

Airline sustainability reporting in Europe: Progress, compliance and challenges

Luis Martín-Domingo^{a,b}, Marina Efthymiou^a, Miguel Mujica Mota^{c,*}

^a Dublin City University, Business School, Glasnevin, Dublin 9, Ireland

^b Ozyegin University, Faculty of Aviation, 34794, Istanbul, Türkiye

^c Aviation Academy, Amsterdam University of Applied Sciences, 1091, Amsterdam, The Netherlands

ARTICLE INFO

Keywords:

airlines sustainability
GHG emissions
Reporting
European airlines

ABSTRACT

This study systematically evaluates greenhouse gas (GHG) emissions reporting practices of European airline groups, covering both mandatory and voluntary key performance indicators (KPIs) under evolving regulatory frameworks. By analysing annual and sustainability reports from 16 major airline groups, the research identifies significant progress in the reporting of core metrics, with Scope 1 CO₂ totals reported by 94 % and emissions intensity by 88 %, reflecting growing regulatory alignment and stakeholder expectations. However, persistent gaps remain: Scope 2 and Scope 3 reporting appears in only 56 % and 50 % of cases, respectively, while non-CO₂ emissions are disclosed by just 38 %, despite forthcoming European Union Emissions Trading System (EU ETS) monitoring requirements. Reporting on sustainable aviation fuels (SAF) life-cycle emissions is limited (19 %), and CO₂ offsetting disclosures are rare (6 %), complicating verification of decarbonisation claims and readiness for ReFuelEU Aviation and Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The proliferation of voluntary KPI disclosures further complicates comparability due to a lack of standardization and clear definitions. These challenges are compounded by risks of greenwashing, where airlines selectively report favourable data such as emissions intensity, and greenhushing, where substantive achievements are under-communicated. The study concludes that while regulatory frameworks such as the Corporate Sustainability Reporting Directive (CSRD), the EU ETS, CORSIA, and ReFuelEU are driving improvements, further harmonization and methodological clarity are required to ensure transparency, comparability, and genuine progress toward aviation's climate goals.

1. Introduction

The planet is today warmer than it was in the pre-industrial period (1850–1900) (WMO, 2022). The aviation industry's contribution to climate change is estimated to be around 2.5 % when measuring only carbon dioxide (CO₂) emissions (Larsson et al., 2019). However, this rises to 4 % (0.05 °C) if both CO₂ and non-CO₂ output, like nitrogen oxide, are taken into account. It is forecasted that aviation will contribute an additional 0.05 °C in the next 30 years (2020–2050) (Klöwer et al., 2021). Factoring this figure into the 0.3 °C–0.8 °C remaining in order not to exceed 1.5 °C–2 °C of increased global warming, ratified at the 2015 Paris Agreement (UN, 2016), aviation represents a share of between 6 % and 17 % (Klöwer et al., 2021), which is a substantially higher than the currently perceived reference figure of 2.5 %.

Aviation's growing climate impact has placed the sector under increasing scrutiny from policymakers, investors, and the public. In response, the world's aviation sector has committed to reduce emissions to net zero by 2050 in line with the Paris Agreement. Nevertheless, there are persistent doubts as to whether the sector will be able to achieve this target (Klöwer et al., 2021). The European Union (EU), through the Green Deal and Regulation (EU) 2021/1119 (EC, 2019), has set legally binding targets to achieve climate neutrality by 2050 and to reduce net GHG emissions by at least 55 % by 2030 compared to 1990 levels (EU, 2023). These ambitions place European aviation at the forefront of regulatory transformation, requiring strict monitoring, reporting, and verification of emissions (Davies and Armsworth, 2010). Despite these regulatory advances, the academic literature consistently highlights a lack of standardization and inconsistency in how airlines report their environmental sustainability metrics—a challenge identified over two

* Corresponding author. Aviation Academy, Amsterdam University of Applied Sciences, 1091, Amsterdam, The Netherlands.

E-mail address: m.mujica.mota@hva.nl (M. Mujica Mota).

<https://doi.org/10.1016/j.indic.2025.101008>

Received 30 July 2025; Received in revised form 27 October 2025; Accepted 29 October 2025

Available online 7 November 2025

2665-9727/© 2025 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

decades ago and still present today (Caraveo Gomez Llanos et al., 2023; Hooper and Greenall, 2005; Zieba and Johansson, 2022). This lack of harmonization undermines transparency, comparability, and the effectiveness of regulatory oversight.

A critical gap persists in the literature and in practice because, although numerous environmental KPIs exist, there is limited understanding of how KPIs are defined and measured, which metrics are most widely adopted, and to what extent they are used to genuinely track progress toward climate goals versus simply serving as tools for corporate legitimacy. The objective of this research is to systematically identify and evaluate the use and misuse of both mandatory and aspirational GHG-related KPIs in European airline sustainability reports. By mapping current reporting requirements and practices, this study aims to provide a measure of clarity concerning drivers for, differences among, and implications of KPI selection and KPI reporting in the aviation sector. In doing so, it seeks to support the development of more transparent, consistent and effective sustainability reporting frameworks for aviation.

This paper is structured as follows: the next section reviews the academic literature on environmental indicators and sustainability reporting in aviation, identifying key emissions related frameworks and the challenges associated with their implementation. This is followed by a methodology section detailing the approach followed for extracting and analysing greenhouse gas (GHG) key performance indicators from European airline reports. Results and discussion then present findings on reporting practices and regulatory compliance, and the conclusions covers implications and recommendations for advancing transparency and standardization in airline sustainability reporting.

2. Literature review

In the context of aviation's increasing contribution to climate change, environmental indicators have become essential tools for tracking and communicating the sector's environmental performance. Airlines are now required—through regulatory and voluntary frameworks—to monitor and report on various sustainability metrics, particularly those related to GHG emissions.

Environmental indicators are essential for environmental reporting and policy, as they collate diverse data to provide objective insights into environmental issues. Recent research has shown that large language models (LLMs) can assist in automating the extraction of airline emission KPIs from sustainability reports, providing a scalable complement to manual analysis (Martín-Domingo et al., 2025). Literature on environmental indicators has been divided into three dimensions: a) development of norms, b) use of indicators in policy and c) the authoritative power of norms that help create a reality (Dobruszkes and Efthymiou, 2020). The development of sustainability indicators involves both the scientific process of "knowledge production" and the political process of "norm creation," and it is essential to recognize both aspects (Fuglestedt et al., 2010; Rametsteiner et al., 2011). Moreover, sustainability indicators (especially the mandatory ones) are set at the interface between science and policy and, to avoid misunderstanding, should be clearly described before they can be translated into goals (Heink and Kowarik, 2010).

Sustainability indicators have been classified by Smeets and Weterings (1999) into four groups: a) *Descriptive indicators*, describing 'what is happening to the environment and to humans' (e.g. total CO₂ emissions from air transport and its overall share); b) *Performance indicators*, comparing the difference between the current environmental situation and the desired situation, i.e. the target (e.g. planet temperature increase during 2023 of 1.3 °C (Copernicus, 2024) compared to the 1.5°C–2°C of global warming limit ratified at the 2015 Paris Agreement) c) *Efficiency indicators*, providing insight into the efficiency of products and processes, in terms of the emissions generated per unit of desired output (e.g. CO₂ emissions generated by airlines per passengers and km transported, i.e. emissions intensity) and d) *Total Welfare indicators*, providing

some measure of total sustainability (e.g. 'Green GDP'). For airlines, these indicators now serve as key tools in demonstrating progress towards sustainability targets and compliance with regulatory requirements.

The growing use of environmental indicators has however coincided with increasing concerns about *greenwashing and greenhushing*, both of which threaten the credibility of sustainability practices. Greenwashing refers to the process by which companies overstate or misrepresent their environmental achievements and consequently threaten the credibility of sustainability practices (Neureiter & and Matthes, 2023; Zieba and Johansson, 2022). This can take various forms, including the use of false or exaggerated claims (Neureiter et al., 2024; Neureiter and Matthes, 2023), omitting crucial environmentally damaging information (Neureiter et al., 2024; Tsoi and Liu, 2025), making vague or unprovable statements (Neureiter & and Matthes, 2023; Tsoi and Liu, 2025), and spreading misleading claims around environmental compensation measures like carbon offsets (Guix et al., 2022; Neureiter et al., 2024; Neureiter & and Matthes, 2023).

In addition to greenwashing, recent research highlights the phenomenon of *greenhushing*, which involves the deliberate undercommunication or non-disclosure of genuine environmental initiatives and achievements (Dias et al., 2025; Font et al., 2017; Hilton, 2025). Studies suggest that greenhushing often arises from institutional complexity, such as competing stakeholder demands and regulatory uncertainty. For example, businesses may fear accusations of hypocrite or greenwashing if they openly communicate their sustainability efforts but fail to meet heightened expectations across all areas (Font et al., 2017; Hilton, 2025). This practice can deprive stakeholders of valuable information about corporate sustainability performance and hinder broader environmental progress by limiting knowledge-sharing and collaboration across industries (Hilton, 2025). The airline industry has faced increasing scrutiny regarding both greenwashing and greenhushing due to the inherent environmental impact of air travel (Neureiter et al., 2024; Neureiter & and Matthes, 2023). Airlines often engage in sustainability communication, such as promoting voluntary carbon offset programs (Guix et al., 2022; Neureiter et al., 2024). However, these programs and related claims have been identified as potential avenues for greenwashing if they lack transparency, omit crucial information about their effectiveness, or distract from the broader environmental impact of flying (EU, 2005, 2024a, 2024b; Guix et al., 2022; Peixoto de Mello and Macario, 2024). In this respect, while the Carbon Offset and Reduction Scheme for International Aviation (CORSA) relies on carbon offsets (ICAO, 2025a), the EU calls carbon offsets greenwashing (EU, 2024a), which means that the normalization of KPIs and legitimacy depends on the regulatory authority geographical limits of its jurisdiction. Additionally, airlines may engage in greenhushing by deliberately downplaying their sustainability efforts to avoid public criticism or regulatory backlash (Font et al., 2017). For instance, airlines highlight reductions in emissions intensity over time, but omit increases of total emissions data due to increasing flight traffic and capacity.

Studies have shown that both false environmental claims and environmental compensation claims made by airlines can trigger perceptions of greenwashing among consumers (Neureiter et al., 2024). Research on airline Environmental Social and Governance (ESG) reports indicates that better performance in environmental and social engagement activities has a positive impact on financial performance (Yang and Baa-sandorj, 2017). However, high ESG scores, which investors may rely on, do not necessarily reflect a company's real environmental performance and might even be associated with a higher risk of greenwashing accusations in sectors like the airline industry (Cregan et al., 2024; Kathan et al., 2025). It is also important to note that there is a decoupling of ESG performance from real environmental outcomes, as symbolic KPIs are prioritized over substantive ones. ESG ratings reward reporting and formalisation rather than environmental performance, particularly in carbon-intensive industries like aviation.

Aviation, having for decades been seen as a relatively new industry, was excluded from environmental regulations, but as the scientific understanding of environmental issues is slowly maturing in aviation, so is the acceptance of accountability from the industry. CO₂ emissions has been a consistently reported KPI by the aviation industry, but other KPIs have been formulated more recently. For example, the IPCC (2018) stated that contrails cause climate warming, which has subsequently been corroborated by academia (Borella et al., 2024; Fredenburgh, 2022; Gryspeerdt et al., 2024). Yet, their scientific understanding is remaining lower than the CO₂. Thus, several indicators are nominally monitored without having an agreed specified target. Moreover, aircraft emit a variety of pollutants, including CO₂, water vapour, nitrogen oxides (NO_x), and particulate matter, which contribute to warming both directly and indirectly (German Environmental Agency, 2023). Reporting aviation emissions in CO₂ equivalent (CO₂e) allows a comprehensive assessment of the environmental impact of CO₂ and non-CO₂ effects, which are especially significant at high altitudes (Lee et al., 2021).

A clear and standardised set of airline GHG KPIs is a critical foundation for achieving net zero GHG emissions by 2050. These KPIs need to be closely monitored through periodic reporting. However, the academic literature agrees that there is a lack of standardization in airline environmental reporting. This issue was already identified over 20 years ago by Hooper and Greenall (2005), who noted inconsistencies in how environmental indicators were defined and used. We have observed that airlines often use KPIs in ways that may present a more favourable environmental profile than is entirely accurate. For example, Ryanair (2022) indicated that “environmental initiatives will help us deliver our 2030 carbon intensity goal of 60 g CO₂ pax/km (10 % reduction)” highlighting more indicators that show marginal improvements in fuel efficiency or emissions per passenger-kilometre without fully addressing overall emissions growth due to increased traffic. Additionally, this flexibility in KPI selection allows companies to set benchmarks that are relatively easy to meet, thus enhancing their public image without necessarily driving meaningful environmental change. Such practices raise concerns about greenwashing, where the narrative of sustainability progress outpaces actual climate impact reductions.

Although corrective initiatives such as the Non-Financial Reporting Directive (NFRD), i.e. Regulation 2014/34/EU (2014a), the ‘Green Claims’ directive, and supplementary guidelines on climate-related reporting in 2019 (EU, 2019) have been introduced, recent research continues to highlight this lack of standardization in airline environmental reporting (Caraveo Gomez Llanos et al., 2023; Zieba and Johansson, 2022). Furthermore, IATA’s Director General, Willie Walsh, has suggested that the aviation industry needs to agree on a unified method of measurement (Eurocontrol, 2021). Therefore, a critical examination of environmental claims and sustainability initiatives within the aviation sector is essential to distinguish between genuine efforts and misleading claims.

The aviation emission KPIs can be divided into two main groups, mandatory and non-mandatory KPIs. The latter group of non-mandatory KPIs are schemes often followed by European airlines on a volunteer basis. The first group corresponds to mandatory KPIs defined by regulatory schemes: Non-Financial Reporting Directive (ESG Reporting), the EU ETS, CORSIA, and ReFuelEU. These four schemes, together with the emission intensity KPI (emissions per passenger) widely used in the industry, are introduced below in detail.

2.1. Environmental Social and Governance (ESG)

The origin of ESG measures can be traced back to the 1970’s when the Baptist minister, social activist and General Motors board member Leon Sullivan established a Code of Conduct for conducting business with South Africa’s then apartheid regime. This later became known as the Sullivan Principles and resulted in widespread US disinvestment from many South African companies (Bernasek and Porter, 1997). In the

early 2000’s the UN invited financial institutions to develop guidelines and recommendations on how to better integrate environmental, social and corporate governance issues in asset management, securities brokerage services and associated research functions. Later, released a report titled “Who Cares Wins” and the term ESG started to be adopted (ABN Amro et al., 2004). The term corporate social responsibility (CSR) has also been used for sustainability reporting, but ESG can be considered as a broader term (Caraveo Gomez Llanos et al., 2023).

ESG investing, also known as sustainable investing, has gained significance in mainstream finance over the past 20 years. This approach involves considering ESG factors when making investment decisions (EC, 2023b). ESG ratings assess the sustainability profile of companies or financial instruments, evaluating their exposure to sustainability risks and impact on society and the environment. The growing influence of ESG ratings is increasingly shaping the operations of capital markets and affecting investor confidence (EC, 2023c). EU Regulation 2024/3005 establishes a comprehensive framework for ESG rating activities in the European Union. The regulation aims to enhance the integrity, transparency, and reliability of ESG ratings, contributing to the EU’s sustainable finance agenda and helping to prevent greenwashing. Key aspects include mandatory authorization from the European Securities and Markets Authority (ESMA, 2024) for ESG rating providers, requirements for separate E, S, and G ratings, implementation of sound governance practices, disclosure of methodologies and assumptions, and integration with other EU sustainability initiatives. This regulation is designed to improve the quality and comparability of ESG ratings used in investment decisions and corporate sustainability assessments across the EU (EU, 2024f).

Large European airlines are incorporating ESG reporting into their corporate structures and strategies. For example, starting from January 2023, the Lufthansa Group’s Supervisory Board established an ESG Committee to advise both the Supervisory and Executive Boards on environmental, social, and governance matters. The ESG strategy undergoes an annual review and is debated with the Executive Board within the framework of Strategic Roadmap Discussions. During this reporting year, particular emphasis was placed on the CO₂ reduction trajectory and complementary measures (Lufthansa Group, 2023).

The Non-Financial Reporting Directive (NFRD) - Directive 2014/95/EU (EU, 2014b) laid the foundation for ESG reporting. More recently, the Corporate Sustainability Reporting Directive (CSRD) - Directive (EU) 2024/3005 (EU, 2024f) represents an evolution of the regulations, introducing stricter requirements, a broader scope, and an enhanced focus on sustainability transparency.

2.2. Emissions Trading System (EU ETS)

The EU Emissions Trading System (EU ETS) is a ‘cap-and-trade’ system begun in 2005 with which the cap reduces overtime to cause the overall emissions to fall. Aviation has been included since 2012 and applies to all aircraft operators (with some exceptions) that take off and land at airports in the EU. Airlines receive a tradeable allowance of emissions that cover part of their total CO₂ emissions and are required to monitor, report and verify these (EC, 2023a). The original baseline cap of aviation emissions was defined in 2011, for the period 2012–2020, as 95 % of average total emissions in the years 2004–2006 (221.4 million), which corresponded to 210.3 million per year (EC, 2023a). One emissions allowance¹ is defined as 1000 kg. (1 ton) of carbon dioxide equivalent emissions. Airlines received, for the period 2012–2020 (EU ETS phase III), 0.6422 annual allowances per 1000 tonne-kilometres

¹ Article 3(a) of the EU ETS Directive defines the emission allowance as being “an allowance to emit one ton of carbon dioxide equivalent during a specified period, which shall be valid only for the purposes of meeting the requirements of this Directive and shall be transferable in accordance with the provisions of this Directive”.

flown in 2010, which was kept constant for each year of phase III. Airlines requiring more allowances needed to purchase these from EU auctions where other emitters can trade their allotted share, including other airlines or at other international emission trading mechanisms (Efthymiou and Papatheodorou, 2019).

The emission cap was reduced annually by 2.1 % from 2021 to 2023, including for aviation. Subsequently, following the 2023 revision of the EU ETS Directive, the EU ETS cap has aimed to reduce emissions by 62 % by 2030 compared to 2005 levels. To achieve this, the annual reduction factor has been raised to 4.3 % for the period 2024–2027 and to 4.4 % per year from 2028 onward. Since 2024, the share of the aviation cap that can be auctioned has gradually increased. As a result, free allowances in aviation will be reduced by 25 % in 2024, by 50 % in 2025 and will be phased out completely by 2026. Over the 2024–2030 period, 20 million aviation allowances are reserved to support Sustainable Aviation Fuels adoption (EU, 2024c). Thus, the EU ETS will assist in the implementation of the ReFuelEU scheme (explained below). In addition, the EU ETS has been adapted in light of the implementation of CORSIA and has excluded non-EU based aircraft operators, which were included in its origins and thus referred to as “stop the clock” measure. Aircraft operators have also been required to monitor their non-CO₂ emissions since January 2025, by calculating CO₂ equivalence per flight (EU, 2024e).

2.3. Carbon Offset and Reduction Scheme for International Aviation (CORSIA)

CORSIA is a global market-based measure introduced by ICAO to reduce emissions from international aviation. CORSIA is designed to offset any remaining emissions after airlines have taken steps to reduce their carbon footprint through fuel efficiency improvements, operational changes, and the use of sustainable aviation fuels (SAF) (ICAO, 2023a).

The implementation of the scheme consists of three phases: a pilot phase (2021–2023), a first phase (2024–2027), and a second phase (2027–2035). Participation remains voluntary for the pilot and first phases (2021–2026) and will become mandatory for the second phase from 2027 onward for most ICAO member states. Since 2021, EU member states have already participated in the pilot phase, and the European Commission (EC) has proposed an amendment to the EU ETS to incorporate CORSIA for the flights that operate outside of the EU ETS (Emissions Trading System) and either depart from or arrive in countries which apply CORSIA (EC, 2021). In 2025, 129 countries had agreed to voluntarily participate in CORSIA (ICAO, 2025b).

The CORSIA scheme is based on a route-based approach, where international routes of participant members are tracked by operators for total CO₂ emissions and reported to their respective national authority. ICAO collects the data and calculates the total amount of emissions. Subsequently, it calculates the sectoral growth factor of emissions using 2019 emissions as the reference (Escobar et al., 2024). The growth factor is multiplied by the total CO₂ emissions from applicable routes for each operator to calculate the amount of CO₂ emissions that need to be offset. The operator must then acquire the required offsets in the carbon market. For ICAO, the unit is a carbon credit, which, as in the EU ETS, represents one tonne of CO₂ reduction (ICAO, 2016). The ICAO CORSIA CO₂ estimation and reporting tool uses two templates, which includes fields such as origin aerodrome, destination aerodrome and number of flights. A full set of the required data fields is provided in Table 1.

2.4. ReFuelEU aviation (ReFuelEU)

Regulation (EU) 2023/2405 - ReFuelEU (EU, 2023), mandates the blending of Sustainable Aviation Fuels (SAF), including fuels of biomass origin and synthetic aviation fuel (aka e-fuel). The regulation requires a 2 % SAF blend in 2025, increasing to 70 % by 2050, and an e-fuel blend of 1.2 % by 2030, rising to 35 % by 2050. Aviation fuel suppliers must

Table 1

Fields required from airlines to assess and report data into the ICAO CORSIA CO₂ Emissions and Reporting Tool – CERT (ICAO, 2023b).

Summary of assessment of applicability of CORSIA and eligibility to use the ICAO CORSIA CERT in 2023	CO ₂ Estimation and Reporting for 2022
<ul style="list-style-type: none"> • Date (Optional) • Flight ID (Optional) • ICAO Aircraft Type Designator • Origin Aerodrome • Destination Aerodrome • Number of Flights 	<ul style="list-style-type: none"> • Date (Optional) • Flight ID (Optional) • ICAO Aircraft Type Designator • Origin Aerodrome • Destination Aerodrome • Total Number of Flights • Total Block Time for all flights (in mins.) • Total Fuel Use for all Flights (in tonnes) • Type of Fuel • Data Gap Ref. (Optional)

ensure that all fuel provided to aircraft operators at each Union airport² meets the minimum required shares of SAF, as specified in Fig. 1, including the minimum proportions of synthetic aviation fuel.

SAF is a drop-in fuel, meaning it can be used in existing aircraft and fuelling infrastructure without any modifications, with a lower emission factor than conventional aviation fuel and can be classified into the following types: i) *aviation biofuels* (derived from feedstock, but not from food or feed crops, per Article 2, second paragraph, points (33)) and (34); ii) *recycled carbon aviation fuels* (produced from liquid or solid waste streams of non-renewal origin, as specified in Article 2, second paragraph, point (35); and iii) *synthetic aviation fuel* (renewable fuels of non-biological origin, as defined in Article 2, second paragraph, point (36)), of Regulation (EU) 2018/2001 (EU, 2018). Eligibility criteria for SAF are established in the Renewable Energy Directive (RED) (EU, 2009).

Following the early adoption of SAF, Norway became the first country to implement a drop-in mandate of 0.5 % SAF for all aviation fuel sold, starting in 2020 (Avinor, 2024). Virgin Atlantic was the first airline to operate an intercontinental flight (without paying passengers) using 100 % SAF between London Heathrow and New York JFK in

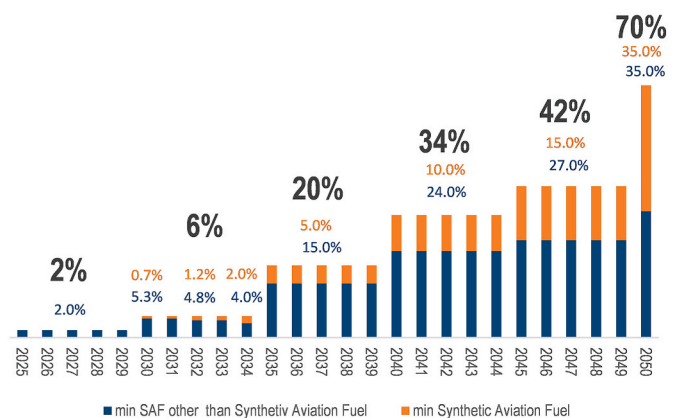


Fig. 1. Obligatory minimum share of Sustainable Aviation Fuel (SAF) at Union airports (Authors based on Regulation (EU) 2023/2405).

² "Union airport" is defined as any airport that is not located in an outermost region (as listed in Article 349 of the Treaty on the Functioning of the European Union), and that handled more than 800,000 passengers or more than 100,000 tonnes of freight in the previous reporting period under Regulation (EU) 2023/2405.

November 2023 (CAA, 2024). However, currently, SAF blends cannot exceed 50 %, according to ASTM International (US Department of Energy, 2024). Total SAF production is estimated to account for only 0.5 % of the total aviation fuel produced in 2024 (IATA, 2023b), thus there is a long way to go to produce the quantities of SAF required in the EU mandate.

Eco-labelling, or green labelling, has been shown to influence air passengers by encouraging them to avoid the most polluting flights and increasing their willingness to pay for more environmentally friendly options. However, providing transparency in relation to the purpose and goals of the eco-label is crucial for its adoption (Baumeister et al., 2022). In line with the broader objectives of the ReFuelEU Aviation regulation to reduce the sector's environmental impact, the European Union has also introduced a Flight Emissions Label (FEL), a form of green labelling that will start to be implemented by airlines as of July 2025, as a complementary measure to promote transparency and informed decision-making among passengers. This label provides standardized, comparable information on greenhouse gas (GHG) emissions expressed in kilograms of carbon dioxide equivalent (kg CO₂e) for each flight operating within the EU, departing from, or arriving to EU airports, reflecting both the type of aircraft as well as average passenger numbers, freight volume, and aviation fuel used (EU, 2024d).

2.5. Emissions intensity: CO₂ Emission per passenger and passenger km

A widely used KPI by airlines is CO₂ emissions per passenger, also referred to as passenger carbon intensity (Miyoshi and Mason, 2013). The CO₂ emissions for a flight are the total fuel consumed multiplied by the emission factor of 3.16 kg CO₂/kg fuel. This metric is based on direct “tank-to-wake” emissions, the CO₂ released when the fuel carried on the aircraft is used for propulsion and onboard energy, and does not follow a life cycle assessment used in other evaluations (Pamukçu et al., 2023). Dividing this by the number of passengers on board yields CO₂ per passenger (Pagoni and Psaraki-Kalouptsidi, 2017; Seymour et al., 2020). A critical factor in this calculation is the passenger load factor, i.e. the percentage of occupied seats, which can significantly impact per-passenger emissions, as higher load factors distribute emissions across more passengers, lowering individual footprints. Additionally, flight distance (calculated as the great circle distance between departure and arrival points) is essential for normalizing emissions on a per-kilometre basis, allowing for a standard measure of CO₂ per passenger-kilometre. This metric, obtained by dividing total CO₂ emissions by the product of passenger count and flight distance, enables comparisons across different routes and airlines. Methodologies often adjust emissions based on seat class, as premium seats typically take up more space and weight, leading to a proportionally higher emissions factor. The first industry-developed Passenger CO₂ Emission Calculator for specific routes was launched by IATA in 2022. IATA reported that this calculator differs from others in the industry in three main ways: (1) it uses actual airline data to calculate fuel burn per aircraft type, averaged across all operators; (2) it applies a flight-time-based approach instead of the distance-based approach used by CORSIA; and (3) it incorporates aircraft-type-specific fuel burn data (IATA, 2025).

As emissions intensity is among the most frequently disclosed KPIs in airline reports, understanding its calculation is essential for interpreting how airlines present emissions efficiency in their disclosures. Indicators related to emissions intensity are particularly prone to strategic interpretation, since improvements can result from better load factors or aircraft efficiency even as total emissions rise. In a context of continued traffic growth, an airline may report declining emissions intensity while its total CO₂ output rises. This creates a misalignment between indicator outcomes and environmental objectives, especially those anchored in science-based targets or the Paris Agreement goals. Emissions intensity indicators therefore can serve to legitimize selective framing of environmental performance in ways that align with corporate narratives of sustainability, rather than offering an accurate representation of

ecological outcomes (Dobruszkes and Efthymiou, 2020). In our analysis, we therefore treat emissions intensity as a symbolic indicator: This aligns with broader findings in the sustainability literature, which suggest that companies may engage in symbolic reporting or greenwashing emphasising favourable metrics while omitting less flattering data.

In summary, the literature points to three unresolved challenges in airline sustainability reporting: the absence of standardised definitions and methodologies for KPIs, the risk that disclosure practices are shaped more by legitimacy management, manifested through greenwashing or greenhushing, than by genuine environmental performance, and the fragmented alignment between regulatory demands and corporate reporting practices. These challenges provide the conceptual anchor for our study. Building on them, our research asks: (1) which mandatory and voluntary KPIs European airlines currently report, (2) how consistent and comparable these disclosures are, and (3) what such reporting patterns reveal about the credibility and effectiveness of sustainability transitions in aviation. The following Methodology section builds on this foundation, detailing the specific steps and techniques employed to achieve the study's objectives.

3. Methodology

The methodology includes three main steps: firstly, the process for extracting mandatory KPIs for European airlines is described in detail to ensure transparency and reproducibility; secondly, the steps taken to create a full list of public listed European airline groups as well as to gather each of the airline's group annual and sustainability reports; lastly the approach for systematically extracting both mandatory and non-mandatory GHG emissions-related KPIs from the ESG reports is explained, including procedures for expert validation and data classification.

Mandatory KPIs for European airlines were first extracted by selecting the regulation affecting each of the schemes (ESG Reporting, the EU ETS, CORSIA and ReFuelEU). A comprehensive documentary analysis was conducted to identify all relevant regulations and reporting requirements. Then, each of the mandatory environmental KPIs affecting European airlines was manually extracted, using documentary analysis, by indicating: i) name of the scheme; ii) EU Regulation from where it was extracted; iii) KPI name; iv) KPI unit; and lastly the date when it entered into force in 2024 or later. For the KPI name, a KPI shortened versions were created. To enhance clarity and facilitate comparison, all extracted KPIs were compiled into a standardized table, including definitions and units.

This research includes 16 European airline groups operating from European Economic Area (EEA), the UK, and Switzerland (see Appendix A). This selection was based on three primary criteria: (1) coverage of airlines subject to common EU sustainability and reporting frameworks, ensuring comparability across similar regulatory contexts; (2) the significance of these groups in terms of market share, as they represent the largest publicly traded European airline groups and their subsidiaries, together accounting for the majority of regional passenger air traffic; and (3) the availability of consistent and accessible non-financial disclosures within annual or sustainability reports (EU, 2014b). The researchers created a comprehensive list beginning with 121 European IATA members, which together transport 83 % of global air passenger traffic (IATA, 2024) and narrowed down to 88 airlines within the specified European region. Research was conducted for each airline using information provided on their respective investor relation web pages, which also helped to establish the relationships between large publicly traded European airline groups and their subsidiary airlines.

The Pitchbook³ database was used to verify ownership when necessary, and airlines providing cargo services alone were excluded from the analysis. To ensure comprehensive coverage of non-IATA members, the researchers also examined the top 40 airlines by number of flights from Eurocontrol, identifying additional non-IATA publicly traded European airlines (e.g., Ryanair and Wizzair). This process resulted in a final sample of 31 airlines belonging to 16 airline groups, as detailed in [Appendix A](#). The non-financial reports (part of annual reports) of the 16 airline groups were downloaded from airline group investor relations websites for analysis. It was assumed, for comparability, that “2023” defined the analysis year. Because some airlines report on non-calendar fiscal years, this assumption used each carrier’s period overlapping 2023 (for example, easyJet’s financial year ended September 30, 2023, i.e., October 2022–September 2023; Ryanair’s fiscal year ended March 31, 2024, i.e., April 2023–March 2024). Under this assumption, the months falling in 2023 captured the largest share of reported data across all airlines analysed. All data extracted from airline annual and sustainability reports are considered accurate as presented by the respective airlines.

All the analysed airlines reported financial and non-financial data in the annual report, although they adopted different names: “Annual Report” (Aegean, Croatian, Finnair, Lufthansa, Norse, Norwegian, Ryanair, and TUI); “Annual Reports and Accounts” (easyJet, Jet2, IAG, and Wizzair); “Annual and Sustainability Report” (Air Baltic, Icelandair, and SAS); and “Universal Registration Document” (Air France). Some airline groups publish a specific sustainability report in addition to the annual report and named: “Sustainability Report” (Aegean, and Ryanair); “ESG Factsheet” (easyJet); “Consolidated Statement of Non-Financial Information” (IAG); and “Sustainability Factsheet” (Lufthansa). For the latter, both annual reports and sustainability reports were downloaded for analysis. This comprehensive collection ensured all relevant reporting was captured for each airline group.

Emission-related KPIs systematically extracted using a structured content analysis approach following established methodologies ([Zieba and Johansson, 2022](#)). Two senior experts in sustainable aviation independently coded all reports using a standardized framework that captured: (1) metric name and definition, (2) unit of measurement, (3) reported values, and (4) scope boundaries. Inter-rater reliability was assessed, achieving 91.2 % initial agreement. Their approach was to review the section related to emissions of each airline’s group report, which were titled as follows: Sustainability (Aegean, easyJet, Finnair, IAG, Jet2, TUI, and Wizzair); Environment (Air France-KLM, Lufthansa, Ryanair, and SAS); Climate (Air Baltic and Icelandair); and Environmental Responsibility (Norse and Norwegian). They then extracted the full metric name, unit, and values of each KPI and stored them in one table. To enhance reliability, extraction was performed independently by both experts, and any discrepancies were resolved through joint review and consensus. Disagreements (8.8 % of cases) were systematically resolved through structured consensus-building processes until 100 % agreement was achieved. When a discrepancy appeared between the experts, a joint revision of the report was conducted until an agreement was reached. A table of published KPIs in 2023 was created for each airline group. Lastly, each KPI was classified as mandatory or non-mandatory based on the previously generated KPI list (see [Table 2](#)). This classification was cross-validated against regulatory definitions to ensure accuracy.

All data used in this study is publicly available, and no confidential or proprietary information was accessed. The methodology was designed to maximize transparency and reproducibility, but limitations include potential inconsistencies in self-reported data and variations in

reporting formats across airline groups.

4. Results and discussion

Results include: a) GHG emissions mandatory KPIs extracted from regulatory frameworks, including ESG Reporting, the EU ETS, CORSIA, and ReFuelEU; b) Mandatory and Non-mandatory KPIs reported by European airlines groups in 2023 annual and sustainability reports. This structure enables a clear comparison between regulatory requirements and actual industry reporting practices, highlighting both progress and ongoing challenges in sustainability reporting.

The analysis of regulatory frameworks yielded a comprehensive list of 18 mandatory environmental KPIs for European airlines, as summarized in [Table 2](#). These KPIs reflect the evolving landscape of regulatory demands, with increasing emphasis on transparency, comparability, and comprehensiveness in airline emissions reporting. The identified KPIs cover a broad scope, including total and disaggregated CO₂ emissions, Scope 1, 2, and 3 GHG emissions, energy consumption, emissions intensity, SAF lifecycle emissions, GHG removals, and offsetting requirements. It is notable that recent and forthcoming regulations, such as the CSRD/ESG and ReFuelEU frameworks, have further expanded the scope of mandatory disclosures since 2024, having introduced requirements for reporting non-CO₂ emissions and emissions per flight. This regulatory evolution underscores the sector’s growing responsibility for climate action and the need for robust data infrastructure.

Turning to the reporting practices of European airline groups, the analysis reveals significant variability in both the breadth and depth of reporting. As shown in [Fig. 2](#), the most widely reported KPIs were “Total CO₂ Scope 1,” disclosed by 94 % of airlines, and “Emissions Intensity,” reported by 88 %. These high reporting rates suggest increasing alignment with core regulatory expectations and recognition of the importance of these metrics for stakeholders. This selective high-frequency reporting can also be interpreted through the lens of greenwashing and the prioritization of symbolic over substantive KPIs, a key concern raised in the literature ([Cregan et al., 2024](#)). For instance, the focus on ‘Emissions Intensity’, an efficiency indicator, can present a favourable narrative of progress, even if an airline’s absolute emissions are increasing due to traffic growth. This practice aligns with observations that companies may strategically frame environmental performance in ways that legitimize their operations rather than offering a complete picture of their ecological impact ([Dobruszkes and Efthymiou, 2020](#)). Across the sample, airlines reported efficiency gains (lower CO₂ intensity) alongside higher absolute emissions driven by capacity recovery and demand, with illustrative disclosures: Lufthansa Group’s absolute CO₂ emissions from aviation fuel rose 16 % while specific CO₂ per passengerkm fell 1.8 % to 88.4 gCO₂/pkm; IAG improved carbon intensity by 3.6 %–80.5 gCO₂/pkm amid strong demand; easyJet linked higher total GHG emissions to market recovery while reporting a record 67.23 g/RPK intensity; Ryanair’s intensity improved to 65 g CO₂ per pax/km despite traffic growth. This communication pattern risks greenwashing when efficiency gains are emphasized while growth in total emissions is downplayed, potentially overstating environmental progress and confusing stakeholders. This risk reinforces the need to present standardised, contextualized reporting of both absolute and intensity metrics, consistent with the transparency gaps identified in this study. At the same time, the under-reporting of areas where genuine progress is likely—such as sustainable aviation fuel (SAF) uptake or GHG removals—indicates possible greenwashing behaviours, where substantive actions are communicated cautiously to avoid external scrutiny or accusations of inconsistency.

In contrast to the high reporting rates for Total CO₂ Scope 1 and Emissions Intensity, the reporting rates for other mandatory KPIs, such as Scope 2 and 3 GHG emissions, energy consumption, and GHG removals, were considerably lower, ranging from 6 % to 56 %. This is a significant finding, as the low disclosure rates for Scope 2 (56 %) and

³ The Pitchbook database was used for reliability for those airlines whose investor relations websites couldn’t confirm whether they were publicly traded companies. The link to access the online database is <https://pitchbook.com/profiles/company/129567-61>.

Table 2

Mandatory airlines GHG emissions related KPIs for airlines operating in the EEA, UK and Switzerland (Authors using ESG, EU ETS, CORSIA and ReFuelEU related regulations).

ID #	KPI long name	KPI short name	Unit	Scheme	Regulation	Type
1	Total verified emissions (domestic emissions covered by EU ETS, and international emissions covered by EU ETS or reported for MRV purposes for CORSIA)	Total CO ₂ Scope 1	tonnes of CO ₂	EU ETS	Reg. (EU) 2018/2066	M
2	CO ₂ emissions reported pursuant to implementing Regulation 2018/2066 (domestic and international emissions covered by EU ETS effective carbon pricing)	Total EU ETS CO ₂ Scope 1	tonnes of CO ₂	EU ETS	Reg. (EU) 2018/2066	M
3	CO ₂ emissions reported from flights within a Member State (domestic flights)	Domestic EU ETS CO ₂ Scope 1	tonnes of CO ₂	EU ETS	Reg. (EU) 2018/2066	M
4	CO ₂ emissions reported pursuant to Delegated Regulation (EU) 2019/1603 (emissions reported for MRV purposes for CORSIA)	Total CORSIA CO ₂ Scope 1	tonnes of CO ₂	EU ETS CORSIA	Reg. (EU) 2019/1603	M
5	Scope 1 GHG emissions	Scope 1 GHG	tonnes of CO ₂ e	CSRD/ ESG	Reg. (EU) 2023/2772	M 1.1.24
6	Scope 2 GHG emissions	Scope 2 GHG	tonnes of CO ₂ e	CSRD/ ESG	Reg. (EU) 2023/2772	M 1.1.24
7	Scope 3 GHG emissions	Scope 3 GHG	tonnes of CO ₂ e	CSRD/ ESG	Reg. (EU) 2023/2772	M 1.1.24
8	Total Scope 1, 2 and 3 GHG emissions	Total Scop1, 2 and 3	tonnes of CO ₂ e	CSRD/ ESG	Reg. (EU) 2023/2772	M 1.1.24
9	Total energy consumption	Energy	MWh	CSRD/ ESG	Reg. (EU) 2023/2772	M 1.1.24
10	Total energy consumption per net revenue	Energy intensity		CSRD/ ESG	Reg. (EU) 2023/2772	M 1.1.24
11	CHG emissions intensity from Scope 1	Emissions Intensity	g of CO ₂ per RPK	EU ETS	Reg. (EU) 2018/2066	M
12	GHG removals and mitigations	GHG removals	tons of CO ₂ e	CSRD/ ESG	Reg. (EU) 2023/2772	M 1.1.24
13	Total Non-CO ₂ Emissions	Total Non-CO ₂	tonnes of non-CO ₂	EU ETS	Reg. (EU) 2023/958	M 1.1.25
14	Total of CO ₂ equivalent per flight	Total of CO ₂ per flight	tonnes of CO ₂ e	EU ETS	Reg. (EU) 2023/958	M 1.1.27
15	Total CO ₂ emissions disaggregated by the Member State of departure and arrival	CO ₂ per State	Tonnes	EU ETS	Reg. (EU) 2018/2066	M
16	SAF lifecycle emissions (calculated using the methodologies of Directive (EU) 2018/2001)	SAF CO ₂	tonnes of CO ₂	ReFuelEU	Reg. (EU) 2023/2405	M 1.1.25
17	CO ₂ offsetting requirements due to CORSIA	CO ₂ offsetting	tonnes of CO ₂	CORSIA	Reg. (EU) 2024/1879	M
18	Total GHG emissions per net revenue	Emissions per net revenue	grams per euro	CSRD/ ESG	Reg. (EU) 2023/2772	M 1.1.24

Notes: 1 Emission Allowance = 1 metric tonne of CO₂ (EU ETS); 1 Carbon Credit = 1 metric tonnes of CO₂ (CORSIA); M: Mandatory; V: Voluntary. CO₂e: CO₂ equivalent.

Scope 3 (50 %) GHG emissions signal a potential compliance gap for many airlines with the imminent CSRD, which mandates such reporting from 2024. A failure to accurately report these emissions could not only lead to regulatory penalties but also undermine the ability of investors and stakeholders to assess an airline's full climate impact. [Table 3](#) complements [Fig. 2](#) by presenting the airline-by-airline matrix of 2023 mandatory KPI disclosures, naming carriers and highlighting leaders (e. g., IAG, AF-KLM, easyJet, SAS, Wizzair) and laggards (e.g., Croatian), thus enabling comparison beyond aggregate percentages.

KPIs related to SAF emissions, non-CO₂ emissions, and offsetting were seldom reported, which may reflect the novelty of these requirements, data availability challenges, or a lag in regulatory implementation. These specific omissions have direct policy implications. For instance, only 19 % of the airlines reported on SAF use without disclosing how many tonnes and its life cycle assessment (LCA) is particularly concerning given the ReFuelEU Aviation regulation, which will require fuel suppliers, and thus to airlines by extension, to meet blending mandates from 2025. Without robust and standardized reporting, it can be challenging for policymakers to verify compliance and for the market to accurately value the use of these crucial alternative fuels. Similarly, the low reporting of non-CO₂ emissions (38 %) ahead of the 2025 EU ETS monitoring requirement indicates a lack of preparedness across the sector. This omission hinders a comprehensive assessment of aviation's total climate forcing and could affect the future design of policies aimed at mitigating these effects. Furthermore, these reporting gaps, particularly the inconsistencies in Scope 1 data and the

near-absence of offsetting disclosures (6 %), directly impact the transparency and verifiability of obligations under international schemes like CORSIA, making it difficult to assess sectoral compliance with global offsetting targets. Furthermore, several KPIs mandated for future years, such as non-CO₂ emissions and emissions per flight, were not yet reported in 2023, indicating that airlines are still adapting to the expanding regulatory landscape.

The variability in report naming conventions and formats, such as "Annual Report," "Sustainability Report," and "ESG Factsheet", further complicates comparability across airline groups. While most airline groups published environmental disclosures, there remain notable gaps; for example, Croatian Airlines did not report any mandatory KPI. This inconsistency in disclosure practices and terminology highlights the need for greater harmonization in sustainability reporting frameworks within the sector.

In addition to mandatory KPIs, as shown in [Table 4](#), several airlines disclosed non-mandatory (voluntary) KPIs, such as customer offsetting by Lufthansa and Wizzair, voluntary SAF purchases by Finnair and Norwegian, and emissions per output scaling factor by Icelandair. These voluntary disclosures demonstrate that some airlines are striving to go beyond regulatory requirements, often as part of broader sustainability or marketing strategies. However, the lack of standardization in voluntary KPIs and inconsistent definitions limits their utility for benchmarking or sector-wide analysis. This finding provides a clear, real-world example of the debate between standardization and flexibility in indicator development ([Rametsteiner et al., 2011](#)). While

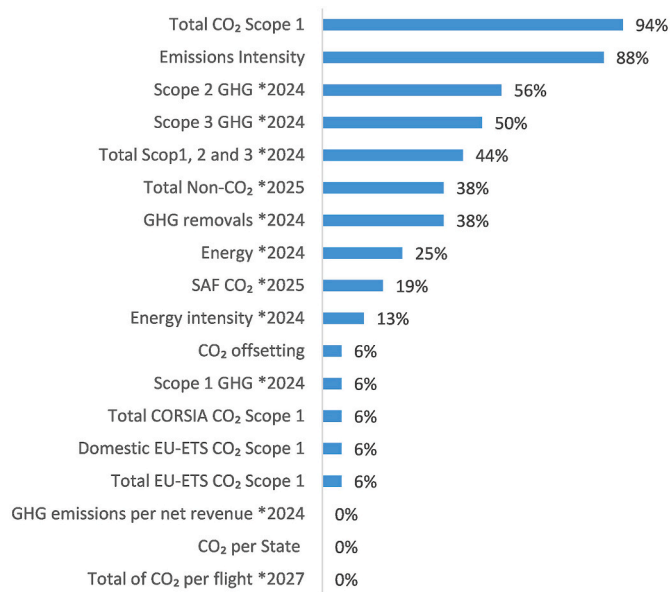


Fig. 2. Percentage of European Airline Groups publishing Mandatory KPIs in 2023 on the sustainability reports (Authors)

An asterisk (*) indicates that the mandatory KPIs have an effective date later than the 2023, the year for which airline data was used in this study. The year indicates when the regulations take effect.

flexibility can foster innovation, the resulting proliferation of bespoke, non-comparable metrics can obscure performance and, as the literature warns, create fertile ground for greenwashing by allowing companies to report on niche initiatives that may lack materiality or transparency (Guix et al., 2022). The low and inconsistent reporting on mandatory offsetting requirements, contrasted with the voluntary disclosures on customer offsetting, further complicates the picture, making it difficult to distinguish genuine decarbonisation efforts from reputation management.

Overall, the findings of this study highlight both progress and persistent challenges in airline emissions reporting, directly reflecting the theoretical tensions outlined in the literature review. The widespread reporting of core KPIs such as Total CO₂ Scope 1 and Emissions Intensity indicates a positive trend towards regulatory compliance and stakeholder engagement. However, the low reporting rates for other mandatory KPIs and the absence of some required disclosures point to ongoing barriers to comprehensive and standardized reporting. This variability empirically confirms the challenge of non-standardization that the literature has highlighted for over two decades (Hooper and Greenall, 2005; Zieba and Johansson, 2022). While regulations are clearly driving some convergence, the lack of standardization in reporting practices allows significant inconsistencies to remain, undermining the comparability that is essential for effective policy and stakeholder oversight.

Differences in report structure, terminology, and KPI definitions continue to hinder transparency and comparability, making it difficult for stakeholders to assess and compare airline performance effectively. The anticipated expansion of mandatory KPIs under CSRD/ESG and ReFuelEU from 2024 onwards is expected to drive further improvements, but may also pose compliance challenges for some airlines. Voluntary disclosures, while innovative, require greater standardization to support meaningful cross-company and cross-border comparisons.

Finally, the inconsistencies in Scope 2 and 3 emissions reporting expose deeper systemic weaknesses in how sustainability transitions are governed in aviation. Unlike Scope 1, these categories demand the integration of data across highly fragmented value chains, covering energy procurement, aircraft manufacturing, airport operations, and even passenger and freight travel behaviour. The patchy disclosures

observed suggest that airlines are not only constrained by methodological ambiguities but also by a lack of leverage over upstream and downstream actors whose cooperation is essential. This reflects a broader structural problem: regulatory regimes such as the CSRD mandate comprehensive disclosures, yet without parallel harmonization in supply chain accounting and enforcement across jurisdictions, compliance remains partial and uneven. In effect, the reporting gaps illustrate how sectoral decarbonisation is slowed by institutional misalignment, conflicting stakeholder incentives, and the absence of robust infrastructures for cross-industry data sharing, systemic barriers that extend well beyond aviation and characterise sustainability transitions more broadly.

5. Conclusions

For the aviation sector, KPIs serve as essential tools for objectively tracking, measuring, and communicating progress toward environmental sustainability and regulatory compliance. This study provides a comprehensive analysis of the current status of greenhouse gas (GHG) emissions reporting among European airline groups, focusing on both mandatory and voluntary key performance indicators (KPIs) as shaped by evolving regulatory frameworks. The findings reveal that while there has been notable progress in the alignment of airline reporting practices with core regulatory requirements, particularly for metrics such as Total CO₂ Scope 1 emissions and Emissions Intensity—significant inconsistencies and gaps remain. Most airline groups now routinely disclose these core KPIs, reflecting both regulatory pressure and growing stakeholder demand for transparency. However, reporting rates for other mandatory indicators, such as Scope 2 and 3 GHG emissions, energy consumption, GHG removals, and KPIs related to SAF and non-CO₂ effects, are considerably lower. This may also be explained by increasing public attention to airline emissions and the threat of having its ‘license to operate’ revoked. Airlines therefore may choose to disclose only what makes them look ‘good’, adding to the complexity of ensuring the efficacy of KPIs. These issues point to persistent barriers to data availability, methodological standardization, and the sector’s capacity to adapt to new and upcoming environmental reporting obligations. Similar to comparative analyses in other sectors, such as sustainability standards in green building (Saleh et al., 2024), our study illustrates how mapping and contrasting frameworks can reveal inconsistencies that may impede genuine progress.

The study also highlights the proliferation of voluntary KPIs, which, while indicative of the willingness of some airlines to go beyond mere compliance, are characterized by a lack of standardization and consistency in definition. This variability in voluntary disclosures, in combination with varying report structures and terminology, undermines comparability and transparency, making it difficult for stakeholders to benchmark performance or assess the sector’s genuine progress toward climate targets. The risk of greenwashing, when airlines selectively report favourable metrics (e.g. CO₂ emission per passenger kilometre, that reduces with technological improvements) or omit less flattering data (e.g. active communication of the total CO₂ Emissions), remains a concern. However, this study reveals a more nuanced and underexplored phenomenon: greenhushing, where airlines deliberately undercommunicate genuine sustainability achievements to avoid scrutiny or backlash. Our empirical findings demonstrate that while airlines widely report basic emissions metrics (94 % for Total CO₂ Scope 1), they significantly under-report more comprehensive sustainability efforts, with only 38 % of airline groups disclosing GHG removals and merely 19 % reporting SAF lifecycle emissions despite substantial industry investments in these areas. This pattern of strategic silence represents a novel contribution to understanding airline sustainability communication, as it suggests that regulatory pressure may inadvertently encourage conservative reporting strategies that obscure genuine environmental progress. The greenhushing phenomenon poses distinct risks to policy effectiveness: it deprives stakeholders of critical information needed to

Table 3
Mandatory KPIs published in the annual and sustainability reports of European airline groups (authors).

ID #	KPI short name	Mandatory	Aegean	Air Baltic	AF-KLM	Croatian	easyJet	Finnair	IAG	Icelandair	Jet 2	Lufthansa	Norse	Norwegian	Ryanair	SAS	TUI	Wizzair	# of airlines	%
1	Total CO ₂ Scope 1		x	x	x		x	x	x	x	x	x	x	x	x	X	x	x	15	94 %
2	Total EU ETS CO ₂ Scope 1															X			1	6 %
3	Domestic EU ETS CO ₂ Scope 1															X			1	6 %
4	Total CORSIA CO ₂ Scope 1																	x	1	6 %
5	Scope 1 GHG	2024	x																1	6 %
6	Scope 2 GHG	2024			X		x	X	x	x	x			X	X			x	9	56 %
7	Scope 3 GHG	2024			X		x	X	x	x	x				X			x	8	50 %
8	Total Scop1, 2 and 3	2024	x		X		x	X			x				X			x	7	44 %
9	Energy	2024	X				x		X	x									4	25 %
10	Energy intensity	2024								x									2	13 %
11	Emissions Intensity		x	x	X		x	X	X	x	x	x		x	X	X	x	x	14	88 %
12	GHG removals	2024			X		x	X	X						X	X			6	38 %
13	Total Non-CO ₂	2025	x		X							x				X		x	6	38 %
14	Total of CO ₂ per flight	2027																	0	0 %
15	CO ₂ per State																		0	0 %
16	SAF CO ₂	2025							x			x		x					3	19 %
17	CO ₂ offsetting															X			1	6 %
18	GHG emissions per net revenue	2024																	0	0 %
	Total:		6	2	7	0	7	6	7	6	5	4	1	5	6	7	3	7		

Table 4
Non-Mandatory KPIs extracted from the 2023 annual and sustainability reports of European airline groups (authors).

ID	KPI	Unit	Airline Group
A	Offsetting CO ₂ by Customers	thousand tonnes	Lufthansa
B	Offsetting CO ₂ by Lufthansa Group for own business trips ¹	thousand tonnes	Lufthansa
C	Scope 1 CO ₂ emissions with voluntary offsets by customers (CHOOOSE)	tCO ₂	Wizzair
D	Sustainable Aviation Fuel, Customer purchases (CO ₂ emissions reductions)	tonnes of CO ₂	Finnair
e	SAF under voluntary market (Biogenic Emissions)	tCO ₂ e	Norwegian
F	Revenue per tonne CO ₂ e	€/tonne CO ₂ e	IAG
G	Total GHG emission per output scaling factor	tCO ₂ e per FTEs	Icelandair

assess true sectoral progress, hinders peer learning and knowledge sharing across the industry, and may ultimately slow the pace of aviation decarbonisation by concealing innovative practices and successful implementation strategies. Both greenwashing and greenhushing practices threaten the credibility and effectiveness of sustainability reporting in aviation. By explicitly linking these reporting patterns to greenwashing and greenhushing dynamics, this study contributes to a deeper understanding of the communicative and institutional barriers that hinder transparent decarbonisation in the airline sector.

The anticipated expansion of mandatory disclosures under the CSRD, EU ETS, CORSIA, and ReFuelEU frameworks is expected to drive further improvements in the breadth and depth of airline sustainability reporting. New requirements, such as reporting non-CO₂ emissions and emissions per flight, reflect a broader and more holistic approach to aviation's climate impact. However, these regulatory advances will also pose compliance challenges, especially for airlines with limited resources or experience in comprehensive data management. Challenges of integrating heterogeneous data sources, also observed in domains such as location-based social networks (e.g. Dutta et al., 2025), mirror the difficulties of achieving comparability in sustainability reporting. The sector's ability to meet these challenges will be critical for achieving meaningful decarbonisation and maintaining public trust.

To address the identified reporting gaps and enhance harmonization, several concrete recommendations emerge from this analysis. First, regulatory authorities should establish unified technical standards that specify exact definitions, calculation methodologies, and reporting formats for all mandatory KPIs, with particular attention to Scope 2 and 3 emissions and SAF lifecycle calculations. Second, industry-led initiatives should complement regulatory efforts by developing voluntary common standards for non-mandatory KPIs through existing associations such as IATA and Airlines for Europe, creating a hybrid approach that combines regulatory standardization for core metrics with structured flexibility for additional KPIs. Third, to counteract greenhushing behaviours, policymakers should consider implementing "safe harbor" provisions that protect airlines from regulatory penalties based on greenwashing when they voluntarily disclose innovative sustainability initiatives, thereby encouraging rather than discouraging transparent communication of genuine environmental efforts. Lastly, the development of integrated digital open access reporting platforms could significantly reduce administrative burden while improving data consistency and real-time monitoring capabilities across the sector.

Some limitations should be acknowledged. First, the study relies

exclusively on publicly available data from the annual and sustainability reports of airline companies, which may be subject to inconsistencies in self-reporting, varying levels of detail, and differences in reporting periods. The manual extraction and classification of KPIs, while independently validated by experts, may still be influenced by subjective interpretation, particularly given the lack of harmonized definitions across the sector. Additionally, the analysis is limited to listed airline groups operating within the European Economic Area, the UK, and Switzerland, which may not capture the full diversity of reporting practices among smaller, non-listed, or non-European carriers. Moreover, the analytical lens interprets a selective emphasis on intensity indicators over absolute emissions, as well as omissions of comprehensive disclosures, as legitimacy-oriented choices indicative of greenwashing and greenhushing; however, these phenomena on non-mandatory KPIs are not directly measured, which constrains causal inference about underlying motives.

Future research should focus on several key areas. First, there is a need for longitudinal studies to assess how airline reporting practices evolve in response to the implementation of new regulatory requirements, particularly as the CSRD and ReFuelEU mandates take full effect. Comparative research across global regions could provide insights into the effectiveness of different regulatory approaches and the potential for international harmonization of sustainability reporting standards. Most critically, further investigation into the prevalence, drivers, and sectoral impacts of greenhushing in airline communications represents a significant research opportunity, particularly through qualitative studies involving airline sustainability managers and stakeholders to understand the decision-making processes behind selective disclosure practices. Further investigation into the drivers and impacts of greenwashing and greenhushing in airline communications would also be valuable, especially in light of growing consumer and regulatory scrutiny. Finally, research should explore the integration of digital technologies and data analytics to enhance the accuracy, timeliness, and comparability of emissions reporting, supporting the sector's transition to net-zero emissions.

CRediT authorship contribution statement

Luis Martín-Domingo: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Marina Efthymiou:** Writing – review & editing, Validation, Supervision, Methodology, Funding acquisition, Conceptualization. **Miguel Mujica Mota:** Writing – review & editing, Software, Investigation, Funding acquisition.

Funding

This research was co-funded by the European Union under Grant Project 101151804 — AZERO. Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the European Research Executive Agency (REA) can be held responsible for them.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix-A

Table A1

Listed European airlines groups from EEA (i.e. EU27, Iceland, Liechtenstein and Norway), the UK and Switzerland (Authors)

ID	Airline Group	Number of airlines	ASK (million)
1	Aegean Group	2	20,434
2	Air Baltic Corporation	1	10,781
3	Air France-KLM Group	3	309,563
4	Croatian Airlines	1	1991
5	easyJet plc	1	113,334
6	Finnair Group	1	36,154
7	IAG Group	5	323,111
8	Icelandair Group	1	15,666
9	Jet2 plc	1	19,730
10	Lufthansa Group	7	300,582
11	Norse Atlantic ASA	1	8672
12	Norwegian Group	1	32,322
13	Ryanair Group	3	255,576
14	SAS Group	1	42,566
15	Tui Group	1	76,100
16	Wizzair Holdings plc	1	121,749

Data availability

Data will be made available on request.

References

- ABN Amro, Aviva, AXA Group, Banco do Brasil, Bank Sarasin, BNP Paribas, Calvert Group, CNP Assurances, Credit Suisse Group, Deutsche Bank, Goldman Sachs, Henderson Global Investors, HSBC, Innovest, ISIS Asset Management, KLP Insurance, Morgan Stanley, RCM, UBS, & Westpac, 2004. Who cares wins. The global compact. Connecting financial markets to a changing world. https://www.unepfi.org/fileadmin/events/2004/stocks/who_cares_wins_global_compact_2004.pdf.
- Avinor, 2024. Annual and Sustainability Report 2023. https://avinor.no/contentassets/b5d94158f9de40709e917343fde524aa/avinor_arsrapport_2023-eng.pdf.
- Baumeister, S., Zeng, C., Hoffendahl, A., 2022. The effect of an eco-label on the booking decisions of air passengers. *Transp. Policy* 124, 175–182. <https://doi.org/10.1016/j.tranpol.2020.07.009>.
- Bernasek, A., Porter, R.C., 1997. Private pressure for social change in South Africa: the impact of the Sullivan principles. *Rev. Soc. Econ.* 55 (2), 172–193. <https://doi.org/10.1080/00346769700000032>.
- Borella, A., Boucher, O., Shine, K.P., Stettler, M., Tanaka, K., Teoh, R., Bellouin, N., 2024. The importance of an informed choice of CO₂-equivalence metrics for contrail avoidance. *Atmos. Chem. Phys.* 24 (16), 9401–9417. <https://doi.org/10.5194/acp-24-9401-2024>.
- CAA, 2024. In: Flight 100 – Our Role in Enabling the First Transatlantic Sustainable Fuel Flight. Civil Aviation Authority. <https://www.caa.co.uk/newsroom/blogs/flight-100-our-role-in-enabling-the-first-transatlantic-sustainable-fuel-flight/>.
- Caraveo Gomez Llanos, A.F., Vijaya, A., Wicaksono, H., 2023. Rating ESG key performance indicators in the airline industry. *Environ. Dev. Sustain.* <https://doi.org/10.1007/s10668-023-03775-z>.
- Copernicus, 2024. European State of the climate—report 2023. <https://climate.copernicus.eu/widespread-floods-severe-heatwaves-esotc-2023-puts-europes-climate-focus>.
- Cregan, C., Kelly, J.A., Clinch, J.P., 2024. Are environmental, social and governance (ESG) ratings reliable indicators of emissions outcomes? A case study of the airline industry. *Corp. Soc. Responsib. Environ. Manag.* 31 (2), 909–928. <https://doi.org/10.1002/csr.2608>.
- Davies, Z.G., Armsworth, P.R., 2010. Making an impact: the influence of policies to reduce emissions from aviation on the business travel patterns of individual corporations. *Energy Policy* 38 (12), 7634–7638. <https://doi.org/10.1016/j.enpol.2010.09.007>.
- Dias, L.P.C., Bagatini, F.Z., Perin, M.G., 2025. Green “Under-Communication:” A systematic literature review on greenhushing. *ReMark - Revista Brasileira de Marketing* 24 (1). <https://doi.org/10.5585/2025.26718>. Article 1.
- Dobruszkes, F., Efthymiou, M., 2020. When environmental indicators are not neutral: assessing aircraft noise assessment in Europe. *J. Air Transport. Manag.* 88, 101861. <https://doi.org/10.1016/j.jairtraman.2020.101861>.
- Dutta, P.K., Kumar, A., Sakici, S., Mensah, B., 2025. Enhancing point-of-interest recommendation systems through multi-modal data integration in location-based social networks: challenges and future directions. *EDRAAK 2025*, 12–18. <https://doi.org/10.70470/EDRAAK/2025/003>.
- EC, 2019. *The European Green Deal* [Text]. European Commission - European Commission. https://ec.europa.eu/commission/presscorner/detail/en/ip_19_6691.
- EC, 2021. Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending directive 2003/87/EC as regards aviation’s contribution to the Union’s economy-wide emission reduction target and appropriately implementing a global market-based measure. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0552>.
- EC, 2023a. Aviation and the EU ETS. https://climate.ec.europa.eu/eu-action/european-green-deal/delivering-european-green-deal/aviation-and-eu-ets_en.
- EC, 2023b. Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the transparency and integrity of environmental, social and governance (ESG) rating activities. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52023PC0314>.
- EC, 2023c. Sustainable finance: council agrees negotiating mandate on ESG ratings. <https://www.consilium.europa.eu/en/press/press-releases/2023/12/20/sustainable-finance-council-agrees-negotiating-mandate-on-esg-ratings/>.
- Efthymiou, M., Papatheodorou, A., 2019. EU emissions trading scheme in aviation: policy analysis and suggestions. *J. Clean. Prod.* 237, 117734. <https://doi.org/10.1016/j.jclepro.2019.117734>.
- Escobar, N., Seber, G., Skalsky, R., Wögerer, M., Jung, M., Malina, R., 2024. Spatially-explicit land use change emissions and carbon payback times of biofuels under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSA). *Sci. Total Environ.* 948, 174635. <https://doi.org/10.1016/j.scitotenv.2024.174635>.
- ESMA, 2024. European securities and markets authority (ESMA). <https://www.esma.europa.eu/about-esma>.
- EU, 2005. Directive 2005/29/EC of the European parliament and of the council of 11 May 2005 concerning unfair business-to-consumer commercial practices in the internal market and amending Council directive 84/450/EEC. Directives 97/7/EC, 98/27/EC and 2002/65/EC of the European Parliament and of the Council and Regulation (EC) No 2006/2004 of the European Parliament and of the Council (“Unfair Commercial Practices Directive”) (Text with EEA relevance). <http://data.europa.eu/eli/dir/2005/29/oj/eng>.
- EU, 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. <http://data.europa.eu/eli/dir/2009/28/oj/eng>.
- EU, 2014a. Directive 2014/95/EU Amending Directive 2013/34/EU as Regards Disclosure of Non-financial and Diversity Information by Certain Large Undertakings and Groups 2013.
- EU, 2014b. Directive (EU) 2014/95 of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups text with EEA relevance. <http://data.europa.eu/eli/dir/2014/95/oj/eng>.
- EU, 2018. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources. <https://eur-lex.europa.eu/eli/dir/2018/2001/oj>.
- EU, 2019. Communication from the Commission—Guidelines on non-financial reporting: supplement on reporting climate-related information. [https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019XC0620\(01\)&from=EN](https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019XC0620(01)&from=EN).
- EU, 2023. Regulation (EU) 2023/2405 of the European Parliament and of the council of 18 October 2023 on ensuring a level playing field for sustainable air transport (ReFuelEU aviation) (text with EEA relevance). <http://data.europa.eu/eli/reg/2023/2405/oj/eng>.
- EU, 2024a. *Action Against 20 Airlines for Misleading Greenwashing Pract* [Text]. European Commission - European Commission. https://ec.europa.eu/commission/presscorner/detail/en/ip_24_2322.

- EU, 2024b. Directive (EU) 2024/825 of the European Parliament and of the council of 28 February 2024 amending directives 2005/29/EC and 2011/83/EU as regards empowering consumers for the green transition through better protection against unfair practices and through better information (text with EEA relevance). <http://data.europa.eu/eli/dir/2024/825/oj/eng>.
- EU, 2024c. EU ETS emissions cap—European commission. https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/eu-ets-emissions-cap_en.
- EU, 2024d. EU introduces flight emissions label for more informed and sustainable travelling—European commission. https://transport.ec.europa.eu/news-events/news/eu-introduces-flight-emissions-label-more-informed-and-sustainable-travelling-2024-12-18_en.
- EU, 2024e. Reducing emissions from aviation. https://ec.europa.eu/clima/eu-action/transport-emissions/reducing-emissions-aviation_en.
- EU, 2024f. Regulation—Eu - 2024/3005 - on the transparency and integrity of environmental, social and governance (ESG) rating activities, and amending regulations (EU) 2019/2088 and (EU) 2023/2859. <https://eur-lex.europa.eu/eli/reg/2024/3005/oj/eng>.
- Eurocontrol, 2021. EUROCONTROL aviation sustainability summit [Video]. <https://www.eurocontrol.int/event/eurocontrol-aviation-sustainability-summit>.
- Font, X., Elgammal, Islam, Lamond, I., 2017. Greenhushing: the deliberate under communicating of sustainability practices by tourism businesses. *J. Sustain. Tourism* 25 (7), 1007–1023. <https://doi.org/10.1080/09669582.2016.1158829>.
- Fredenburgh, J., 2022. Clouds created by aircraft have a bigger impact than the emissions they emit. *Imperial News*. <https://www.imperial.ac.uk/news/242017/clouds-created-aircraft-have-bigger-impact/>.
- Fuglestedt, J.S., Shine, K.P., Berntsen, T., Cook, J., Lee, D.S., Stenke, A., Skeie, R.B., Velders, G.J.M., Waitz, I.A., 2010. Transport impacts on atmosphere and climate: metrics. *Atmos. Environ.* 44 (37), 4648–4677. <https://doi.org/10.1016/j.atmosenv.2009.04.044>.
- German Environmental Agency, 2023. CLIMATE IMPACT OF AVIATION scientific knowledge, developments and measures. https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/fb_climate_impact_of_aviation_0.pdf.
- Gryspeerd, E., Stettler, M.E.J., Teoh, R., Burkhardt, U., Delovski, T., Driver, O.G.A., Painemal, D., 2024. Operational differences lead to longer lifetimes of satellite detectable contrails from more fuel efficient aircraft. *Environ. Res. Lett.* 19 (8), 084059. <https://doi.org/10.1088/1748-9326/ad5b78>.
- Guix, M., Ollé, C., Font, X., 2022. Trustworthy or misleading communication of voluntary carbon offsets in the aviation industry. *Tour. Manag.* 88, 104430. <https://doi.org/10.1016/j.tourman.2021.104430>.
- Heink, U., Kowarik, I., 2010. What are indicators? On the definition of indicators in ecology and environmental planning. *Ecol. Indic.* 10 (3), 584–593. <https://doi.org/10.1016/j.ecolind.2009.09.009>.
- Hilton, J., 2025. An integrated analysis of greenhush. *Innov. Green Dev.* 4 (2), 100222. <https://doi.org/10.1016/j.igd.2025.100222>.
- Hooper, P.D., Greenall, A., 2005. Exploring the potential for environmental performance benchmarking in the airline sector. *Benchmark Int. J.* 12 (2), 151–165. <https://doi.org/10.1108/14635770510593095>.
- IATA, 2023a. IATA CO2 Connect calculator frequently asked questions. <https://www.iata.org/en/services/statistics/intelligence/co2-connect/iata-co2-connect-passenger-calculator/calculator-faq/>.
- IATA, 2023b. SAF volumes growing but still missing opportunities. <https://www.iata.org/en/pressroom/2023-releases/2023-12-06-02/>.
- IATA, 2024. IATA members. <https://www.iata.org/en/about/members/>.
- IATA, 2025. Environment & Sustainability Data. <https://www.iata.org/en/services/data/environment-sustainability>.
- ICAO (Director), 2016. The carbon offsetting and reduction scheme for international aviation (CORSIA). <https://www.youtube.com/watch?v=OUfhLkMhc8w>.
- ICAO, 2023a. Carbon offsetting and reduction scheme for international aviation (CORSIA). <https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx>.
- ICAO, 2023b. ICAO CORSIA CO2 estimation and reporting tool (CERT). <https://www.icao.int/environmental-protection/CORSIA/Pages/CERT.aspx>.
- ICAO, 2025a. Carbon offsetting and reduction scheme for international aviation (CORSIA). <https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx>.
- ICAO, 2025b. CORSIA States for Chapter 3 State Pairs. <https://www.icao.int/environmental-protection/CORSIA/Pages/state-pairs.aspx>.
- IPCC, 2018. IPCC special report aviation and the global atmosphere. <https://www.ipcc.ch/site/assets/uploads/2018/03/av-en-1.pdf>.
- Kathan, M.C., Utz, S., Dorfleitner, G., Eckberg, J., Chmel, L., 2025. What you see is not what you get: ESG scores and greenwashing risk. *Finance Res. Lett.* 74, 106710. <https://doi.org/10.1016/j.frl.2024.106710>.
- Klöwer, M., Allen, M.R., Lee, D.S., Proud, S.R., Gallagher, L., Skowron, A., 2021. Quantifying aviation's contribution to global warming. *Environ. Res. Lett.* 16 (10), 104027. <https://doi.org/10.1088/1748-9326/ac286e>.
- Larsson, J., Eloffson, A., Sterner, T., Åkerman, J., 2019. International and national climate policies for aviation: a review. *Clim. Policy* 19 (6), 787–799. <https://doi.org/10.1080/14693062.2018.1562871>.
- Lee, D.S., Fahey, D.W., Skowron, A., Allen, M.R., Burkhardt, U., Chen, Q., Doherty, S.J., Freeman, S., Forster, P.M., Fuglestedt, J., Gettelman, A., De León, R.R., Lim, L.L., Lund, M.T., Millar, R.J., Owen, B., Penner, J.E., Pitari, G., Prather, M.J., et al., 2021. The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmos. Environ.* 244, 117834. <https://doi.org/10.1016/j.atmosenv.2020.117834>.
- Lufthansa Group, 2023. Lufthansa Group Annual Report 2022. <https://www.lufthansagroup.com/en/themes/annual-report-2022.html>.
- Martin-Domingo, L., Fernandez, J.B., Efthymiou, M., Ali, M.I., 2025. Extracting airline emission KPIs from sustainability reports using large language models (LLMs). *Transp. Res. Interdiscip. Perspect.* 33, 101599. <https://doi.org/10.1016/j.trp.2025.101599>.
- Miyoshi, C., Mason, K.J., 2013. The damage cost of carbon dioxide emissions produced by passengers on airport surface access: the case of Manchester Airport. *J. Transport Geogr.* 28, 137–143. <https://doi.org/10.1016/j.jtrangeo.2012.12.003>.
- Neureiter, A., Matthes, J., 2023. Comparing the effects of greenwashing claims in environmental airline advertising: perceived greenwashing, brand evaluation, and flight shame. *Int. J. Advert.* 42 (3), 461–487. <https://doi.org/10.1080/02650487.2022.2076510>.
- Neureiter, A., Grosul, Arina, Nemcova, Veronika, Saumer, Melanie, Matthes, J., 2024. No chance to fool young consumers when it comes to the environment: effects of false and compensation claims in airline advertising on perceived greenwashing. *Int. J. Advert.* 1–22. <https://doi.org/10.1080/02650487.2024.2433345>, 0(0).
- Pagoni, I., Psaraki-Kaloutsidi, V., 2017. Calculation of aircraft fuel consumption and CO2 emissions based on path profile estimation by clustering and registration. *Transport. Res. Transport Environ.* 54, 172–190. <https://doi.org/10.1016/j.trd.2017.05.006>.
- Pamukçu, H., Soyertaş Yapıcıoğlu, P., İrfan Yeşilnacar, M., 2023. Investigating the mitigation of greenhouse gas emissions from municipal solid waste management using ant colony algorithm, Monte Carlo simulation and LCA approach in terms of EU Green Deal. *Waste Manag. Bull.* 1 (2), 6–14. <https://doi.org/10.1016/j.wmb.2023.05.001>.
- Peixoto de Mello, F., Macario, R., 2024. Assessing the efficacy of EU greenwashing directive: a study of European airlines' voluntary carbon offset programs. *Journal of the Air Transport Research Society* 3, 100028. <https://doi.org/10.1016/j.jatrs.2024.100028>.
- Ramestein, E., Püzl, H., Alkan-Olsson, J., Frederiksen, P., 2011. Sustainability indicator development—Science or political negotiation? *Ecol. Indic.* 11 (1), 61–70. <https://doi.org/10.1016/j.ecolind.2009.06.009>.
- Ryanair, 2022. Ryanair Group—Aviation with Purpose—Sustainability Report 2022. <https://corporate.ryanair.com/wp-content/uploads/2022/07/Ryanair-2022-Sustainability-Report-Interactive.pdf>.
- Saleh, N.M., Saleh, A.M., Raed, A. Hasan, Keighobadi, J., Ahmed, O.K., Hamad, Z.K., 2024. Analyzing and comparing Global Sustainability Standards: LEED, BREEAM, and PBRS in Green Building arch article topic. *Babylonian Journal of Internet of Things* 2024, 70–78. <https://doi.org/10.58496/BJIoT/2024/009>.
- Seymour, K., Held, M., Georges, G., Boulouchos, K., 2020. Fuel Estimation in Air Transportation: modeling global fuel consumption for commercial aviation. *Transport. Res. Transport Environ.* 88, 102528. <https://doi.org/10.1016/j.trd.2020.102528>.
- Smeets, E., Weterings, R., 1999. Environmental indicators: typology and overview. <https://www.eea.europa.eu/publications/TEC25>.
- Tsoi, B.H.N., Liu, J.C.-E., 2025. Assessing airline communication for voluntary carbon offsets. *Npj Sustainable Mobility and Transport* 2 (1), 1–9. <https://doi.org/10.1038/s44333-025-00027-7>.
- UN, 2016. Paris Agreement—Status of Ratification | UNFCCC. In: <https://unfccc.int/practice/the-paris-agreement/status-of-ratification>.
- US Department of Energy, 2024. Alternative fuels data Center: sustainable aviation fuel. <https://afd.energy.gov/fuels/sustainable-aviation-fuel>.
- WMO, 2022. 2021 one of the seven warmest years on record. WMO Consolidated Data Shows. <https://public.wmo.int/en/media/press-release/2021-one-of-seven-warmest-years-record-wmo-consolidated-data-shows>.
- Yang, A.S., Baasandorj, S., 2017. Exploring CSR and financial performance of full-service and low-cost air carriers. *Finance Res. Lett.* 23, 291–299. <https://doi.org/10.1016/j.frl.2017.05.005>.
- Zieba, M., Johansson, E., 2022. Sustainability reporting in the airline industry: current literature and future research avenues. *Transport. Res. Transport Environ.* 102, 103133. <https://doi.org/10.1016/j.trd.2021.103133>.