global sustainability practices. Carriers from rapidly growing air cargo markets in Asia and India present promising case studies. Additionally, the study or development of sustainability policies tailored for smaller operators could provide valuable insights within this field. Research on the relationship between ESG factors' performance and a firm's value and financial performance could be yet another research topic.

As personal keynotes working in the airfreight industry, I now stand behind my employer's sustainability offer, and understand to value the comprehensive efforts on all fronts. Having worked as sustainability ambassador on local projects now comparing to bigger picture and seeing how competition performs helps me value the act of my employer. This also helps me argue the importance of everyone joining the sustainability effort, whether it is a colleague recycling, my station working on green certification or a client interested in purchasing SAF. I have a clear understanding of the challenges of the regulatory framework and the reasons for high price tag of SAF, I am able to understand the incentivized SAF program in the USA, and see how it affects the competitive landscape of airlines not having same benefits available in their market. To think of the environmental consequences and future scenarios if the airline industry is not able to reach net zero emissions makes me motivated to work harder and to be the advocate of better sustainability practices. I am looking forward to see how the new mandatory frameworks like ReFuelEu and newly established regulations in Asia will affect the air cargo carrier's ESG performance next year and years to come.

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## **Glossary**

ATK, Available Ton Kilometers

ATM, Air Traffic Management

CA-LCFS, California Low Carbon Fuel Standard

CHG, cycle greenhouse gas emissions

CLF, cargo load factor

CORSIA, Carbon Offsetting and Reduction Scheme for International Aviation

CSDDD, European Union's corporate sustainability due diligence directive

CSRD, European Union's corporate Sustainability Reporting directive

CTK, Cargo ton kilometers

DOE, the U.S. Department of Energy

DOT, U.S. Department of Transportation

EASA, The European Union Aviation Safety Agency

EEU, Eligible Emissions Unit

EU ETS, EU Emissions Trading System

ESG, Environmental, Social and Governance

FAA, The Federal Aviation Administration

IATA, International Air Transport Association

ICAO, The International Civil Aviation Organization

ILS, Instrument Landing System

IPCC, Intergovernmental Panel on Climate Change

IRA, Inflation Reduction Act

KPI, Key Performance Indicators

OEM, original equipment manufacturer

RED, Renewable Energy Directive

RFS, The U.S. Renewable Fuel Standard

SAF, Sustainable Aviation Fuel

SBTi, Science Based Targets initiative

TIACA, The International Air Cargo Association

TRL, The Technology Readiness Level

UN, United Nations

USDA, the U.S. Department of Agriculture