Navigating the Fog: An Evaluation of European Airline GHG Emissions Reporting

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Abstract. The Aviation Zero Emission by 2050 (AZERO2050) study systematically evaluates the greenhouse gas (GHG) emissions reporting practices of European airline groups, focusing on both mandatory and voluntary key performance indicators (KPIs) as shaped by evolving regulatory frameworks and the long-term ambition to reach net zero by 2050. By analysing annual and sustainability reports from 16 major airline groups, the research identifies significant progress in the disclosure of core metrics such as Total CO_2 Scope 1 emissions and Emissions Intensity, reflecting growing regulatory alignment and stakeholder expectations. However, the findings also reveal persistent gaps and inconsistencies, particularly in the reporting of Scope 2 and 3 GHG emissions, energy consumption, GHG removals, and emerging metrics related to Sustainable Aviation Fuel (SAF) and non-CO_2 effects—areas critical for tracking progress towards AZERO 2050. The proliferation of voluntary KPIs 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, and greenhushing, where substantive achievements are under-communicated. The study concludes that while regulatory frameworks such as the CSRD, EU ETS, CORSIA, and ReFuelEU are driving improvements, further harmonization and methodological clarity are required to ensure transparency, comparability, and genuine progress toward aviation climate goals.

Keywords: Sustainable Aviation, Airline Emissions Reporting, Sustainability KPIs, Greenwashing, climate change.

1 Introduction

Aviation's contribution to global warming is estimated to be around 2.5% from CO_2 emissions alone, but this figure rises to approximately 4% when non-CO_2 effects are included [1]. Aviation's growing climate impact has placed the sector under increasing scrutiny from policymakers, investors, and the public. Aviation as a highly regulated industry has environmental regulations imposed by the International Civil Aviation

Organization (ICAO) via Annex 16 or and the European Commission (EC). Investors place more emphasis on Environmental, Social, and Governance (ESG) considerations and often penalize airlines that have received ESG sanctions (Agarwal and Efthymiou 2025). The public increasingly exerts environmental pressure on airlines by demanding stronger climate commitments, supporting regulatory action, and favouring carriers that adopt greener practices. In response, the airline industry has adopted an aspiration goal to reach net zero by 2050. At the same time, the European Union (EU) has established legally binding targets for climate neutrality by 2050 through its Green Deal [2]. These ambitions necessitate strict monitoring and transparent reporting of greenhouse gas (GHG) emissions.

Despite regulatory advances, academic literature consistently highlights a persistent lack of standardization in how airlines report their environmental metrics, a challenge first identified over two decades ago [3] that continues to undermine transparency and comparability [4], [5]. Although numerous environmental KPIs exist, there is limited understanding of how they are defined, which are most widely adopted, and whether they genuinely track progress or serve as corporate "greenwashing" tools. This research systematically evaluates the use and misuse of GHG-related KPIs in European airline sustainability reports, aiming to illuminate the gaps and drivers of KPI selection to support a more effective reporting framework.

Finally, this research is part of the Aviation Zero Emission 2050 (AZERO), a project supported by the Marie Skłodowska-Curie Actions (MSCA) programme that assesses airline reduction commitments for achieving net-zero carbon by 2050. It uses an interdisciplinary approach to map greenhouse gas (GHG) key performance indicators (KPIs), evaluate actions taken, and simulate traffic scenarios to estimate the feasibility of reaching this goal in 2030, 2040, and 2050. This advanced simulation method uses real airline emission data and commitments from environmental, social, and governance (ESG) reports.

2 Regulatory Landscape and Reporting Challenges

To support the EU's decarbonization ambitions in aviation, the European Union has enacted the Green Deal and Regulation (EU) 2021/1119, which establish legally binding targets for climate neutrality by 2050 and a milestone to reduce net greenhouse gas (GHG) emissions by at least 55% by 2030 compared to 1990 levels [6]. These aggressive objectives position European aviation at the forefront of regulatory transformation, necessitating strict monitoring, reporting, and verification of emissions [7]. The evolving regulatory landscape—driven by the Green Deal, the Corporate Sustainability Reporting Directive (CSRD), EU Emissions Trading System (EU ETS), and the ReFuelEU initiative—reflects both the sector's substantial climate impact and the EU's commitment to place aviation on a credible pathway to zero emissions. As the sector navigates these requirements, comprehensive and harmonized emissions reporting is vital to ensure progress, comparability, and accountability in meeting Europe's decarbonization targets.

Key European regulations aim to address these issues by mandating specific disclosures. The Corporate Sustainability Reporting Directive (CSRD) expands on previous rules, demanding more detailed and audited sustainability information, including Scope 1 (direct GHG emissions), Scope 2 (indirect GHG emissions from purchased energy), and Scope 3 (all other indirect GHG emissions). The EU Emissions Trading System (EU ETS) is a "cap-and-trade" system that requires airlines to monitor and report their CO_2 emissions for flights within the European Economic Area, with free allowances being phased out by 2026 to incentivize reductions [8], [9]. For international flights, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) provides a global framework for offsetting CO_2 emissions, primarily through carbon credits. Finally, the ReFuelEU Aviation regulation mandates a progressively increasing blend of Sustainable Aviation Fuel (SAF) at EU airports, rising to 70% by 2050 (Breen et al., 2025), and introduces a Flight Emissions Label to enhance passenger information.

Environmental indicators are essential for consolidating complex data into objective insights, but their effectiveness is shaped by both scientific knowledge and political norm-setting [10], [11]. The credibility of these indicators is threatened by two key issues: greenwashing and greenhushing. Greenwashing involves the overstatement or misrepresentation of environmental achievements through exaggerated or vague claims, particularly around measures like carbon offsetting, which the EU has criticized [12], [13]. Conversely, Greenhushing is the deliberate under-communication of sustainability achievements to avoid scrutiny or accusations of hypocrisy [14]. Airlines are susceptible to both; for instance, they may highlight improvements in "emissions intensity" (emissions per passenger-kilometre) while their total emissions increase due to traffic growth, creating a misleading narrative of progress [10]. Moreover, the lack of standardization in the reporting poses significant challenges for an efficient assessment of the environmental KPIs [15].

3 Methodology

The methodology involved three primary steps. First, a comprehensive list of mandatory environmental KPIs was identified by reviewing key EU regulations, including the CSRD, EUETS, CORSIA, and ReFuelEU (Table1). Each KPI was documented with its name, unit, and effective date.

Second, a sample of 16 airline groups was created by narrowing down a list of European IATA members and cross-referencing with Eurocontrol data to include major non-IATA carriers, ensuring broad market representation (Table 2). Reports were then collected from their investor relations websites.

Table 1. Mandatory airlines GHG emissions related KPIs for airline operating in the EEA, UK and CH (Authors based on ESG, EU-ETS, CORSIA and ReFuelEU regulation).

ID	KPI name	Unit	Scheme	Regulation	Type
1	Total CO_2 Scope 1	tonnes of CO_2	EU-ETS	Reg. (EU) 2018/2066	M
2	Total EU-ETS CO_2 Scope 1	tonnes of CO_2	EU-ETS	Reg. (EU) 2018/2066	M
3	Domestic EU-ETS CO_2 Scope 1	tonnes of CO_2	EU-ETS	Reg. (EU) 2018/2066	M
4	Total CORSIA CO_2 Scope 1	tonnes of CO_2	EU-ETS CORSIA	Reg. (EU) 2019/1603	M
5	Scope 1 GHG	tonnes CO_2e	CSRD / ESG	Reg. (EU) 2023/2772	M 1.1.24
6	Scope 2 GHG	tonnes CO_2e	CSRD / ESG	Reg. (EU) 2023/2772	M 1.1.24
7	Scope 3 GHG	tonnes CO_2e	CSRD / ESG	Reg. (EU) 2023/2772	M 1.1.24
8	Total Scop1, 2, 3	tonnes CO_2e	CSRD / ESG	Reg. (EU) 2023/2772	M 1.1.24
9	Energy	MWh	CSRD / ESG	Reg. (EU) 2023/2772	M 1.1.24
10	Energy intensity		CSRD / ESG	Reg. (EU) 2023/2772	M 1.1.24
11	Emissions Intensity	g of CO_2 / RPK	EU-ETS	Reg. (EU) 2018/2066	M
12	GHG removals	tons CO_2e	CSRD / ESG	Reg. (EU) 2023/2772	M 1.1.24
13	Total Non-CO_2	tonnes non-CO_2	EU-ETS	Reg. (EU) 2023/958	M 1.1.25
14	Total of CO_2 per flight	tonnes of CO_2e	EU-ETS	Reg. (EU) 2023/958	M 1.1.27
15	CO_2 per State	Tonnes	EU-ETS	Reg. (EU) 2018/2066	M
16	SAF CO_2	tonnes of CO_2	ReFuelEU	Reg. (EU) 2023/2405	M 1.1.25
17	CO_2 offsetting	tonnes of CO_2	CORSIA	Reg. (EU) 2024/1879	M
18	Emissions per net revenue	grams / Euro	CSRD / ESG	Reg. (EU) 2023/2772	M 1.1.24

Table 2. Listed European airlines groups from EEA (i.e. EU27, Iceland, Liechtenstein and Norway), the UK and Switzerland

ID	Airline Group	# of Airlines	ASK* (mill.)	ID	Airline Group	# of airlines	ASK* (mill.}
1	Aegean	2	20,434	9	Jet2 plc	1	19,730
2	Air Baltic	1	10,781	10	Lufthansa	7	300,582
3	AF-KLM	3	309,563	11	Norse	1	8,672
4	Croatian	1	1,991	12	Norwegian	1	32,322
5	easyJet	1	113,334	13	Ryanair	3	255,576
6	Finnair	1	36,154	14	SAS	1	42,566
7	IAG	5	323,111	15	Tui	1	76,100
8	Icelandair	1	15,666	16	Wizzair	1	121,749

* Note: ASK stands for Available Seat Kilometre

Third, a peer review was done by two experts independently extracted all GHG emissions-related KPIs from the reports, resolving any discrepancies through joint review. Each extracted KPI was subsequently classified as "mandatory" or "non-mandatory" based on the list generated in the first step to ensure systematic analysis.

4 Results and Discussion

The analysis yielded a list of 18 mandatory environmental KPIs (Table 1) that European airlines are required to report under current and forthcoming regulations, covering a broad range of metrics from direct CO_2 emissions to energy consumption and SAF lifecycle emissions. However, the reporting practices of the 16 airline groups revealed significant variability with values ranging from a high of 94% to a low of 6% (Table 3). Disclosure was high for well-established, core metrics but poor for newer and more complex ones. The findings highlight a clear divide, with Total CO_2 Scope 1 emissions and Emissions Intensity being the most widely disclosed KPIs, reported by 94% and 88% of airlines, respectively. This reflects strong alignment with long-standing regulatory requirements and stakeholder expectations.

Table 3. Reporting Rates for Key Mandatory KPIs in 2023

KPI Short Name	Reporting Rate	KPI Short Name	Reporting Rate
Total CO_2 Scope 1	94%	GHG Removals	38%
Emissions Intensity	88%	Domestic CO_2 Scope 1	13%
Scope 2 GHG	56%	SAF CO_2	19%
Scope 3 GHG	44%	Total non-CO_2	38%
Energy	25%	CO_2 Offsetting	6%

In stark contrast, reporting rates for other critical areas were significantly lower. Scope 2 and Scope 3 emissions were reported by only 56% and 44% of airlines, respectively, representing a major gap, as Scope 3 emissions are a substantial part of an airline's total carbon footprint. KPIs related to Sustainable Aviation Fuel (SAF), non-CO_2 emissions, and offsetting were seldom reported, with disclosure rates ranging from just 6% to 38%. This may reflect the novelty of the regulations, data availability challenges, or a strategic delay in implementation. Furthermore, the study found a proliferation of non-mandatory, or voluntary, KPIs. While these can indicate a willingness to go beyond compliance, their lack of standardized definitions and methodologies makes them difficult to compare, undermining transparency and making it challenging for stakeholders to benchmark performance and assess the sector's genuine progress toward decarbonisation.

5 Conclusions

This study confirms that while European airlines are making progress in reporting core GHG emissions metrics, significant gaps and inconsistencies persist. Regulatory frameworks like the CSRD and ReFuelEU are clearly driving improvements, but the industry lags in disclosing crucial information on Scope 2 and 3 emissions, SAF usage, and non-CO_2 effects, all of which are critical for achieving net-zero emissions by 2050. The high reporting rates for Scope 1 CO_2 and emissions intensity are positive signs, but the low rates for other mandatory KPIs point to ongoing challenges in data collection and methodological standardization. The wide variety of voluntary KPIs further complicates the landscape, creating risks of greenwashing and making true comparability difficult. To ensure transparent and credible progress toward the industry's climate goals, further harmonization of reporting standards is essential. Regulators, airlines, and other stakeholders must collaborate to establish clear definitions and consistent methodologies for all material KPIs.

6 Limitations and Future Research

This study has some limitations. First, the analysis relies on publicly available, self-reported data, which may contain inconsistencies in scope, definition, and calculation methods. Second, quantitative analysis is restricted to descriptive statistics, which, while appropriate for mapping current disclosure practices, does not allow for deeper statistical testing of relationships between reporting behaviour and airline characteristics. Third, the sample focuses on 16 major European airline groups, which limits the generalizability of findings to airlines operating under different regulatory regimes globally. Fourth, the cross-sectional design provides a snapshot of 2023 reporting practices, making it difficult to track how disclosure evolves over time as regulations such as CSRD, EU ETS, CORSIA, and ReFuelEU mature.

Future research should address these limitations through longitudinal studies tracking reporting maturation as mandatory frameworks take full effect, comparative analyses across global regions to assess whether European patterns are unique or reflect

broader industry trends, and more advanced quantitative approaches examining the drivers of KPI adoption and disclosure quality. Additionally, these limitations are partially addressed in subsequent work by [16], which extends this analysis by providing quantitative evidence of reporting progress, compliance patterns, and the challenges European airlines face in meeting evolving sustainability disclosure requirements, offering stronger stakeholder implications and policy recommendations for harmonizing airline GHG reporting standards.

7 Declaration of Interest Statement

This research was 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.

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