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Faculty of Business Economics

Master of Management

Master's thesis

Challenges of SAF production under the requirements of the ReFuelEU aviation initiative

IBETH VERONICA DIAZ TAPIA

Thesis presented in fulfillment of the requirements for the degree of Master of Management, specialization Data Science

SUPERVISOR :
dr. Sumit MAHARJAN

MENTOR :
dr. Alessandro MARTULLI

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PREFACE

This thesis marks the completion of my Master’s in Management specialization in Data Science at Hasselt University. The research focus on the aviation industry's shift towards sustainability and specifically investigates the utilization of Sustainable Aviation Fuels (SAF) by the five prominent European airlines, referred to as the "Big 5," within the regulatory structure of the European Union's Refuel EU Aviation Initiative.

Throughout my career, I have found myself captivated by the interaction between technological progress and environmental effect, particularly in the area of aviation. In order to combine my passion for aviation and my commitment to sustainability, I decided to focus my research efforts in this field. The pressing need to decrease Co2 emissions and embrace sustainable methods in aviation has driven me to thoroughly explore this topic.

During my research journey, I have been fortunate to receive invaluable support and direction from a variety of individuals and organizations. I am truly thankful for the exceptional guidance, valuable feedback, and constant encouragement provided by my promotor, Dr. Sumit Maharjan and supervisor, Dr, Alessandro Martulli, which have been crucial in shaping this thesis and navigating the complexities of the subject matter. It has been their continuous support that has motivated me to accomplish this thesis, and I am thankful for their devotion and diligence in assisting me along the way.

It is also my pleasure to express my deepest gratitude to my beloved parents, siblings, friends, and peers who have continuously supported me, provided valuable feedback, and taken time to review my work. Your combined efforts have been crucial in helping me attain my objectives. In addition, I would like to express my gratitude to the University of Hasselt for providing me with the essential resources, amenities, and academic environment that encouraged a culture of learning and exploration.

Finally, I would like to thank everyone who contributed to the success of this thesis. This incredible adventure would not have been possible without them. This study not only signifies the end of my master's program but also acts as a foundation for a career committed to promoting sustainability in the aviation sector.

SUMMARY

The aviation industry is encountering significant obstacles due to its notable environmental impact, especially in light of the growing urgency to tackle climate change and lessen CO_2 emissions (A4E, 2023b; Eurocontrol, 2022c). There are three probable future scenarios with varying development patterns (low, base, and high scenario). Regardless of the scenario, the projection suggests that flights will continue to be the leading source of CO_2 emissions, surpassing those of other modes of transportation at an unprecedented rate. Among all strategies to reduce CO_2, SAF will have the strongest impact on making the net zero achievable in all scenarios. In late 2023, the EU enacted the ReFuelEU Aviation legislation, mandating a gradual increase in SAF, starting at 2% in 2025 and reaching 70% by 2050 (EUROCONTROL 2021). The change means that airlines need to adapt to this new Initiative. This thesis explores *a comprehensive analysis of the strategies and barriers faced by 'the big 5'(Air France-KLM, EasyJet, International Airlines Group (IAG), Lufthansa Group (LG), and Ryanair) air companies in adopting sustainable aviation fuels (SAF) under the Refuel EU regulation.*

The study utilized a thorough theoretical framework, which involved a detailed investigation of the airline industry within the managerial environment. SAF andexplored environmental issues and sustainability challenges, examined the influence of aviation on climate change, assessed aviation emissions in Europe, predicted CO_2 emissions for 2050 in the EU, highlighted the importance of SAF, and examined the tactics and obstacles for the leading aviation firms.

The information was gathered through secondary data from various sources, including document analysis, literature review, policy and regulation examination, podcast listening, and database usage. This thesis involved comprehensive qualitative analysis and scrutiny using the qualitative multi-case study method.

A thorough analysis of each airline was conducted, followed by developing comparative strategies and identifying obstacles. The focus was on five prominent European airlines integrating SAF, examining their roadmap to net zero by 2050. This involved a deep dive into their strategies, which encompassed SAF integration, investment in new technologies and fleet modernization, operational efficiency in air traffic management, and investment in economic strategies. Additionally, the challenges associated with integrating SAF were also analysed.

The discovery emphasizes the leading "Big 5" airlines in Europe, which have historically initiated pilot projects and gradually increased the usage of SAF in response to regulatory and public pressures. Presently, these airlines are focused on enhancing operational efficiencies, modernizing their fleets, and ensuring a steady supply of reliable SAF. Their future objectives encompass substantial CO_2 reduction targets to achieve net-zero emissions by 2050. Nonetheless, challenges such as high production costs, regulatory policies, technology expenses, limited capacity, infrastructure requirement and the availability of sustainable feedstocks continue to persist. Strategies such as forging strategic partnerships, exploring alternative feedstocks, and advocating for regulatory support are being pursued to address these challenges. Each airline is committed to investing in new technologies and infrastructure to bolster fuel

efficiency and sustainability.

The study's ultimate implication is that the critical role of strategic management will determine the aviation sector's future. This includes forming tactical partnerships, actively engaging with regulatory bodies, implementing diversification strategies to mitigate risks, and making significant investments in innovation and integrating new technologies.

The thesis highlights the limitations, such as biases in secondary data, which could present an overly optimistic picture of the aviation industry's sustainability initiatives. As a result, future research should consider expanding its scope to encompass smaller and non-European airlines to obtain a more thorough understanding of the challenges and strategies related to SAF integration. This may involve conducting primary research, such as interviewing industry executives and exploring consumer attitudes toward paying for more environmentally friendly travel options. Furthermore, it is important to conduct thorough, extended studies to monitor the impact of incorporating SAF into the ‘Big 5’ over long periods, including assessing the viability of non-drop-alternatives like green hydrogen. This research would offer insights into SAF's long-term sustainability, environmental advantages, and its potential to decrease carbon emissions. It would also assess whether these airlines, after adopting SAF, maintain their position as Europe's top five airlines.

CONTENTS

CHAPTER 1 INTRODUCTION

The aviation sector is an economic facilitator, supporting investment, tourism, trade, and job development throughout Europe, particularly in distant and peripheral locations. In all, aviation supports an estimated 13.5 million employment and contributes €886 billion (4.4%) to European Economy (A4E, 2023b; Eurocontrol, 2022c)

In January 2020, France reported the first COVID-19 case in Europe, bringing the entire industry to an unprecedented crisis level. Following the World Health Organization's proclamation of a global pandemic on March 11, 2020, numerous governments-imposed travel restrictions worldwide to slow the spread of illnesses. These actions resulted in a large fall in flight numbers, producing a rapid and severe impact on the income stream of the whole aviation business. The International Civil Aviation Organization (ICAO) estimated a 60% drop worldwide in 2020, creating significant problems for the air transportation industry. Europe, in particular, was hit worse than other areas, causing numerous nations to provide financial assistance to their individual airlines. (Air Traffic Organization of the FAA, 2021)

Research indicated that traditional scheduled airlines and low-cost carriers, who account for most of the European air traffic, were severely impacted, with a 62% fall in traffic compared to 2019. In the following year, business aviation in Europe fell by 24.4% in 2020 compared to the previous year, demonstrating a lower impact on the second wave due to the virus. As the globe dealt with the severe shock of the pandemic in 2020, aviation traffic gradually recovered in the years that followed. By the end of 2022, Europe's total recovery rate had reached 83% of pre-pandemic levels, indicating a favourable trajectory in the steady return of the aviation sector (Air Traffic Organization of the FAA, 2021; Eurocontrol, 2023)

Despite the short-term setbacks inflicted by the COVID-19 crisis, the airline industry is anticipated to witness substantial progress in the coming decades, with estimates ranging from 3% to 5% annual growth and even though the pandemic is shaking the foundations of the aviation industry, the industry is in the midst of another crisis that might severely affect the industry in the following decades: the climate crisis. Global warming is no longer a distant concern; it demands urgent attention from all quarters (EUROCONTROL 2021).

The burning of fossil fuels in airplane engines is responsible for around 2-3% of worldwide greenhouse gas emissions (GHG) (Eurocontrol, 2022a). The aviation sector contributes 3.7-4.7% of total GHG emissions in the European Union (EU), making it the second-largest contributor to transportation emissions after road transport. Between 2013 and 2019, GHG emissions from commercial aircraft in the EU increased by 30% (Tiseo I., 2020), hitting all-time highs before collapsing due to the COVID-19 epidemic (Air Traffic Organization of the FAA, 2021).

Despite a 57% drop in CO_2 emissions in 2020 due to fewer flights, emissions increased as traffic recovered. CO_2 emissions climbed by 57% in 2022, exceeding traffic recovery but remaining 19% lower than in 2019 (Eurocontrol, 2022a). During that time Ryanair was the most polluting airline followed by EasyJet (UK), Lufthansa, British Airways, and Air France until 2021 based on verified emissions covered by the European Union Emissions Trading Scheme (EU ETS) (Tiseo I., 2023).

Furthermore, Aviation is one of the most challenging sectors to achieve greenhouse gas emissions (GHG) reductions. The EU, a major worldwide aviation emitter, faces a projected rise in intra-EU flights of more than 80% by 2030 compared to 2005 levels. Without action, emissions might increase by up to 300% by 2050. In response, the European Commission (EC) has set strict emission reduction objectives in its Regulation (EU) 2021/1119, with the goal of reducing CO2 emissions from aviation by 80% by 2050 as compared to typical fossil jet fuel. The 'Fit for 55' project has an intermediate objective of reducing net GHG emissions by 55% by 2030. (Pang&Chen, 2023).

Addressing climate change necessitates novel approaches, with Sustainable Aviation Fuel (SAF) emerging as a possible drop-in substitute. According to Eurocontrol Aviation Outlook 2050, SAF will be the greatest contributor to net-zero emissions by 2050, followed by Market-Based Measures, aircraft technology, and Air Traffic Management. SAF not only decreases the overall GHG emissions but also pollutants, resulting in significant reductions in Sulphur dioxide and particulate matter emissions (Eurocontrol, 2022a). Despite this, SAF production is energy and cost intensive and lacks competition with conventional fuel: blending SAF with fossil fuels or switching to it only helps decarbonize aviation if this is produced entirely from renewable sources. A major consequence of this will be an increase in (sustainable) energy consumption for aviation by 2050, it also creates competition among airline industries seeking to decarbonize (Eurocontrol, 2022a; Pang&Chen, 2023).

While adopting SAF strategically is viewed as a critical step in attaining climate objectives in the aviation sector, there are worries about the execution of rules requiring airlines to utilize more sustainable fuels. European airlines, represented by Airlines for Europe (A4E), express concern about the potential impact of sustainable fuel objectives, including ticket hikes (Payne 2023). Furthermore, the five major European airline firms —International Airlines Group (IAG), Air France-KLM, EasyJet, Lufthansa Group, and Ryanair—who account for more than 70% of European air traffic, are concerned that the age of low-cost flights in Europe is coming to an end (Orban A., 2016). A study by Pricewaterhouse Coopers Germany affirms that flying sustainably in the future may come at a higher cost (Welle D., 2023). Willie Wash, director of the International Air Transportation, said that the 'Customer will end up footing the bill in airfare prices' (Palazzo A., 2023). Moreover, Ryanair CEO Michael O'Leary, is concerned about what impact the proliferation of SAF usage might have on food prices in the future. However, despite this concern, Ryanair has set itself an ambitious goal of using 12.5% SAF by 2030 (Plucinska & Payne, 2023; Ryanair, 2023).

SAF has the potential to reduce CO2 emissions significantly, residual effects remain (Eurocontrol, 2021b). The work on SAF is only getting started, and policymakers will need to create a favorable regulatory and investment climate for Europe's SAF sector to guarantee inexpensive sustainable fuels flow and place European aviation on a more sustainable path. Otherwise, the implementation of the “Fit 55 package” will affect consumers in price rises as sustainable techniques grow increasingly expensive (A4E 2023).

This requires a critical examination of historical, current, and future initiatives undertaken to incorporate sustainable aviation fuel by the Big Five airlines in Europe in response to the Regulation (EU) 2021/1119. This analysis aims to understand the future impact of the regulation on these airlines. Although there are signs of early efforts, information is still dispersed, and a thorough investigation is required. This research will be conducted by employing a qualitative approach with an extensive document analysis and conducting a comparative analysis of SAF adoption strategies among the big 5 airlines in Europe.

1.1 RESEARCH QUESTION

QUESTION RESEARCH: How have the major European airlines, collectively known as the "Big 5," historically, currently, and in their future plans, implemented Sustainable Aviation Fuels (SAF) in response to environmental issues under the mandates of the Refuel EU initiative?

Sub-questions:

- How have these airlines been implementing sustainable aviation fuel, and meeting global climate targets?
- How does the Refuel EU Aviation Initiative's SAF trajectory affect the major five European airlines, including potential obstacles they face in adopting SAFs, and what initiatives do they have set up to address this challenge?

CHAPTER 2 LITERATURE REVIEW

This study of the literature digs into Sustainable Aviation Fuel (SAF) and the different issues impacting the aviation sector, as well as potential solutions due to the Refuel Eu Aviation initiative. The aviation industry has significant economic power, influencing businesses such as aircraft production and tourism. Despite its critical role, attaining sustainability in aviation is a substantial problem, raising worries about reconciling environmental and financial sustainability. Striking a precise balance between these factors makes the aviation sector one of the most difficult to decarbonize (Abdi 2021).

In this chapter, we will look at the origin of the problem and future solutions affecting aviation in Europe. In addition, we will explore potential limitations, providing readers with a thorough assessment of the possible economic impact on European airlines.

2.1 AVIATION INDUSTRY AND ECONOMIC CONTEXT

In 1914, the first commercial airlines took off from the Municipal Pier in St. Petersburg, launching a new era in aviation (Morrison & Winston., 1995). Air transportation has played an essential role in connecting the world more efficiently. Between 1950 and 2020, air passenger and freight traffic experienced growth that consistently surpassed gross world product (GDP) (Dr. Jean-Paul Rodrigue, 2020).

During the 1960s, the air industry witnessed significant growth, with annual increases in passenger and freight volumes typically ranging from 10%-20%. The introduction of the Boeing 747 in 1970 revolutionised air travel, making it more accessible and efficient, resulting in a substantial 31.1% increase in passenger kms. Furthermore, the industry has faced many challenges throughout its history. Economic and geopolitical events have caused significant declines in growth, such as the Arab oil embargo in 1973, the Gulf War recessions of the 80s and 90s, and the Asian Financial Crisis in 1997. The aftermath of September 11, 2001, marked another instance of negative growth, with a similar decline in 2009 following the global financial crisis. However, the COVID-19 pandemic has had the most significant impact on the industry (Dr. Jean-Paul Rodrigue, 2020).

The International Civil Aviation Organization (ICAO) calculated a 60% decline in global flight (domestic and international air travel) capacity in 2020, providing substantial issues for the aviation industry, as we see in figure 1. The pandemic circumstances slow the global economy, which has a significant impact on air transport, since the demand for air transport services is heavily influenced by Gross Domestic Product (GDP) (Drljaca & et al, 2020). It has affected passenger and freight activities differently, leading to a loss of 57 million passengers. The freight activity remained relatively stable, highlighting the unique impact of the pandemic compared to previous crisis (Dr. Jean-Paul Rodrigue, 2020).

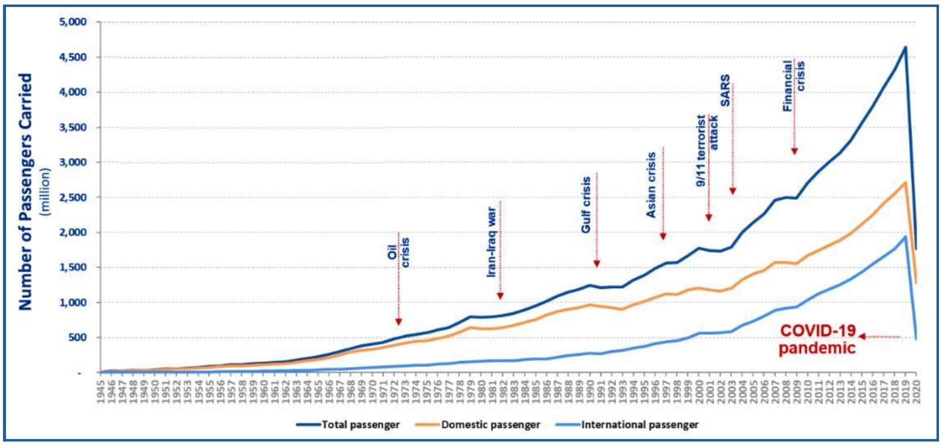


Figure 1 World passenger traffic evolution, 1945 – 2020.
Note: the graph shows domestic and international air travel worldwide evolution from 1945- 2020.
Source: Air Traffic Organization of the FAA, E. (2021).

Furthermore, the above graph (Figure 1) shows that COVID-19 had a greater impact on demand comparing with other crises or disruptions of the past. The large drop in air transport may be traced mostly to cross-border travel restrictions imposed by countries to combat the spread of the virus (Drljaca & et al, 2020).

2.1.2 AVIATION INDUSTRY IN EUROPE

Aviation has contributed to the economy, supporting investment, tourism, commerce, and job development throughout Europe, particularly in rural and peripheral locations. In terms of traffic evolution, Europe increased over time by 1.5 million flights to reach a peak in 2019 (Air Traffic Organization of the FAA 2021). It can be seen from figure 3 that air travel demand follows economic cycles of growth and decline from year to year. In addition, the figure shows a slowdown in economic growth rates, a trend which has also been observed in flight growth. However, it is evident from the graph that the correlation between flight and economic growth in 2020 and 2021 is distorted, but in future years the relationship is likely to be restored (Eurocontrol, 2022d).

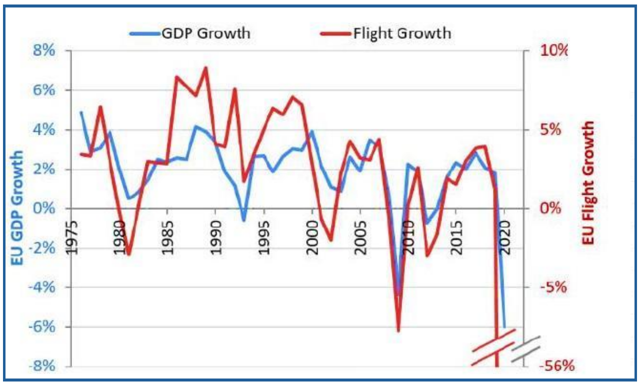


Figure 2 Correlation between IFR flights growth and GDP growth in Europe (1975-2020).
Note: The graph shows Correlation between IFR (Instrument Flight Rules) flights growth (red line) and GDP growth (blue line) in Europe between 1975 to 2020.
Source: EUROCONTROL. (2022).

A major influence on the growth of air travel demand over the long term will continue to be economic growth (measured by GDP) which can continue to affect the demand for air travel in the long run**.** The most recent report from ACI EUROPE (Airport Council International) states that air transport, directly and indirectly, supports an estimated 13.5 million employment and contributes €886 billion in European economy Activity (4.4% of GPD) (A4E, 2023b; Eurocontrol, 2022c).

The airline sector experienced unprecedented worldwide hurdles in 2020 as a result of the adoption of precautionary travel restrictions in reaction to the COVID-19 pandemic. The damage was particularly severe in Europe. The first case in Europe, reported in France in January 2020, signalled widespread infections. Consequently, on March 11, 2020, the World Health Organization declared a global pandemic. Governments throughout the world quickly enacted travel restrictions, causing a huge drop in air travel demand. In addition, the European Council agreed to impose travel restrictions on March 17, 2020. Figure 3 depicts an overall traffic evolution thought the 7-day moving average of daily flights in Europe, including the percentage recovery compared to 2019, from 2019 to 2023.

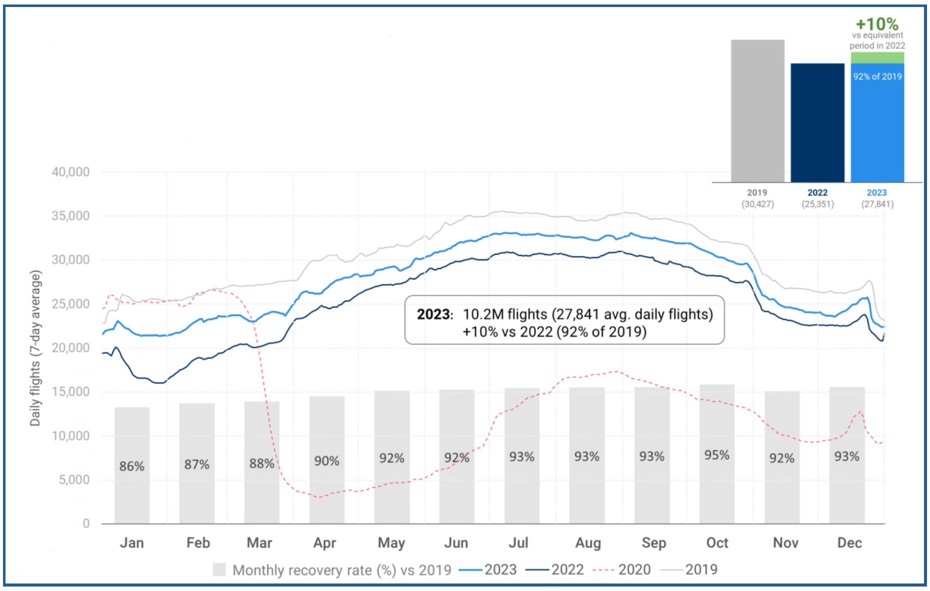


Figure 3 Overall traffic evolution In Europe.

Note: The graph shows Traffic and percentage increase flight increase in Europe (7-day average).
Source: EUROCONTROL. (2024).

The number of new COVID-19 cases increased and decreased in waves. As show in the previous Figure, European flights began to rise in the summer of 2020, but fell again in September owing to changes in airline schedules in reaction to the pandemic's second wave. In October 2020, the resurgence of COVID-19 caused cases to increase dramatically, and EU states tightened travel restrictions, causing traffic in Europe to decrease again with only a slight increase during the holiday season (EUROCONTROL, 2024). The crisis led to exceptional cost-cutting measures by EU airlines, and some were recapitalized, nationalized, and obtained loans and government guarantees from the government. Some of this assistance was conditional on environmental measures like emission reductions and the prospective phase-out of short-haul flights that may be replaced by train travel (Air Traffic Organization of the FAA 2021).

Based on the Figure 3, we can compare the evolution of traffic between 2019 and 2023. The following years in Europe showed a steady increase in traffic despite a considerable decrease during 2020. Aviation traffic gradually rebounded in the years that followed (Air Traffic Organization of the FAA 2021, EUROCONTROL 2023). By the end of 2023, Europe's entire recovery rate had reached 92% of pre-pandemic levels and 10% plus equivalent to the previous year, suggesting a positive trend in the gradual comeback of the aviation sector (EUROCONTROL, 2024)

However, the aviation sector is expected to increase an average annual rise of 1.2% per year in the future decades (Eurocontrol, 2022b) The graph 4 depicts three probable future scenarios with varying development patterns: low, base, and high scenarios.

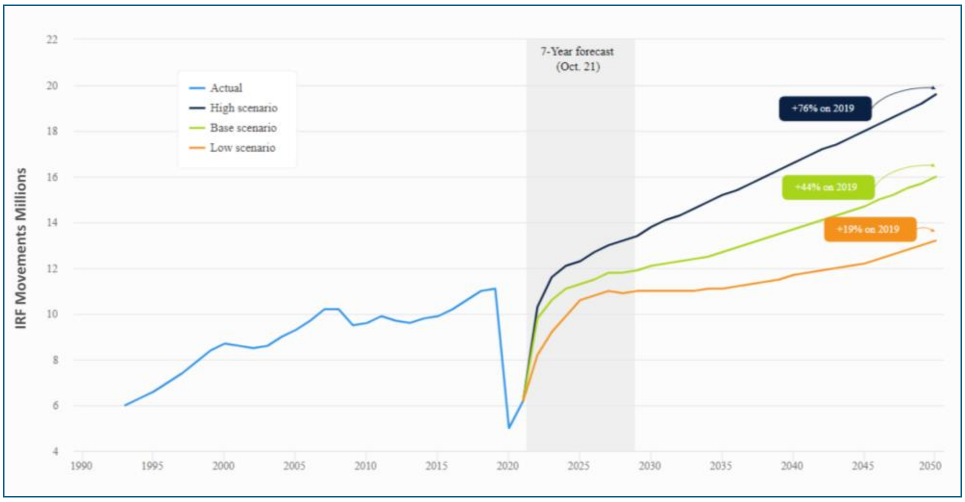


Figure 4 Flight forecast for Europe between 2019 and 2050
Source: EUROCONTROL. (2022).

The most likely scenario is the base scenario expects modest economic growth and regulatory measures aimed at environmental, social, and economic sustainability. In Table 1 and Figure 4 show that there are expected to be 16 million flights in 2050, a 44% increase over 2019. The scenario incorporates a phased blending obligation for SAF beginning in 2035. While travel expenses may rise, the desire for air travel will remain. The COVID-19 outbreak causes delayed initial growth compared to the previous long-term traffic forecast (EUROCONTROL 2018 "Challenges to Growth" report) where was expected to pass the 16 million flights bar in 2024 (Eurocontrol, 2022d).

ECAC (European Civil Aviation Conference)	**IFR Flight**						
	2019		2050			2050/20219	
	Total (Million)	AVG. Daily (Thousands)	Total (Million)	AVG. Daily (Thousands)	Extra Flights/day (Thousands)	Total Growth	Average Annual Growth
High Scenario	11.1	30.4	19.6	53.6	23.2	+76%	+1.8%
Base Scenario			16.0	43.7	13.4	+44%	+1.2%
Low scenario			13.2	36.2	5.8	+19%	+0.6%

Table 1 Flight Forecast for Europe, with total growth between 2019 and 2050.
Note: The table shows the Flight forecast for Europe, with total growth between 2019 and 2050.
Source: EUROCONTROL. (2022).

In the low scenario, various factors impede the growth of air traffic. Higher fuel prices, SAF, and CO2 allowances add to travel costs, while slower economic growth weakens flight demand. Thus, the aviation industry is unable to invest in fleet renewal, resulting in delayed groundbreaking projects. Air travel companies need to adjust to environmental and trade limitations by adopting a more inward-looking approach. European tourists are expected to travel and consume more regionally. This forecast assumes of high energy costs and a potential economic recession over the next 30 years. Table 1 and Figure 4 demonstrated that flight growth is gradual, reaching 13.2

million flights by 2050, representing a 19% increase from 2019, with an average annual growth (AAGR) of 0.6%. It is predicted that the economy will fully recover by 2034, followed by a slow growth rate of 1.2% over the next 15 years (Eurocontrol, 2022d).

The High scenario predicts high increase in air travel, fuelled by strong global economic expansion and major investments in sustainable aviation technology. This optimistic view anticipates continued economic development, a strong preference for air travel, and relatively low pricing for both SAF and conventional fuel. Between 2030 and 2050, several new fleet projects are launched, including electric, hybrid-electric, and hydrogen-powered aircraft. The scenario as we see in Figure 4 and Table 1 predicts 19.6 million flights in Europe by 2050, a significant 76% increase from 2019, with an average annual growth rate of 1.8%. The initial years (2019-2034) show a greater growth rate of 2%, whereas the latter years (2035-2050) see a decrease to 1.7% per year. This slowdown is due to reasons such as market maturity, the introduction of bigger aircraft, and airport capacity limits (EUROCONTROL 2021).

Regardless of the scenario analysed, the projection suggests that flights will continue to be the leading source of CO2 emissions, surpassing those of other modes of transportation at an unprecedented rate (EUROCONTROL 2021).

2.1.2 ENVIRONMENTAL CONCERNS AND SUSTAINABILITY CHALLENGES

Climate change poses a serious and perhaps permanent threat to human cultures and the planet. In awareness of this, most nations ratified the Paris Agreement in December 2015, with the fundamental goal of limiting global temperature rise to 1.5°C (IPCC., 2023). The influence of human beings on the climate has been causing the global average surface temperature to increase by 0.85°C between 1880 and 2012, which represents a significant contribution to the observed warming since the mid-20th century. The warming has already reached greater regional-scale dimensions in many parts of the world, with over 1.5°C. As a result of the increase in temperatures thus far, we have already seen profound alterations to human and natural systems, such as droughts, floods, and other types of extreme weather, sea level rise, and the loss of biodiversity. There are several unprecedented risks associated with these changes, which pose a threat to vulnerable people and populations. The consequences of global warming are likely to affect numerous ecosystems worldwide, especially tropical reefs with warm waters and polar ice caps (IPCC, 2018).

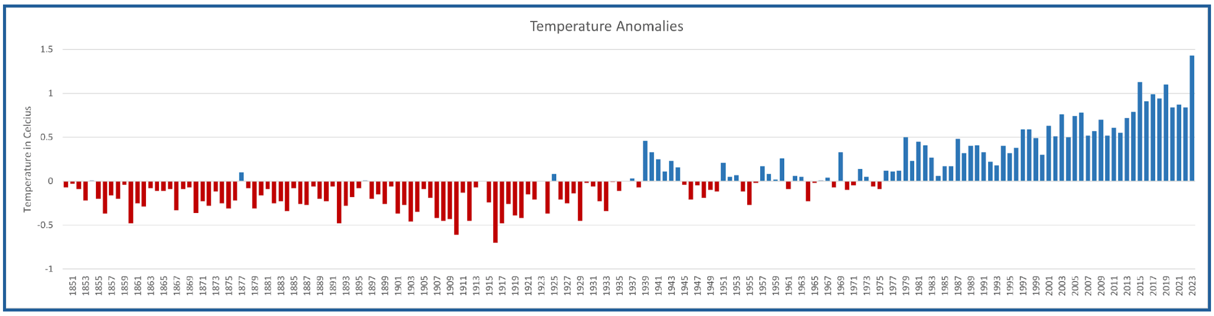


Figure 5 Temperatures anomalies worldwide.

Note: The Graph shows Global Land and Ocean December Temperature Anomalies (1850-2023).

Source: NOAA. (2024)

Figure 5 shows that the Earth's temperature has risen about 1.5° C since 1850, an average increase of 0.06° Celsius per decade. Global warming has been highly attributed to human activities, particularly through emissions of GHG. Figure 5 also shows the global surface temperature has increased by 1.1°C in the period 2011-2020, which is the highest on record. As a result of global warming, 2023 was the warmest year since global records began. In fact, the temperature was 1.18°C warmer than it was in the 20th century. The ten (2014-2023) hottest years on record have all occurred during the last decade of the 174-year period. (NOAA, 2024).

The total emissions of GHGs are steadily increasing, nearing the critical threshold of 1.5°C for global warming (meaning a world limited to 1.5°C warming relative to pre-industrial levels). The rise of temperatures poses a serious threat to human health, climate patterns, and biodiversity, with mounting concerns following every incremental increase (IPCC, 2018). Annex 1 shows the temperature increases and repercussions for the planet at +1.5°C, +2°C, +3°C, and +4°C. The picture depicts variances in temperature levels and their accompanying consequences:

a) The first forecast focuses on the change in annual maximum daily temperature, which is measured in degrees Celsius. This gives insight into how the peak daily temperatures are likely to fluctuate over time.

b) The second projection includes calculating the change in annual mean total column soil moisture, given in standard deviation (a statistical metric that reflects the level of variability from the average), throughout the historical period of 1850-1900. In this setting, it is conceivable to see big positive relative changes in arid locations, yet they may correlate to minor absolute changes.

c) The third forecast, is the change in annual maximum 1-day precipitation, represented as a percentage. This represents the projected change in the highest quantity of precipitation that falls in a single day. As global warming increments, regional changes in both average climate conditions and extreme weather events become more extensive and pronounced. In order to tackle climate change, global GHG emissions must be reduced dramatically, quickly, and permanently (IPCC., 2023).

Based on current implemented policies, Figure 6 represents projected emissions until 2100, with percentile bars indicating the range of uncertainty (25-75% and 5-95%). In this projection, emissions will lead to a warming of 3.2°C, which ranges from 2.2°C to 3.5°C (medium confidence) by 2100 (Kaupa C., 2023). That is why sustainability has evolved as a critical concern in politics, economics, and society, in order to stay below the 1.5-2°C warming threshold mandated by the Paris Agreement, deep reductions in GHG emissions are essential in this decade. By 2030, it is estimated that emissions need to be reduced by -45% (from 2019 levels) (Eurocontrol, 2022a). The range of Nationally Determined Contributions (NDCs) in 2030 indicates that if current contributions are implemented, emissions will fall within a range that partially overlaps the band of policies implemented and exceeds the range needed to limit global warming to 2°C. There is more than a 50% probability that global warming will not exceed 1.5°C with the green band, and there is little to no chance of the warming exceeding 2°C with the blue band.

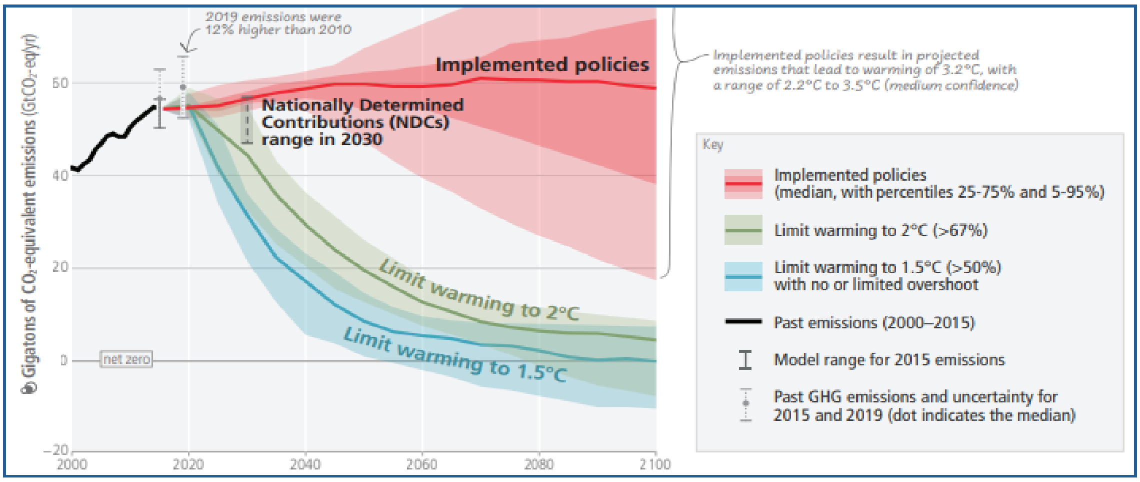


Figure 6 Net Global greenhouse gas (GHG) emissions.

Note: The graph shows Net Global greenhouse gas (GHG) emissions Limiting warming to 1.5°C and 2°C.
Source: IPCC. (2023).

2.3 AVIATION AND CLIMATE CHANGE

Aviation accounts for around 3.5% of global warming or 2.5% of CO2 global emissions and will be one of the most challenging industries to tackle. Prior to the pandemic, passenger air travel had the largest and quickest rise of individual emissions, despite major improvements in aircraft and flight operations efficiency over the previous 60 years (Ritchie H., 2023). Aviation emissions come from aircraft, support vehicles, and ground transportation. These sources' emissions are divided into the following categories:

- Emission that degrades local air quality
- Emission that causes climate change: divided into two groups:

  1. GHGs, which drive climate change by trapping heat in the atmosphere. These emissions occur when fossil fuels are burned. The Kyoto Protocol (An international convention approved in 1997 as an extension of the United Nations Framework Convention on Climate Change) set emission reduction objectives for GHGs, which include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride. To assist comparisons, global warming factors are assigned to each gas, representing emissions in terms of Co2 equivalents. This technique offers a consistent way to evaluate the total influence of various gases on global warming (Eurocontrol, 2022a).

  2. Airplane emissions have the potential to modify radioactively active chemicals, cause aerosol production, and cause cloud modifications. These effects are collectively known as radiative forcing (Eurocontrol, 2022d).

Furthermore, aircraft emits considerable non-CO2 pollutants such as nitrogen oxides, sulfur dioxide, soot, and water vapor. Soot and water vapor cause contrails to develop, which have a considerable warming impact. Non-CO2 emissions account for 66% of aviation's total warming effect. In other words, aviation's overall warming effect is three times that of its CO2 emissions alone (Kaupa C., 2023). It's also worth noting that, unlike the most prevalent GHGs, carbon dioxide, methane, and nitrous oxide, non-CO2 forcings from aviation are not addressed in the Paris Agreement (Adopted in 2015 by the UNFCCC (United Nations Framework Convention on

Climate Change), it reflects a more inclusive and ambitious global effort to tackle climate change. This implies they might be easily ignored; particularly as international aviation is not included in any country's emissions inventories or objectives (Ritchie H., 2020).

2.3.1 ENVIRONMENTAL IMPACT OF TRADITIONAL AVIATION FUELS

CO2 is the most significant component of aircraft discharges, accounting for over 70% of the debilitate. The gas combines with the environment, causing the same coordinated warming as when emitted from other fossil fuel combustion sources. Fly fuel use emits CO2 at a predictable rate (3.16 kilos of CO2 per kilogram of fuel consumed), regardless of the stage of flight. CO2's longer lifespan in the atmosphere makes it a highly effective nursery gas. After being transmitted, 30% of a particular volume of gas is typically evacuated from the environment within 30 years, 50% disappears within a few hundred years, and the remaining 20% persists in the environment for thousands of years (Overton j., 2022).

In Figure 7, shows the growth of global emissions from the mid-18th century through to today. It shows that before the Industrial Revolution, emissions were quite low. Aviation emissions have doubled since 1987. Global aviation, including passenger and freight flights, is expected to have released 1.04 billion tonnes of CO2 in 2018. This accounted for 2.5% - 2.8% of total CO2 emissions in the same year (Ritchie H., 2020).

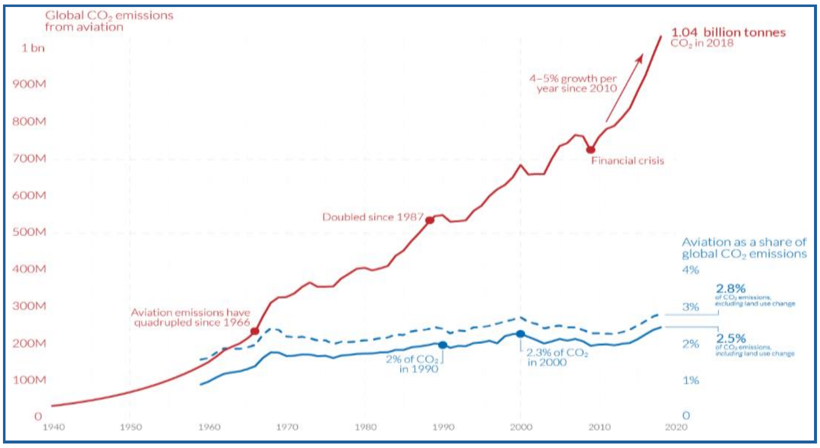


Figure 7 Global C02 emissions from Aviation.

Note: *The graph shows Global C02 emissions from Aviation from 1940 to 2020. Aviation emissions includes passenger air travel, freight, and military operations. It does not include non- Co2 climate forcing, or a multiplier for warming effect altitude.*

Source: Ritchie H. (2020).

The window of opportunity to limit climate change is rapidly closing. The emissions need to be reduced by at least 45% from 2019 levels (*2.2 Environmental concerns and sustainability challenges*) by 2030. In order to limit warming to 1.5°C - 2°C as the Paris Agreement prescribes, drastic reductions in GHGs emissions must be implemented deeply and within a short period of time (Ritchie H., 2020).

2.4 EMISSION ANALYSIS IN EUROPE

In the EU, in 2019 Transport emission reach almost 29% of the total GHG aviation emissions more than doubled between 1990 and 2019, rising from 1.5% to 3.8% (0.4% domestic and international

3.4) of total European emissions, making aviation the second-largest contributor to transportation emissions behind road transport (Air Traffic Organization of the FAA, 2021; Gössling S., 2020).

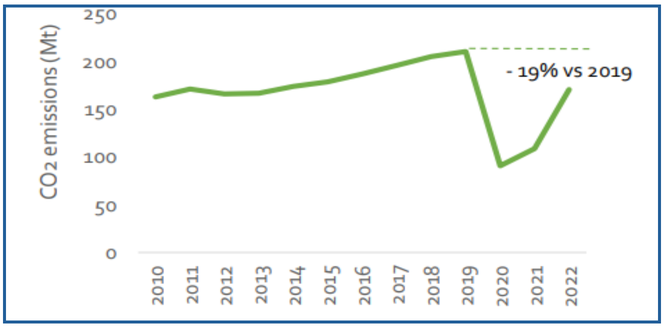


Figure 8 CO2 emissions from Europe departures (2010-2022)

Note: The graph shows CO2 emissions from Europe departures (2010-2022). Analysis of the IFR departures (full trajectory). Source: Eurocontrol. (2022).

The Figure 8 shows us the CO2 emissions from IFR all departures within the European Civil Aviation Conference (ECAC) territory increased steadily until 2019, exceeding 200 Mt (metric ton). Despite a significant drop in CO2 emissions owing to reduced flights in 2020, emissions returned with a large increase in 2022 (topping to 150 Mt), staying 19% lower than in 2019 (Eurocontrol, 2022a). GHG emissions from commercial aircraft in the EU increased by 30% between 2013 and 2019, with Ryanair identified as the most polluting airline until 2021, followed by EasyJet (UK), Lufthansa, British Airways (a subsidiary of IAG), and Air France, based on verified emissions covered by the EU ETS (Tiseo I., 2020).

Addressing these emissions represents a key challenge for the aviation industry. At the same time, the industry is investigating additional environmental and well-being consequences, including as air quality, noise, and the climate impact of non-CO2 emissions (Donceel L., 2022). As a significant worldwide aviation emitter, the EU expects an increase of more than 80% in intra-EU flights by 2030 compared to 2005 levels. Without action, emissions might increase by up to 300% by 2050. In response, the European Commission (EC) established rigorous emission reduction objectives under Regulation (EU) 2021/1119 (Pang&Chen 2023).

2.4.1 CO2 EMISSIONS IN THE EU FORECAST TO 2050

According to the base scenario (Figure 9), aviation CO2 emissions in the EU and associated countries (EU+) will increase by 1.6 percent annually until 2050, with 67% higher emissions than in 2018. The cargo operation shows a faster growth rate of 3.1% per year, and by 2050 will account for 7% of the total emissions. It is expected that flights within the EU+ will emit 115 Mt of CO2 by 2050, while flights outside the EU+ will emit 178 Mt. A decrease of at least 293 Mt of CO2 is needed to reach net-zero emissions (NLR – Royal Netherlands Aerospace Centre, 2021).

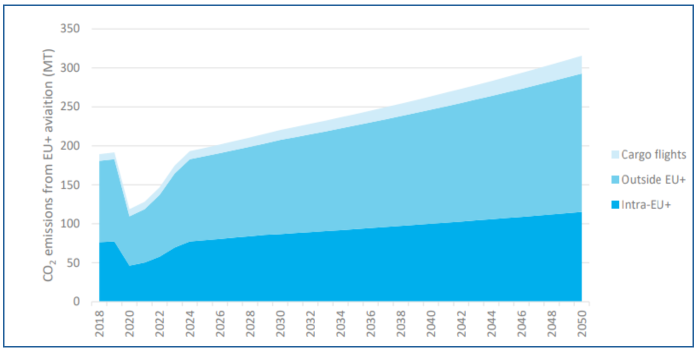


Figure 9 Emissions in EU aviation.
NOTE: The graph shows the forecast emission in Europe in reference scenario from 2018 to 2050.
Source: NLR – Royal Netherlands Aerospace Centre. (2021).

Aviation will most certainly look different in 2050. A significant part of the future will be determined by the technologies and policies in place today or in development tomorrow, whether it is SAF, hydrogen powered or electric aircraft, market-based measures, or something else.

In order to provide a comprehensive view of the future, EUROCONTROL Aviation Outlook uses scenarios, enabling airlines to prepare for uncertainty and change as they move forward. Considering the effects of the 2022 Russian invasion of Ukraine, there is a need to consider a number of issues related to the oil price and the economic cycle prior to making any decisions. The majority of significant past events have had a relatively short- to medium-term impact (Euro control, 2022d). The scenarios were previously described in *Chapter 2.1.2 Aviation industry in Europe (Low, base, and high scenario)*. All models and strategies for reducing aviation's impact on climate primarily focus on four pillars, but their contributions differ according to the area.

1. Technology relating to aircraft (airframes and engines),
2. The use of SAF,
3. market based measures (MBM),
4. improved operations and infrastructure (operational efficiency) (Eurocontrol, 2022a).

Table 2 shows the Net zero CO2 results for across the three scenarios by 2050, of which SAF will have the strongest impact on making the net zero achievable in all scenarios (Eurocontrol, 2022d). Therefore, SAF fuels need to be developed at all costs (AIR BP, 2022).

Net zero CO Can be achieved by 2050 via the following	Low Scenario	Base Scenario	High Scenario
Required Co2 reduction for Net Zero (Co2 Without normal fleet renewal)	194 MT	279MT	359 Mt
Fleet evolution: More efficient conventional aircraft	17%	17%	17%
Fleet revolution: Electric & hydrogen powered aircraft	2%	2%	3%
ATM: Better air traffic management and airlines operations	6%	8%	9%
Sustainable Aviation Fuels	34%	41%	56%
Other measures: Market based measures, carbon capture	41%	32%	15%
Emission compared to 2005 (150 Co2 emission in million tonnes)	-46%	-40%	-65%

Table 2 Net zero CO2 results for each scenario by 2050.
Note: The table indicates Net zero CO2 results for Low, Base, and high scenario.
Source: Eurocontrol. (2022).

In this context, SAF emerges as a key solution to reduces total CO2 emissions and pollutants, leading to considerable reductions in Sulphur dioxide and particulate matter emissions (Eurocontrol

2022). Despite this, SAF only helps decarbonize aviation if this is produced exclusively from renewable sources. This will result in an increase in sustainable energy consumption for aviation by 2050, as well as rivalry among airline sectors striving to decarbonize (Eurocontrol 2022, Pang&Chen 2023).

2.4.2 EUROPEAN CLIMATE LAW: REGULATION (EU) 2021/1119

According to the European Commission's 2019 climate plan, the Green Deal, the EU must attain overall climate neutrality aiming for an 80% decrease in CO_2 emissions from aviation by 2050 in contrast to 1990 levels at the latest. This commitment, making Europe the first climate-neutral continent by 2050, was legally enforced through the European Climate Law (Regulation 2021/1119) (Eurocontrol, 2021a). This rule aims to create a framework for the irreversible and gradual reduction of anthropogenic GHGs emissions by sources and enhancement of removals by sinks regulated under Union law (Pang&Chen, 2023; Thalin Et Al., 2023).

THE EU'S "FIT FOR 55" PACKAGE.

On July 14, 2021, the EU Commission implemented the 'Fit for 55' package, intending to improve EU rules in climate, energy, and transportation in order to achieve a 55% decrease in emissions by 2030 in contrast to 1990 levels. This comprehensive bundle includes new legislative ideas as well as revisions to existing laws, and it addresses a wide range of issues, including energy generation, industry, and transportation (Thalin Et Al., 2023).

The package proposes numerous interrelated measures establish a unified plan to control emissions across many industries (Sandrin A., 2021). Among those are three main ideas (Table 3) that directly influence business aviation (EU-ETS).

THE ENERGY TAXATION DIRECTIVE EU	EU EMISSIONS TRADING SYSTEM (EU-ETS)	REFUELEU AVIATION PROGRAM INITIATIVE
Defines principles for taxation of energy products and electricity. It intends to classify fuels and electricity based on their energy content and environmental performance, allowing member countries to charge them accordingly. This guarantees that greater tariffs are levied on more polluting energy items.	It is a cap-and-trade system that establishes aviation emission limitations and allows airlines and general aviation operators to sell emission permits. This technique is intended to reduce CO_2 emissions from aircraft.	Initiative aims to increase the use of SAF in order to minimize CO_2 emissions from aviation. This program is an important policy instrument for promoting the use of this fuels. (Ricci F., 2023)

Table 3 Fit for 55 that Influence on Business Aviation
Source: Ricci F. (2023).

Refuel EU Aviation initiative.

The European Union Parliament adopted the 'Refuel EU' project, part of the larger 'Fit for 55' package, in late 2023(IEA 2023). This rule primarily addresses SAF and imposes additional requirements on aircraft operators, fuel providers, and EU airports and airports, and it extends its restrictions to all aircraft leaving EU airports to contribute to emission reductions (Misfund & Wijngaart., 2023). Table 4 shows us the key mandates for the fuel providers, aircraft operators, and airports.

FUEL PROVIDERS	AIRCRAFT OPERATORS	AIRPORTS
Must incorporate SAF in aviation fuel delivered to EU airports, gradually increasing the proportion of sustainable fuels, particularly synthetic carbon dioxide-efficient fuels (e-fuels).	Required to use SAF-blended aviation fuel when departing from EU airports and to refill only with the necessary fuel to minimize excessive emissions-related weight	Must offer SAF storage and blending facilities to help fuel suppliers and aircraft operators satisfy their commitments (Kasm 2022).

Table 4 Refuel EU regulation main points.

Source: Kasm, A. (2022).

The core component of the Refuel EU Regulation is a set of rules requiring fuel providers to incorporate growing volumes of SAF in jet fuel, including a minimum for e-kerosene (aviation category of e-fuels) beginning in 2025. In Table 5, show several goals for the future of the transition to SAF and, specifically the transition to e-kerosene. By 2050, the EU aims to fulfil climate objectives by requiring at least 70% of aviation fuel from EU airports to be SAF. This will have an impact on EU and non-EU carriers seeking to operate in EU airports (Knight Et al., 2023).

	2025	2030	2032	2035	2040	2045	2050
MIN DE SHARE OF SUPPLY OF SAF (%)	2	6	-	20	34	42	70
MIN OF SUPPLY OF E-QUEROSEN (%)	-	1.2	2	5	10	15	35

Table 5 Future aviation fuel transition goals: SAF and E-kerosene

Note: The table shows the minimum percentage of Share supply of SAF which should include minimum synthetic aviation fuel (e-querosen).

Source: Own elaboration in based on data taken from Knight Et al. (2023).

The current agreement allows for the use of a broader spectrum of biofuels in SAF production included certified biofuels that meet the Renewable Energy Directive (RED) sustainability and emissions reduction criteria, up to a maximum of 70%, more details will be it on point *2.5.1 SAF production pathways* (Knight Et al., 2023).

2.5 SUSTAINABLE FUEL AVIATION (SAF)

Sustainable Aviation Fuel is the main term the aviation industry uses to describe a non-conventional (fossil derived) aviation fuel that meets sustainability criteria (WRIGHT 2020). SAF is the preferred IATA (International Air Transport Association) term for this type of fuel although when other terms such as sustainable alternative fuel, sustainable alternative jet fuel, renewable jet fuel or bio jet fuel are used, in general, the same intent is meant. SAF can be produced from various feedstocks (Next point *2.5.1 SAF Production Pathways).* Consequently, SAF reduces emissions by considering the carbon absorbed by feedstocks during growth and offsetting the carbon emitted during production, transportation, and combustion (McCurdy M, 2021). This alternative should meet technical and certification requirements for commercial aircraft use, ensuring ecological balance and meeting the technical requirements (SimpliFlying, 2023).

When compared to typical fossil fuels, SAF can reduce CO2 emissions by up to 80% during their life cycle. While emissions are produced throughout manufacturing, the total decrease in CO2 lifetime emissions is significant. The cleaner composition of SAF also leads to a greater reduction in sulphur dioxide and particulate matter emissions compared to existing technology. SAF adoption is considered as a crucial factor in decreasing CO2 emissions by 2050 (WRIGHT 2020). Annex 2 display the History of SAF represents the aviation industry's commitment to environmental sustainability. Significant achievements have been made on the path towards SAF since 2007, which began with renewable military jet fuel development. In 2008, the SAF Users Group (SAFUG) was formed, bringing together major airlines and aviation stakeholders to promote the adoption of SAF and leading to several significant accomplishments. In 2008, Virgin Atlantic conducted the first test flight using bio jet fuel, and the first transatlantic flight using a biofuel blend took place in 2011. Collaboration among industry leaders supported Oslo Airport in regularly supplying SAF by 2016. In 2021, significant endorsements from the EU and the US strengthened policy support, and by 2023, the Refuel EU Aviation initiative, part of the 'Fit for 55' package adopted by the EU, solidified commitments to increase SAF use, highlighting the aviation industry's continued transition to more sustainable practices (IATA 2023).

Although SAF has been in use since 2007-2008, its growth and adoption have been relatively slow. According to Figure 10, the historical production of SAF has increased significantly worldwide. Over the period 2013-2018, the company's production increased from 0.29 to 6.45 million litters per year. With this significant leap, the aviation industry is showing increasing momentum and commitment towards enabling SAF to be used widely (IATA 2023).

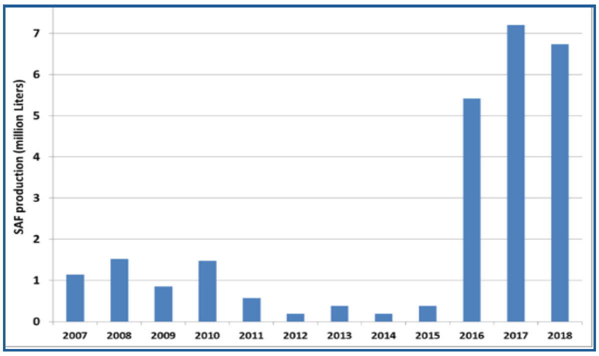


Figure 10 Historical production of SAF.
Note: The graph shows the Historical production of SAF from 2007 to 2018 worldwide.
Source: IATA. (2023).

The predicted future production capacity, illustrated in Figure 11, suggests a potential capacity of 10.9 million metric tons (13.6 billion liters) per year for SAF by 2032. There is, however, substantial uncertainty regarding how much of this capacity is dedicated to SAF. The deployment scenarios presented, dubbed "high ratio" and "low ratio," are intended to highlight this uncertainty and the spectrum of options for diverting production capacity to SAF (IATA 2023).

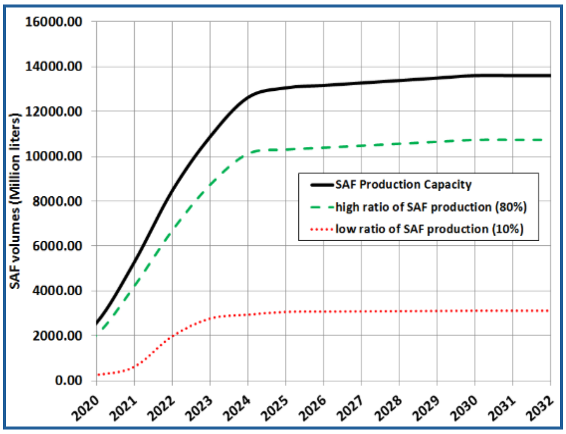


Figure 11 Projected scenarios of SAF production.
Source: IATA. (2023).

2.5.1 SAF PRODUCTION PATHWAYS

RED is a legislative framework adopted by the EU to promote the use of renewable energy, reduce carbon footprints, especially in the transportation sector. In the directive, targets are set, and sustainability criteria are defined for producing and consuming renewable energy sources. Annex IX of the RED specifies a list of materials that may be used in the production of renewable energy, including biofuels derived from crops that are not sustainable. There are four categories of feedstocks listed, which include wastes, residues, co-produces, and some primary products. Table 6 describe these categories for a better understanding (EASA, 2023a).

CATEGORY	DESCRIPTION	EXAMPLE
WASTES	Any substance or object that is discarded, intended to be disposed of, or is required to be disposed of by the holder.	Industrial and municipal wastes, sewage sludge, cooking oil (when not used for other purposes).
RESIDUES	The substance is not the direct end product of the production process; it was not the primary aim and has not been modified deliberately to produce it.	Whenever bagasse is not already being used for energy, it is considered residue like residue from sugarcane processing
CO-PRODUCTS	By-products and residues generated during the production of goods.	Residues from the food industry or animal by-products
PRIMARY PRODUCTS	The crops and materials that can be intentionally grown or cultivated for the purpose of making biofuels. The cultivation must comply with specific sustainability criteria, as well as not affect food production or land use negatively.	Sugar beet and lignocellulosic materials like wood. (TE, 2020)

Table 6 Feedstocks categories listed in Renewable Energy Directive (RED).

Note: The table shows a summary of ANNEX IX of RED.

Source: Own elaboration based on data TE. (2020).

2.5.2 SAF PRODUCTION PATHWAYS (DROP-IN OR NON-DROP IN)

The Refuel EU Aviation regulatory proposal defines SAF as drop-in aviation fuels that are either biofuels produced from feedstocks listed in Annex IX of the RED or synthetic aviation fuels that meet sustainability and GHG emissions reduction criteria (AviationHunt., 2023).

Conventional aviation fuels (CAFs) are aviation fuels derived entirely from petroleum-derived, originating from crude oil or similar sources. All aircraft fuels are petroleum-based, with kerosene-type jet fuel being the most popular, accounting for around 99% of all aviation fuel consumed. There are two types of aviation fuel: Jet Fuel (Jet A-1, Jet A, Jet B) and Avgas (Grande and Grande 100 LL) In contrast, Aviation alternative fuels (AAFs) can be renewable or non-renewable e.g., biomass, natural gas, electricity, or hydrogen. Under AAFs, SAFs can either be drop-in or non-drop-in fuels. The drop-in fuel can be blended with fossil kerosene or replace it without substantial modifications, but the non-drop-in fuel must be adjusted more extensively (AviationHunt., 2023).

By avoiding the use of petroleum as well as utilizing waste that would otherwise contribute to GHG in landfills, SAF derived from municipal waste can be an environmentally friendly solution. In a closed-loop carbon cycle, biomass is the feedstock, with plants absorbing CO2 during growth and releasing it back during combustion (Barke et al., 2022). This would allow the SAF to be carbon-neutral over its life cycle (WRIGHT, 2020). SAF has the potential to considerably reduce life cycle GHG emissions when compared to traditional jet fuel, depending on the feedstock and manufacturing processes used. The SAF manufacturing process begins with the gathering of feedstock (there are a variety of feedstock as shown in *Table 6*, and *Annex 4*). The feedstocks are subsequently transformed into SAF (There are a variety of approved SAF pathway *Annex 3*). Following the conversion process, SAF is blended with conventional jet fuel and sent to airports for usage. This multi-step manufacturing and blending method adds to SAF's environmental benefits when compared to standard jet fuel (Figure 12) (SAFFiRE Renewables, 2023).

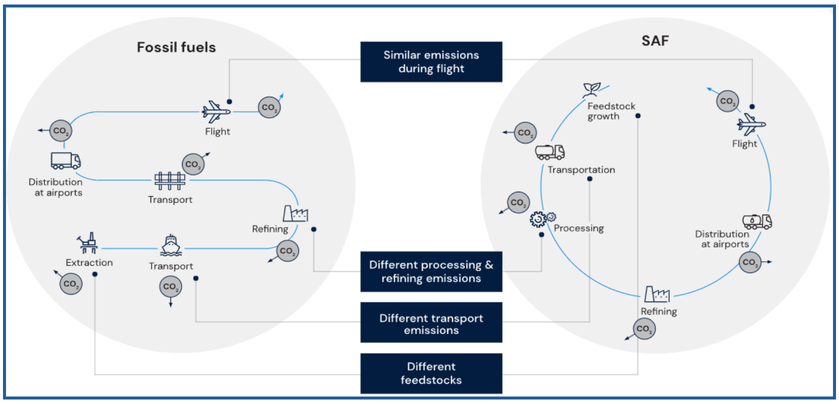


Figure 12 SAF Production VS Fossil Fuel
Source: McCurdy M. (2021).

Drop-in SAF must undergo an exhaustive approval process to be used in commercial aircraft, fulfilling strict certification criteria, and demonstrating that their physical and chemical properties are almost identical to fossil-based jet fuel, allowing them to be safely blended with conventional jet fuel. As a result, SAF can be incorporated into existing global fleets without requiring any infrastructure or aircraft adaptations (Salmi H 2023).

The SAF manufacturing process has been approved for seven production processes as of January 2022. Additionally, two pathways are approved for co-processing renewable feedstocks in petroleum refineries with a blending limit of 5%. Annex 3 shows the production pathway, the feedstocks needed, the approved certification and the technology maturity of each production. Each manufacturing pathway's technical maturity may be specified using a Technology Readiness Level (TRL), which ranges from 1 for basic concepts to 9 for a fully operating system ready for commercial deployment) (EASA, 2023a). It is important to note that while various feedstocks are available, the listed feedstocks are technically feasible for the specific production pathway but may not always be applicable under the Refuel EU Aviation regulations (EASA 2023).

Annex 4 summarizes the key production pathways for SAF by feedstock, initial processing required, and intermediates (Berger, 2020). This shows different materials can be converted into SAF by using a variety of processes (Salmi H 2023). Annex 5 highlights pathways that will play a significant role in Europe over the next few years. Those included Hydroprocessed Esters and Fatty Acids (HEFA), Alcohol to Jet (AtJ), Biomass Gasification + Fischer-Tropsch (Gas+FT) and Power-to-Liquid (PtL). The production cost of seems to be the primary constraint across all the SAF pathways, more details are mentioned on 2*.5.3 challenges and barrier of SAF*.

PTL appears as a more scalable and renewable energy source, relying solely on renewable power and outperforming the usage of biomass feedstocks in traditional biofuels. However, certain sophisticated biofuels, such as tall oil or animal fats, are presently used in other industries, and there are rising worries regarding their long-term sustainability. This encourages more research into generating more sustainable options. When a feedstock is approved for jet fuel production, it frequently provides a current energy or economic function that must be replaced. In consequence, the supply of sustainable advanced biofuels remains significantly constrained, as underlined by Murphy (2021).

It should be noted that non-drop-in fuels (e.g., hydrogen) would not be compatible with the existing global fleet and may therefore require the redesign and certification of aircraft and the construction of new supply infrastructure (EASA, 2023a).

2.5.3 CHALLENGES AND BARRIER OF SAF

In this context, sustainability is defined as anything that may be continuously and repeatedly resourced in a manner consistent with economic, social, and environmental goals, and that preserves an ecological balance by preventing natural resource depletion (Salmi H, 2023).

Despite the benefits, several hurdles exist to producing and deploying SAF. Figure 13 summarise the challenges and barrier of SAF.

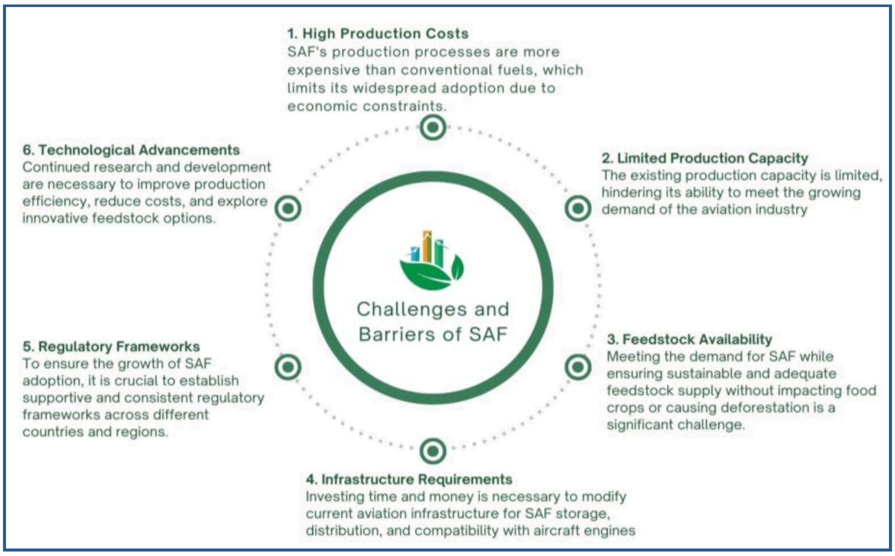


Figure 13 Summary of Challenged and Barrier of SAF
Source: Own elaboration based on information from Greenfield. (2023).

1. ***HIGH PRODUCTION COST*:** When comparing with traditional jet fuels because of complex and resource-intensive procedures, as well as costs associated with sourcing feedstocks and processing. These costs are said to be 2-8 times greater than for regular jet fuel. Recognizing that fuel is the most expensive single operational cost for airlines, accounting for almost one-third of their costs. (SimpliFlying, 2023).

The creation of SAF necessitates substantial investment in infrastructure, such as refining plants and pipelines. Additionally, the process is intricate and relies on sophisticated technologies, which contributes to the overall expense of production. These obstacles create significant challenges for the industry in terms of scaling up the production of SAF to meet demand (Paunoska, 2023).

According to Inner City Fund (ICF) projections, by 2050, the industry cost for SAF will be between $760 and $900 per ton, comfortably coinciding with historical fossil fuel pricing. Furthermore, despite SAF's small market position in commercial aviation fuel, the number and magnitude of SAF offtake agreements between airlines and fuel providers is growing (McCurdy M, 2021). According to popular perception, technological advancement will reduce existing inefficiencies, making SAF a more cost-effective alternative for customers. However, market penetration and wider adoption remains limited due to the pricing discrepancy. Some recommendations include that the EU implement a pricing system for SAF similar to that used for other sustainable technologies such as wind turbines and solar panels. This method tries to ease the energy transition in aviation while maintaining passenger accessibility (AIR BP, 2022).

2. ***LIMITED PRODUCTION CAPACITY:*** Currently, this barrier is making it difficult to meet the growing demand of the aviation industry (Greenfield, 2023)**.** Forecasts show that by 2027, the estimated production capacity would likely be only 1-2%, addressing only a small percentage of total jet fuel demand. To achieve a considerable rise in SAF usage in line with the Net Zero Scenario, supporting policies and major investments in manufacturing capacity would be required. (IEA, 2023)

3. ***FEEDSTOCK AVAILABILITY:*** This varies by area and might be limited. Competition for these resources from other industries exacerbates the supply problem. According to a World Resources Institute analysis, expanding plant-based biofuel production may not coincide with the human population's food supply demands by 2050. Additionally, SAF might utilize over 30% of all sustainably accessible biomass for biofuels by 2050 (SimpliFlying 2023). While SAF are less carbon-intensive than fossil feedstocks across their entire life cycle, some CO2 is emitted during the manufacturing and refinement of SAF feedstocks. GHG assessments of SAF feedstocks include emissions from farming techniques and fertilizers, feedstock transport to the SAF manufacturing site, and, in certain cases, land use changes. (McCurdy M, 2021).

The Figure 14 displays a complete overview of multiple SAF approaches, each of which is assessed based on its environmental effect, cost aspects, and scalability from 2020 to 2030. FT-PTL appears as a highly sustainable solution that uses little water and land, offering greater cost savings as renewable energy costs fall. FT-Biomass and FT-MSW indicate potential for SAF production from a variety of biomass sources, with a focus on decreased net CO2 emissions from agriculture and forestry residues. HEFA fuels, particularly those derived from waste cooking oils, are economically viable and effective in lowering NOX emissions. Catalytic Hydro thermolysis Jet (CHJ) confronts hurdles owing to high production costs and the scarcity of existing feedstocks. ATJ and Hydro processed Fermented Sugars to Synthetic Isoparaffin (HFS-SIP) have land and water use difficulties, with ATJ experiencing cost constraints and HFS-SIP presently being the costliest approach, despite anticipated cost improvements in the future. The research emphasizes the complexities of assessing SAF paths while considering economic, environmental, and operational issues. It is important to note that "Sustainability" is assessed based on the amount of CO2 that can be reduced, non-CO2 emissions, amount of blend, feedstock availability, and land and water utilization. As for "Cost," it is evaluated separately by considering capital expenditures, feedstock costs, and operating costs (Berger, 2020).

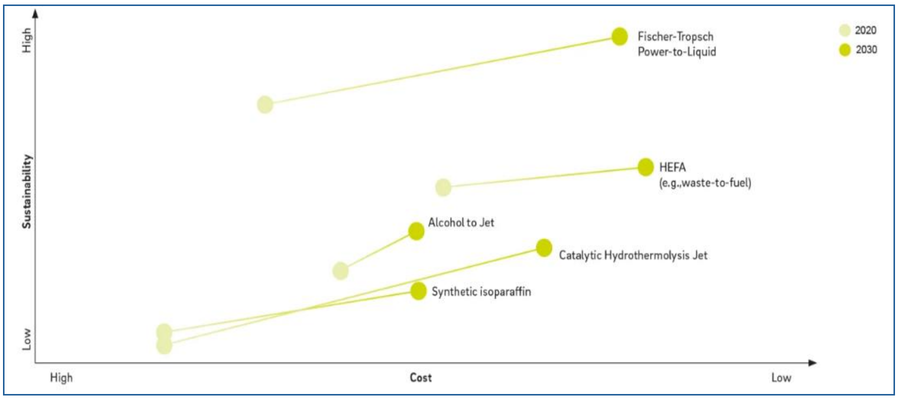


Figure 14 True sustainability and cost of SAF.

Note: The graphs display assess the sustainability and cost of various SAF option from 2020 to 2030.
Source: Berger. (2020).

Organizations such as the Roundtable on Sustainable Biomaterials (RSB) and the International Sustainability and Carbon Certification (ISCC) are now critical in maintaining feedstocks certificates to confirm that the environmental advantages are true and actual, as well as that feedstock operations adhere to social, labor, and land rights criteria (ICF, 2021). The Internal Control Framework consider three key constrains that can be assigned to the availability of the feedstock:

- *Sustainability constraint*: This encompasses environmental and societal constraints on feedstock supply, such as the appropriate allocation of land for energy crop production and the requirement to conserve soil quality by leaving a percentage of agricultural waste.
- *Fairness constraint:* The balance of feedstocks available for SAF manufacturing in comparison to other industries. Many of these feedstocks are now utilized in heating, animal bedding or feed, soaps, lubricants, and as a raw material in the oleochemicals sector. As other sectors decarbonize, there will most certainly be an increase in demand for it used to generate heat and energy, as well as material applications such as bioplastics.
- *Economic limitations:* the amount of feedstock that can be utilized economically to make fuels and enable flights at economically viable and socially acceptable pricing. (ICF, 2021)

4. ***TECHNOLOGY CHALLENGES*:** While the technology for producing SAF is proven, there are problems relating to efficiency, scalability, and the processing of certain feedstocks. For example, the technology for manufacturing SAF from algae or urban garbage is still in its initial stages and requires considerable research before it can be commercially feasible. The issue of large-scale manufacturing is the same for E-fuels: all the world's renewable power would not be enough to create the quantity of fuel consumed by aircraft today (SimpliFlying 2023).

5. ***INFRASTRUCTURE REQUIREMENTS:*** Incorporating SAF into the existing fuel supply chain infrastructure poses logistical challenges. These include segregation and quality control issues during blending, transportation, and storage (SimpliFlying 2023). Physical SAF are not provided in all airports yet. SAF are currently made in a few numbers of areas and are not widely distributed (this would increase their life cycle emissions) (World Economic Forum, 2023), which constrains the ability of airlines to utilize it. The expansion of SAF availability at all airports requires infrastructure investment, which is an additional cost that airlines have to bear (Paunoska, 2023).

6. ***REGULATORY & POLICY SUPPORT:*** Inconsistent policies and regulations between areas can be a problem. To promote the expansion of the SAF sector, policymakers must create a consistent set of incentives, standards, and regulations (SimpliFlying 2023).

Strong support is required to move the emphasis away from carbon-based fuels and toward sustainable, low-carbon alternatives as soon as feasible. According to an International Council on Clean Transportation (ICCT) study, the transition to advanced alternative road fuels may provide a pattern for predicting some of the immediate issues. Policies and incentives such as mandates, fiscal incentives, sovereign guarantees, decarbonization initiatives, and subsidies might help to overcome such hurdles. Procurement contracts and associated measures can and have helped improve the feasibility of SAF projects and mitigate some of the risks associated with production. Tax regimes and specific financing should also be considered to help reduce operational costs and boost investment in SAF projects to accelerate projection and deployment (McCurdy M, 2021).

2.6 STRATEGIES AND BARRIER OF SAF FOR "THE BIG 5"

There are worries, notably among European airlines represented by Airlines for Europe (A4E), about the possible effects of these sustainable fuel standards, which might result in higher ticket costs (Payne 2023).

In 2015, five major European airlines, also called the "Big 5" EU carriers —Air France-KLM, EasyJet, IAG, Lufthansa Group, and Ryanair—joined together to form a cohesive voice on critical aviation issues. A4E, headquartered in Brussels, has grown into the largest airline organization, with 16 major airline companies as members, representing over 70% of European air traffic. With a modern fleet of over 3,300 aircraft, A4E member airlines transported over 610 million passengers to approximately 2,000 locations in 2022 (Writer S., 2021). These airlines deliver about 4 million tons of important products and equipment to over 360 locations, freighters, and passenger planes annually (A4E 2023).

European airlines are working to decarbonize air travel to make the first carbon-neutral continent by 2050. Table 7 summarize strategies implemented supported by four major pillars.

STRATEGY	DESCRIPTION
GREEN FUEL SAF	Renewable SAF is being explored by airlines to reduce emissions by up to 80% (World Economic Forum, 2021).
IMPROVING OPERATIONS AIR TRAFFIC MANAGEMENT (ATM)	Increasing fuel efficiency requires airlines to optimize flight routes, reduce taxiing times, and reduce unnecessary weight. By implementing these operational changes, emissions can be reduced (NLR – Royal Netherlands Aerospace Centre 2021.
NEW TECHNOLOGIES & FLEET REVOLUTION	It is currently being researched and tested to develop hybrid-electric aircraft and low-carbon SAFs (NLR – Royal Netherlands Aerospace Centre 2021). Electric & hydrogen powered aircraft: Research and development efforts are ongoing to make hydrogen-powered planes viable for commercial aviation (Morgan, 2023).
ECONOMIC STRATEGIES	Airlines collaborate with policymakers, industry stakeholders, and regulatory bodies to develop economic strategies (E.g. Air Passenger Taxes Study) (Morgan, 2023).

Table 7 Measures and Innovations implemented in Aviation in EU

Note: Table describe the strategies implemented in Eu to achieve carbon neutral continent by 2050.

Source: Own elaboration based on data from NLR – Royal Netherlands Aerospace Centre. (2021).; World Economic Forum. (2021).; Morgan. (2023).

The commitment includes a significant decrease in CO_2 emissions in absolute terms as well as via mitigation measures, in line with the EU Green Deal and the ICAO Long Term Aspirational Goals.

The rapid adoption of SAF during the next decade will be critical in transitioning to a carbon-neutral economy and meeting climate goals in the aviation industry (A4E, 2023a).

According to a Price Waterhouse Coopers Germany analysis, flying sustainably in the future may be more expensive (Welle D. 2023). Willie Wash, the director of International Air Transportation, stated that the 'customer would wind up bearing the tab in flight pricing' (Palazzo A. 2023). Furthermore, Ryanair CEO Michael O'Leary is concerned about the potential impact of SAF proliferation on food costs (Plucinska & Payne, 2023; Ryanair, 2023).

The work on SAF is only getting started, and policymakers will need to create a favourable regulatory and investment climate for Europe's SAF industry to ensure the flow of affordable SAF and to put European aviation on a more sustainable path (EUROCONTROL 2021). Otherwise, adopting the "Fit 55 package" would increase prices for customers as sustainable approaches become more expensive (A4E 2023).

In a report that features interviews with ten prominent leaders in airline sustainability, including representatives from British Airways (a subsidiary of IAG), EasyJet, and Ryanair, highlights five main challenges that highlight the sector's distinct role in the conversation about environmental sustainability (SHUBHODEEP PAL, 2023):

1. The aviation industry has been recognized to face a ***more challenging situation compared to almost every other industry***. The only practical solution to decrease emissions is to develop an aircraft that produces no emissions, which might take many decades to achieve.

2. They agree that ***SAF is likely to save the aviation industry***. Most airlines want more of it. There are, however, insurmountable challenges relate to supply and price for the near future.

3. They recognize that ***being environmentally conscious*** is not just a way to stand out from their competitors but also a responsibility towards society that requires collective action.

4. The matter of ***economic feasibility*** will remain a significant worry. When it comes down to picking between reducing CO2 emissions at a high price and staying solvent, airlines will understandably choose the latter. The livelihoods of thousands of people are reliant on this industry. It is not possible to close it down or disregard it. The only way to move forward is through significant technological investments and extensive cooperation.

5. Airlines are realizing that sustainability is crucial and ***needs to be embraced at all levels of the organization***. In order for change to occur, it is necessary ensuring that for all tiers of the organization are fully committed and on board in the company to agree and support the effort (SHUBHODEEP PAL, 2023).

The field of sustainable aviation is intricate and involves a variety of multifaceted obstacles. In order to progress towards a more environmentally responsible future, the entire industry must be committed. Chapter Four provides an in-depth exploration of this endeavour by thoroughly examining the obstacles and techniques the five largest airlines have implemented to achieve sustainable aviation. This investigation scrutinizes the intricate and interdependent factors that impact the industry's efforts to decrease its carbon footprint.

CHAPTER 3 METHODOLOGY

This chapter presents a thorough methodology for examining the adoption of SAFs by the "Big 5" European airlines. The research predominantly relies on collecting and analyzing secondary data to provide valuable insights into the topic. The data has undergone comprehensive scrutiny and is presented professionally and respectfully, making it appropriate for internal and external audiences.

3.1 RESEARCH DESIGN

The method used in the current research is a qualitative multi-case study approach, which is a reliable way to investigate intricate phenomena within their genuine contexts. The aim of this research is to assess the methods utilized by the five major airlines in implementing SAF and to compare how these methods tackle the difficulties associated and implementation under the regulation Refuel EU. The key features of this method:

- ***Cross-Case Comparison***: The comparison presented in this thesis examines the approaches and strategies of the five largest European airlines (Air France-KLM, EasyJet, International Airlines Group, Lufthansa Group, and Ryanair) in terms of their adoption of SAF. By using cross-case analysis such mid map, comparative tables, it becomes possible to identify patterns, commonalities, and differences among these airlines.
- ***Purposeful Sampling*****:** It is crucial to emphasize that the airlines included in this study were deliberately chosen as those form part of the biggest airlines in Europe. Each airline has its own specific context, strategy, and approach to SAF adoption, allowing it to understand better the challenges and opportunities involved. By selecting these cases, objectives and valuable insights into this important topic were achieved.
- ***In-Depth Exploration***: Each airline's SAF strategy is thoroughly explored in this thesis. This involves analysing various data sources, including interviews on podcasts, documents, databases, and industry reports. The cases are described in detail, providing readers with context, and enabling them to appreciate the subtleties involved.
- ***External Validity and Generalization***: This thesis intends to offer insights that extend beyond individual airlines by analysing multiple cases. Through these findings, the broader aviation industry can gain knowledge and make informed decisions in their efforts toward achieving sustainability.

The examination of real-life cases allows for the analysis of intricate phenomena and the acquisition of a thorough comprehension of their expression in the actual world. An in-depth comprehension of the complex aspects of the subject can be attained by utilizing this approach, which may demand additional efforts when utilizing other research methods.

3.2 DATA COLLECTION

The data will be gathered solely from secondary sources, include:

- ***Document Analysis*****:** The analysis of the "Big 5" airlines were based on examining various publicly available documents, including annual reports, sustainability reports, press releases, and official statements. To obtain a more comprehensive understanding of each airline's dedication to SAF and broader sustainability initiatives.
- ***Literature Review:*** Analysis of academic journals, industry publications, and research papers on SAF to promote aviation sustainability. It will examine the latest developments, challenges, opportunities, potential solutions, and the impact of SAF on the environment and aviation industry.
- ***Policy and Regulatory Review*****:** Review the regulations set forth by the European Union, along with international agreements and policy documents that have an impact on the adoption of SAF and airline operations.
- ***Podcasts***: The use of podcasts as a means of obtaining information, specifically those related to aviation, sustainability, and industry trends.
- ***Databases:*** The study's data collection process was meticulously planned to ensure comprehensive insights into the aviation sector in Europe, aiming to gather information on aviation statistics, trends, and policies. Data sources from well-established databases were included to obtain reliable information, including Eurocontrol, Eurostat, EASA (European Aviation Safety Agency), ICAO (International Civil Aviation Organization), Planespotters, and Statista, which are known for their extensive records.

3.3 DATA ANALISYS

Thematic analysis will be utilized in this research to examine the gathered data. The purpose is to detect, assess, and present emerging trends related to the strategic execution of SAF by different airlines. This method is skilled in comprehending the intricacies of each airline's efforts to reduce CO2 emissions, providing a comprehensive perspective on their approaches and obstacles.

The examination that will be conducted will be all-encompassing in relation to the role of green fuel SAF. Figure 15 illustrate the process of the data analysis. It will include insights from document analysis and literature reviews to trace the evolution, current practices, and future projections for the implementation of SAF. Furthermore, the research will investigate ways to enhance operations through observational research and policy reviews. This will showcase how operational efficiencies and the integration of SAF impact the daily operations of airlines.

In addition, the examination will expand to include the ATM, utilizing industry podcasts and regulatory documents to obtain insights into the changing strategies in the context of SAF implementation. Advancements in technology and the transformation of the fleet will also be closely studied, with literature reviews and podcasts serving as crucial sources for comprehending the innovations and modifications to the fleet that support the use of SAF.

Another area of focus will be the economic strategies, where financial reports and sustainability documents will provide insights into the financial foundations and stakeholder engagement that drive investment in SAF and cost management. This comprehensive methodological approach aims to uncover the obstacles that airlines face in this transformative shift and to shed light on the strategic areas that directly impact the aviation industry's journey towards reducing CO2 emissions and adopting sustainable practices. This methodology is considered appropriate for obtaining a comprehensive understanding of the strategic implementation of SAF and integrating findings from various sources. The research will adhere to high ethical standards and ensure that all secondary data used is cited appropriately and presented with integrity, while also respecting the original authors' and organizations' rights. The study recognizes the limitations of secondary data analysis, such as potential bias in published materials and the lack of real-time data. Furthermore, the changing nature of the aviation industry and regulatory environment may impact on the findings' relevance.

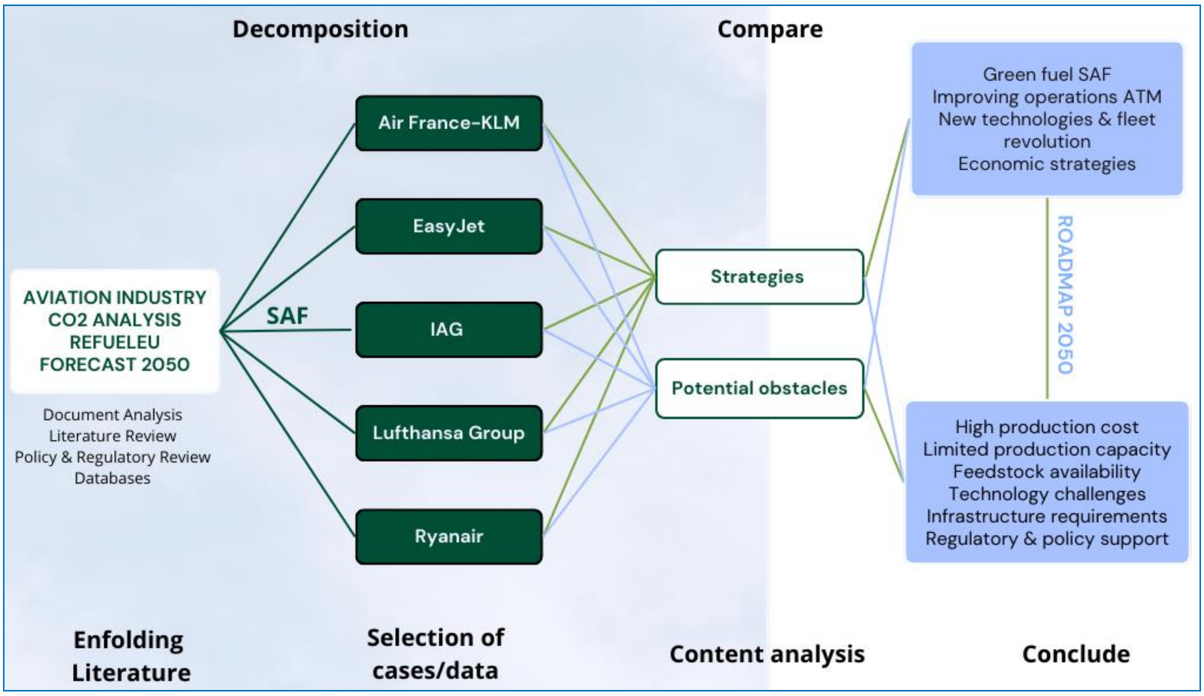


Figure 15 Data analysis.

The results will provide insights for policymakers, industry professionals, and researchers, which will also contribute to the existing literature. The following sections will examine the SAF implementation, present practices, future plans, and the effect of the Refuel EU Aviation Initiative on the "Big 5" airlines' strategies, all based on this methodology.

CHAPTER 4 ANALYSIS

THE BIG 5 ANALYSIS UNDER THE EU AVIATION REFUEL INITIATIVE

As we learn from the literature analysis, the Refuel EU Initiative aimed at decarbonizing the aviation industry by promoting the use of SAF and e-fuels in the EU air transportation market, which begin in 2025 and gradually increase until 2050 (Soone Jaan, 2023).

In Europe, the big 5 airlines are Lufthansa Group, Air France-KLM Group, IAG, Ryanair, and EasyJet, generally referred to as the Big 5. According to a recent A4E analysis, these airlines' degrees of vulnerability and preparation to the Refuel EU legislation vary depending on fleet size, fuel usage, route network, and SAF strategy. First, they concentrate on Green Fuel, working with fuel providers and SAF producers to build long-term contracts and assure a consistent supply. They also invest in SAF production and innovation, with a focus on developing e-fuels and other sustainable alternatives. Second, they prioritise enhancing ATM operations to increase efficiency and decrease environmental effects. Third, they use new technology in their operations to increase efficiency and lower pollution. In terms of fleet management, they take a new strategy targeted at improving performance while reducing environmental impact. Finally, they put economic plans into action by working with a variety of stakeholders, including airports, regulators, and legislators, to create supporting frameworks and incentives for the broad use of SAF. They also communicate effectively with consumers and shareholders to increase awareness and support for sustainability projects (Soone Jaan, 2023; Tuominen, 2021).

The Refuel EU rule provides a positive step toward reducing the aviation sector's carbon impact. However, it presents significant hurdles and uncertainty for the industry's key stakeholders. As a result, these airlines must adopt a proactive and collaborative approach to successfully manage the transition to a low-carbon future (Tuominen 2021).

4.1 AIR FRANCE-KLM

KLM, the world's oldest airline, was established in 1919. In 2004, the merger of KLM and Air France created the prestigious brand name AIR FRANCE KLM. This union combined its strengths and established a leading European group with the necessary teams, skills, and resources to attract and retain customers. KLM is also a member of the SkyTeam alliance, which serves 1,062 destinations in 170 countries. Transavia, a low-cost French airline, was founded in 2006 as a subsidiary of Air France-KLM Group by Air France and Transavia Holland (Royal Dutch Airlines, 2022).

In 2020, the air transport sector and the group's operations were severely impacted by the COVID-19 pandemic. To reduce costs and secure cash flow, Air France-KLM implemented crucial measures and received financial support plans from the French and Dutch governments. However, the crisis continued to affect the group's financial position in 2021, as most of the destinations it serves are subject to travel restrictions and there is limited visibility on demand recovery. The group has taken several steps to improve its cash position. These measures were deemed acceptable by the European Commission, which authorized a €4 billion financial aid package from the French government to recapitalize both Air France-KLM and its holding company (KLM, 2023).

In 2023, Air France-KLM announced that it had achieved its highest revenue ever, amounting to €30 billion. The company also reported an operating profit of €1.7 billion for the full year (Arena, 2024).

The French company has established itself as one of the leading players in international air transportation, playing a prominent role in the European air travel industry. As part of its extensive fleet of 522 aircraft, the group transports 931,000 tons of cargo, shared among Air France, KLM Royal Dutch Airlines, and Transavia, to a wide range of destinations. The expansive global network is facilitated by two central hubs located at Paris-Charles de Gaulle and Amsterdam-Schiphol. The organization is highly specialized in three main areas: air passenger transportation, cargo transportation, and aircraft maintenance. A major player in the aviation industry, AF-KLM operates three different airlines under its umbrella and employs 73,000 people. In year of 2022, the firm accomplished an important milestone by conveying 83,3 million people transported (AIR FRANCE KLM, 2024a).

The Air France-KLM Group is committed to reducing its environmental impact. In order to achieve this, the Group has established a decarbonization goal through its Destination Sustainability program, focusing on three primary approaches: *Incorporating the use of SAF, improving operational efficiency, and upgrading its airline fleets with the latest aircraft* (AIR FRANCE, 2023).

ROADMAP 2050

Vincent Etchebehere, who is the Director of Sustainability and New Mobilities at Air France, has recently introduced a roadmap that aims to reduce CO_2 emissions and achieve net-zero emissions by 2050. According to the roadmap, the airline targets to reduce CO_2 emissions by 50% per passenger-km by 2035. Its plans to increase the use of SAF, upgrade its fleet with more efficient aircraft, implement carbon compensation methods, and enhance operational efficiencies. After

2035, the company hopes to introduce hydrogen-powered planes as a significant step towards achieving net-zero emissions. However, this integration of progressive hydrogen technology will only be possible with concurrent infrastructure and regulatory support advancements to ensure a smooth transition. Furthermore, the company has a strong dedication towards achieving sustainability, and to fulfil this commitment by 2050, it is focusing on three key pillars: operations, compensation, and sustainable development (Etchebehere, 2020):

1. Committed to sustainable development (45%): This will include updating its fleet with more fuel-efficient aircraft and exploring the use of hydrogen-powered planes. The Group will also invest in developing and integrating SAF to reduce the carbon footprint of its flights (Table 8)

2. Compensation (10%): AF-KLM will comply with EU regulations, including participation in the EU ETS, to offset emissions for flights within the EU. The airline will also voluntarily offset emissions from all its domestic flights by supporting sustainability projects that contribute to CO2 reduction (Table 12).

3. Operations (45%): The airline will train pilots in fuel-efficient flying techniques (Table 9). The airline is also encouraging the use of more sustainable modes of transportation (intermodality) for part of the journey to decrease the environmental impact of travel (Table 12) (Etchebehere, 2020).

These pillars play a crucial role in ensuring that the sustainability goals are met (ANNEX 6). A thorough examination will be carried out, which will be in line with the sustainability goals of AF-KLM and Refuel EU. The analysis will delve deeper into these initiatives to understand their impact on EasyJet's 2050 sustainability objectives.

GREEN FUEL SAF

AF-KLM reaffirms its commitment to decarbonizing air transport and is increasing the use of SAF. In order to achieve its incorporation objectives by 2030, the Group continues to secure the volumes necessary to become the world's largest user of biofuels. The airline employs vegetable oil and cooking oil as raw materials for producing jet fuel. These feedstocks are more economical and easier to transform into aviation fuel than other alternatives. Additionally, the company incorporates synthetic fuels that are generated from CO2 harvested from the air and hydrogen extracted from water. The following table 11 illustrates the development of SAF adoption.

YEAR	MILESTONE
2008	The Air France KLM Group becomes member of Roundtable on Sustainable Biomaterials (RSB) to ensure supply of sustainable feedstock (Etchebehere, 2020)
2009	The first flight ever using bio kerosene fuel (Royal Dutch Airlines, 2022).
2011	Conducts its initial flight with SAF (Etchebehere, 2020).
2012	Launch of KLM Corporate Biofuel Program (Etchebehere, 2020)
2014-2016	78 flights were operated powered by SAF. This first long-term experiment was recognized for its innovative nature by the European Commission and IATA. And Air France corporate biofuel program calls Lab line
2017-2020	Together with the General Commission for Sustainable Development, initiated and committed to the Commitment for Green Growth (ECV). • Support several programs that aim to develop French sectors (Call for expressions of interest).
2021	Launch the SAF Corporate program, which enables Corporate Customers to contribute financially to the supply and usage of SAF beyond regulatory incorporation. Join with a world first: utilize a French SAF to reduce CO_2 emissions by 91% during the whole life cycle on a Paris-Montreal journey. And continues to experiment in the areas, operating a Paris-Nice flight with 30% SAF.
2022	Implementation of a SAF contribution and the establishment of an optional SAF financing offer for our individual clients. Utilizing 17% of the global SAF supply in 2022, Signed supply contracts with Nesté and DG Fuels for 1.6 million tonnes of SAF (2023-36), followed by a memorandum of understanding with Total Energies for 800,000 metrics tonnes of SAF (2023-30).

2023	Contracted OMV, a Vienna-based energy company, to supply 2,000 metric tonnes of SAF in 2023, with an MoU for over 300,000 metric tonnes by 2030 (Informa Markets, 2023). Sustainable Aviation Fuel plant in NL and FR (Etchebehere, 2020).
2030	Plans to utilize at least 10% of SAF internationally reduce its CO2 emissions per passenger-km by 30% relative to the benchmark year of 2019.
2050	Plans to use 63% of SAF internationally. (AIR FRANCE KLM, 2024b) 'Net Zero by 2050" intra and dep. From Europe

Table 8 SAF Milestones in AIR FRANCE KLM

Source: Own elaboration-based on information from: Etchebehere, V. (2020).; Royal Dutch Airlines. (2022).; Informa Markets. (2023).; AIR FRANCE KLM. (2024).

IMPROVING OPERATIONS AIR TRAFFIC MANAGEMENT (ATM).

AF-KLM is committed to cooperating with civil aviation and air traffic authorities to further reduce CO2 impacts. This includes initiatives such as the adoption of continuous descent, especially in Paris, and support for the SES project. As a result of these efforts, aviation emissions across Eu could be reduced by 10% (AIR FRANCE, 2024b). Table 9 summarizes the company's efforts to enhance ATM operations.

IMPROVING OPERATIONS ATM	**Eco-piloting strategy:** These include optimizing ground operations such as using electricity from the bridge instead of the aircraft's auxiliary power unit (APU) before engine startup, resulting in a 4-5% decrease in fuel consumption and CO2 emissions. Pilots have the option to conserve fuel on the ground by using the airport's electrical supply instead of relying on the aircraft's APU. While taxiing on the runway, an Airbus can safely operate on a single engine, resulting in a fuel savings of up to 700 kg. During the flight, pilots employ AI tools to optimize the flight trajectory and ensure a continuous descent, which further contributes to fuel savings. The company train its employees to use these techniques properly. **Single European Sky project**: The European SES initiative is focused on improving air navigation services by achieving increasing airspace capacity, reducing environmental impact, enhancing safety, and cutting costs for airlines and passengers (AIR FRANCE, 2024b).
	MORE RESPONSIBLE CATERING **Meal Pre-selection for Long-Haul Business Cabin**: This ensures the availability of chosen meals, allowing only those meals expected to be consumed to be boarded. By board only selected meals, the on-board weight is reduced, *resulting in a reduction in fuel consumption.* **Transition to Bio-sourced Materials:** Replacing plastic things with bio-sourced materials, both aboard and on ground. By 2023, the firm reduced/replaced single-use plastic goods onboard by 90% (cups, silverware, trays, etc). **Installation of Water Fountains:** Water fountains installed in French lounges eliminate the need for 3.5 million plastic bottles annually, aligning with French regulations. **Packaging Sorting Effort**: Since 2019, Paris flights sort packaging for recycling in France or Europe. 20 tons of plastic bottles, cartons, and cans, and 530 tons of glass bottles have been recycled in 2022 (AIR FRANCE, 2024c).

Table 9 Strategies in AIR FRANCE -KLM operations air traffic management (ATM)

Source: Own elaboration in based on information from AIR FRANCE. (2024).; AIR FRANCE. (2024).; Media Relations KLM. (2024).

NEW TECHNOLOGIES & FLEET REVOLUTION

AF-KLM Group's fleet included 533 aircraft (Flightchic, 2023), 505 of which were actively engaged in commercial service. Table 10 summarizes the group fleet. The fleet includes aircraft from Airbus, Boeing, and Embraer with an average age of 13.5 years, the fleet is one of the oldest in Europe (AIRFRANCE KLM GROUP, 2024).

FLEET	168 Long-Haul	245 Medium-Haul (238 In Operation)	99 Regional (93 In Operation)	6 Cargo
TYPES	AIRBUSES, BOEING	AIRBUSES, BOEING	BOMBARDIER, EMBRAER	BOEING
AVERAGE AGE	12.2 Years	13.2 Years	8.9 Year	19.8 Years

Table 10 AIRFRANCE-KLM Group's fleet 2024

Source: Own elaboration-based data from AIRFRANCE KLM GROUP. (2024).

In the fleet, the oldest narrowbody aircraft is an Airbus A321, which has been in service for 29 years. And the oldest widebody aircraft is a Boeing 777, which has been in service for over 25 years. One of the oldest regional jets still in operation was registered in March 2004. On the other end of the scale, the youngest narrowbody jet is an Airbus A320, built in February 2018 and 5 years old. The most recent widebody acquisition is an Airbus A350, which was delivered last year (Lomas, 2023). Table 11 shows a summary of the strategies that the company is implementing.

NEW TECHNOLOGIES & FLEET REVOLUTION	**Fleet Renewal:** The company aims to reduce its CO2 by replacing its fleet with more fuel-efficient equipment. They plan to reduce fuel consumption per passenger to less than 3 Liters by 2030 and have established fleet renewal percentages to meet this goal: **2021**: 7%, **2025**: 45%, **2028:** 64%, **2030**: 70%. The company is investing over 2 billion euros annually in new-generation Airbus and Boeing aircraft (AIR FRANCE, 2023). These recently developed models are anticipated to produce an average of 15% lower CO2 emissions than the older ones (ALDEN-HULL, 2023b). **BagPRO Model Routing Optimization:** Model to optimize suitcase routing, saving time and money. This has resulted in increased safety, quality, and reduced workload due to improved data strategies. **Big Data for Proactive Component Replacement:** The airline uses big data to pre-emptively replace aircraft components before failure, improving reliability and minimizing aircraft downtime (Royal Dutch Airlines, 2022). **Artificial Intelligence (AI) to Reduce Food Waste:** the amount of food waste in Business, Premium Comfort, and Economy classes can be reduced by predicting the number of boarding passengers and calculating precise meal quantities. This results in up to 63% less food waste per flight (Media Relations KLM, 2024). **Hydrogen-Powered Aircraft:** The objective is to reduce CO2 emissions in air transportation by using hydrogen as a fuel, which includes hydrogen-electric propulsion systems and hydrogen combustion. Hydrogen combustion modifies jet engines to directly burn hydrogen, while hydrogen-electric systems use fuel cells to convert hydrogen into electricity for propulsion. The team aims to fly a manned aircraft using gaseous hydrogen, followed by liquid hydrogen in 2025. AF-KLM is actively pursuing the adoption of hydrogen-powered aircraft by 2035. Also the company launched H2 hub airport to explore the opportunities offered by hydrogen (KLM, 2023). **Electric cars:** AF-KLM will transition ground support equipment to electric power to reduce emissions and improve airport air quality.

Table 11 AIR FRANCE – KLM New technologies & fleet revolution

Source: Own elaboration based on information from Royal Dutch Airlines. (2022). ; AIR FRANCE. (2023). ; KLM. (2023).; ALDEN-HULL, M. (2023, JUN 15,).; Media Relations KLM. (2024).

ECONOMIC STRATEGIES

The Group employs various methods to assess the sustainability performance as perceived by its customers, employees, shareholders, suppliers, associations, local authorities, and civil society entities such as NGOs. The aim is to identify their expectations and views on the Group's sustainability actions. Table 12 summarise the economic strategies.

DIALOGUE WITH STAKEHOLDERS	**Engages stakeholders** to enhance its CSR efforts: by actively engaging with a broad spectrum of stakeholders to strengthen its sustainability initiatives. This includes evaluating supplier CSR performance, sharing best practices with industry peers, engaging in dialogue with shareholders, SRI (Socially Responsible Investment) investors, and rating agencies, and establishing open communication channels for employees, customers, and local communities. The Group seeks to align its efforts with national and international policies through discussions with authorities and leverages digital platforms to gather stakeholder feedback efficiently (AIR FRANCE KLM GROUP, 2024). **Air France in the SkyTeam's Sustainable Flight Challenge (TSFC):** The challenge provided a platform to implement and improve sustainability strategies. This helped create a culture of innovation and enthusiasm towards achieving a sustainable future for employees and stakeholders. (ALDEN-HULL, 2023). **The Corporate SAF Programme:** by Air France-KLM facilitates corporate customers in assessing and contributing towards their travel-related CO_2 emissions by investing in SAF procurement. This collaborative effort involves the Group, their corporate clients, SAF suppliers, and research partners, all working towards the common goal of promoting sustainable aviation (France.fr, 2023). **Intermodality:** The "Train + Air" service combining rail and plane travel reduces CO_2 emissions. Intramodality encourages customers to combine modes of transportation and access worldwide destinations from French regions. Travelers can enjoy online check-in for their entire journey without needing separate tickets (AIR FRANCE, 2024a). **Enhancing Traffic Control and Partnerships:** Working with authorities to optimize traffic control. KLM's partnership with Delta Air Lines, Air France, and Virgin Atlantic allows passengers to combine products across airlines, highlighting the power of partnerships (AIR FRANCE, 2024a). **Hydrogen Strategy H2 HUB AIRPORT:** AF-KLM, Airbus, Groupe ADP, and Choose Paris Region have jointly launched a worldwide call for expressions of interest to study the potential of hydrogen in Paris airports. The objective is to evaluate ways to reduce the carbon footprint of the aviation industry by exploring the potential of hydrogen (KLM, 2023). • **Project Phoenix:** KLM is collaborating with AeroDelft to build a hydrogen-powered aircraft. The project will focus on designing liquid hydrogen tanks and integrating crucial safety features. This puts KLM at the forefront of developing new aviation technologies (KLM, 2023). **Environmental NGOs and Foundations**: Air France-KLM collaborates with NGOs that preserve the environment and carry out carbon offset projects. These groups supervise programs to ensure they adhere to sustainability standards and minimize CO_2 emissions. **Single European Sky project.** The European Union's SES project is a bold endeavour to revamp the European air traffic management structure. As a result of these efforts, aviation emissions across Europe could be reduced by 10 % (AIR FRANCE, 2024b).

Table 12 AIR FRANCE - KLM Economic Strategies

Source: Own elaboration based on information from France.fr. (2023).; KLM. (2023).; ALDEN-HULL, M. (2023, JUN 15,).; AIR FRANCE. (2024).; AIR FRANCE KLM GROUP. (2024).

POTENTIAL OBSTACLES

In Section *2.5.3 of Chapter 2, entitled "Challenges and Barriers to SAF"* we explore the various challenges associated with adopting SAFs. Air France-KLM faces numerous obstacles as it strives towards sustainability. Vincent Etchebehere describes specific challenges encountered by the company as it advances towards sustainable aviation as follow:

1. **High production cost**: Which leads to a price disparity between SAF and conventional jet fuel (ALDEN-HULL, 2023b). However, the airline group has taken proactive measures by signing multi-year contracts with SAF providers, like Neste and DG Fuels, to integrate SAF into their operations by 2030 (Table 8). Etchebehere highlights the importance of increasing the demand for SAF as a fundamental part of the airline's strategy to encourage production growth. By becoming one of the significant consumers of SAF and utilizing 17% of the global SAF supply in 2022, The Group not only supports the SAF market but also sets an example for the industry's sustainable transformation (ALDEN-HULL, 2023b).

Furthermore, The Group acknowledges how it could affect customer demand. In a podcast, Etchebehere highlighted the need to distribute the financial burden of SAF usage fairly among all the stakeholders, which includes passengers and industry partners. This approach is aimed at managing the cost implications while continuing to make progress towards the goal of a more sustainable aviation sector (ALDEN-HULL, 2023b).

2. Limited Production Capacity: The airline is working closely with its partners and suppliers to tackle the challenge of limited production capacity for SAF and surpass the regulatory target of incorporating over 10% SAF by 2030 (Table 8). This initiative is crucial for reducing the indirect CO2 emissions across the value chain. Etchebehere has emphasized the transition is facing significant obstacles limited availability of SAF, exacerbated by the forecast of nearly doubling the number of aircraft by 2040 by Boeing. This growth poses a challenge, potentially outpacing the EU's mandate of a 6% transition to sustainable fuel due to possible severe supply shortages. In response, AF-KLM is making substantial investments in SAF, including signing off-take agreements with suppliers (Table 8 and 11). These measures are part of a broader strategy to stimulate the demand for SAF, which is crucial for scaling up future production and narrowing the cost difference between SAF and conventional jet fuel.

3. Feedstock Availability: AF-KLM has committed to using SAF that meets strict sustainability requirements. This ensures that the airline's SAF sources require minimal fresh water, do not contribute to deforestation, and do not compete with food production. The airline only uses SAF, which complies with international standards such as ASTM, RED2, and RSB. Vincent Etchebehere acknowledges that sourcing sustainable feedstocks is a challenge, citing issues with availability. For now, the airline depends on feedstocks such as vegetable oil and used cooking oil, which are relatively simpler and more cost-effective to convert into jet fuel (ALDEN-HULL, 2023b; Etchebehere, 2020).

The company intends to increase the usage of SAF by looking into different feedstocks like waste, agricultural residues, forestry residues, and combinations of CO2 and renewable hydrogen (Table 11 and 12). Although these sources have the potential for higher volumes, they require substantial development and investment to be technically and economically feasible (Etchebehere, 2020).

4. Technology Challenges: The company is implementing strategies to tackle technological challenges. The airline is presently upgrading its fleet (Table 11) (ALDEN-HULL, 2023b). However, Etchebehere has expressed worries about the strict testing protocols that are mandatory for new technologies. He stressed that any innovative solution must go through thorough assessments to demonstrate its effectiveness. The Sustainable Flight Challenge (TSFC) presents a crucial platform for this purpose, enabling comprehensive testing of novel technologies such as AI trajectory optimization, APU belt acceleration, and alternating engines. Additionally, Etchebehere highlights a paradox; the expansion of the fleet size may increase overall emissions, which would require more significant efforts to mitigate environmental impact. As a solution, the airline is investing in eco-piloting practices and new-generation aircraft. These practices include using airport electric supplies to minimize fuel consumption on the ground, single-engine taxiing with an Airbus A350 to save significant amounts of fuel and implementing AI tools during flights to optimize trajectories and ensure efficient fuel consumption (Table 11). By employing these multifaceted approaches, the company demonstrates its commitment to overcoming technology challenges and progressing towards its sustainability goals (ALDEN-HULL, 2023b).

5. Infrastructure Requirements: The airline is committed to sustainable aviation through infrastructure development, flight procedure improvement, climate change research, and sustainable biofuel production. It advocates for including aviation in agreements to strengthen infrastructure for sustainable transformation. One of the remarkable efforts is the Corporate SAF Programme (Table 12). This investment directly contributes to the development of the SAF industry, which leads to an eco-friendlier air transport system. Henri de Peyrelongue, the Commercial Sales Executive Vice President at Air France-KLM, highlights the significance of this initiative. He emphasizes that the Corporate SAF Programme showcases Air France-KLM's long-standing commitment to reducing its environmental impact. Also, this program offers corporate customers an opportunity to be at the forefront of the energy transition in line with environmentally conscious travel policies (France.fr, 2023).

6. Regulatory & Policy Support. The group is committed to going beyond regulatory mandates and is actively engaging with policymakers and industry stakeholders to influence the development of policies that support sustainable aviation (Air France-KLM, 2022; ALDEN-HULL, 2023b). Etchebehere, who understands the crucial role of employee engagement in achieving sustainability goals, acknowledges the challenge of adding sustainability to employees' already busy schedules. However, he advocates for transforming sustainability into a source of inspiration rather than an additional task, with the goal of motivating employees to feel inspired by their contributions to environmental efforts. AF KLM's participation in the SkyTeam's Sustainable Flight Challenge (TSFC) (Table 12) is an example of this approach. Additionally, he highlights the positive impact of the challenge on employee engagement across various departments, including ground operations and flight crews, emphasizing the importance of inclusive and engaging sustainability initiatives in driving AF-KLM's decarbonization efforts (ALDEN-HULL, 2023b).

Furthermore, the airlines acknowledge that integrating high-speed train travel with air journeys is complex due to logistical challenges associated with intermodality. These challenges include coordinating flight delays and ensuring seamless transitions from airplane to train. This presents significant challenges to the efficacy of intermodal transport solutions. To address these challenges, Air France has partnered with France's national rail operator, SNCF, resulting in the development of the 'Train+Air' program (Table 12). The primary objective of this program is to ensure passenger mobility in the event of delays or cancellations by providing a guaranteed free seat on the subsequent available flight or train (ALDEN-HULL, 2023b).

AF-KLM has set ambitious environmental targets for 2050 and is committed to promoting a comprehensive strategy to reduce its CO_2, which includes investing in fuel-efficient aircraft, using SAFs, and implementing operational efficiencies. By demonstrating its leadership in the aviation industry and its commitment to creating a more sustainable future, the airline shows its dedication to environmental sustainability (ALDEN-HULL, 2023b).

4.2 EASYJET

British low-cost airline founded in 1995 as a low-cost airline based in London Luton Airport. Today, it is one of Europe's leading budget carriers with a wide network of destinations (EasyJet PLC, 2024). Although cargo operations are not their primary focus, EasyJet has teamed up with DHL for ground handling services. These services include baggage handling services, and potentially, small cargo items (Mwanalushi, 2019).

In 2019, the airline introduced EasyJet Holidays to provide customers with customizable holiday packages that meet their preferences and budget. Unfortunately, the launch of this new service coincided with the COVID-19 pandemic which severely impacted the industry. Nonetheless, EasyJet Holidays partnered with Voucherify to overcome the pandemic's disruptive effects (Voucherify, 2020).

In 2023, EasyJet rebounded from COVID-19 losses and achieved profitability. The airline's revenue increased by nearly 9.6 billion Euros (Statista, 2024b) and an operating profit of 530 million Euros (Statista, 2024a). The company is now the second-largest low-cost carrier in Europe, surpassed only by Ryanair (Informa Markets, 2023).

The airline is committed to upholding sustainability standards, exemplified by its adherence to the EU's SAF usage increase mandate. Such practices showcase the company's progressive mindset towards air travel. With a fleet of 336 Airbus aircraft, they service over 1,100 routes spanning 35 countries. The airline employs a workforce of over 16,000 individuals. In the past year, they have successfully transported over 90 million passengers (OAG Route Mapper, 2024). EasyJet is committed to achieving net-zero carbon emissions *through a variety of initiatives, such as upgrading its fleet, enhancing operations, modernizing airspace, utilizing SAF and Residual removal* (EasyJet Press Office, 2022)

ROADMAP BY 2050

EasyJet has unveiled an ambitious sustainability roadmap to achieve net-zero carbon emissions by 2050. The Sustainability Director, Jane Ashton, is leading the initiative. She has extensive experience in sustainable tourism and leisure travel management across Europe. Ashton's expertise informs a vision for sustainable tourism that ensures commercial success while upholding social value and environmental boundaries (Alden-Hull, 2023a). To achieve its interim goal of reducing well-to-wake CO2 by 35% by 2035, EasyJet PLC plans to implement several strategies. These strategies include renewing its fleet with NEO aircraft, modernizing airspace, increasing its use of SAF, and improving operational efficiency (Alden-Hull, 2023a; EasyJet PLC, 2022). The company has updated its strategy to include zero carbon emission aircraft in its approach towards 2050.

1. **Zero carbon emission Aircraft (31%):** Committed to be an early adopter in transitioning the fleet.
2. **SAF (26%):** Scale at or above proposed Refuel EU mandates. (Table 13)
3. **Fleet renewal NEO (13%):** Transitioning to more fuel-efficient planes and utilizing larger aircraft, offering greater fuel efficiency and lower emissions per passenger (Table 16).

4. Airspace modernization (7%): reduction through Single European Sky and modernisation of UK airspace

5. Operation efficiency (1%): Initiatives such as washing and single engine taxi contribute to fuel savings. (Table 14).

6. Residual removal (22%): To achieve Net Zero by 2050, all remaining emissions will be eliminated (EasyJet, 2022).

It is important to emphasize that the percentages presented in this roadmap are based on thorough analytical and investigative work and have yet to be officially validated by EasyJet. As a result, these numbers may differ from the actual data (Annex 7). A comprehensive analysis, aligned with Refuel EU and EasyJet PLC's strategies, will be conducted to explore further these initiatives and its implications for EasyJet's 2050 sustainability goals.

GREEN FUEL SAF

The company described itself as dedicated to leading the way towards positive change for our planet, communities, and people. Every day, they strive to take one step closer to achieving net zero (EasyJet PLC, 2024). In collaboration with industry leaders like Airbus, Rolls-Royce, GKN Aerospace, Cranfield Aerospace Solutions, and Wright Electric, EasyJet is striving to accelerate the advancement of zero-emission aircraft technology (EasyJet Press Office, 2022). The production of SAF by the airline involves the utilization of numerous sustainable feedstocks, which comprises a range of sustainable resources such as municipal solid waste, used cooking oils, and animal fat waste. Table 13 provides a comprehensive summary of the SAF milestones that span from 2019 to 2050 in the company. This table offers a valuable overview of the significant accomplishments achieved by the SAF initiative over the years, and the noteworthy goals that have been set for the future.

YEAR	MILESTONE
2019	EasyJet has been the very first airline to counterbalance carbon emissions from all flights within its network. This was made possible by their carbon offsetting initiatives and by partnering with Airbus to explore hydrogen and electric aircraft concepts through the ZEROe program. (Informa Markets, 2023).
2021	The initial SAF flight with a 30% blend was successfully showcased from London Gatwick (EasyJet PLC, 2022).
2022	Rolls-Royce and EasyJet have successfully run a modern aero engine using green hydrogen produced from wind and tidal energy. This is a crucial step towards demonstrating hydrogen's potential as a zero-carbon aviation fuel. And EasyJet took a leading role in the formation of the Hydrogen in Aviation (HIA) alliance. The company signed long-term SAF offtake agreements with fuel suppliers to receive SAF from Q8 Aviation until 2027 (Informa Markets, 2023).
2023	EasyJet has secured a contract with Airbus to aid in the advancement of Direct Air Carbon Capture and Storage (DACCS) technologies. This involves EasyJet receiving carbon removal credits from the 1PointFive DACCS facility in Texas between 2026 and 2029 (EasyJet PLC, 2022).
2035	Set an interim target of a 35% carbon emissions intensity improvement
2050	committed to reducing emission intensity by 78% to achieve net-zero carbon emissions from air travel using 63% SAF (EasyJet PLC, 2022).

Table 13 SAF Milestones in EASYJET

Source: Own elaboration based on information from EasyJet PLC. (2022).; Informa Markets. (2023).

IMPROVING OPERATIONS AIR TRAFFIC MANAGEMENT (ATM).

Managing airspace in an efficient manner is crucial for reducing emissions in the aviation industry. This is because shorter flight paths can significantly reduce flying times and minimize the environmental impact. EasyJet is currently collaborating with key stakeholders and public authorities to promote the modernization of airspace. These joint efforts include taking part in initiatives like the SES, which is essential for establishing a more environmentally friendly and efficient air traffic management system (EasyJet Press Office, 2022).

AIR TRAFFIC MANAGEMENT	**Training in sustainability:** Staff completion rates of sustainability training modules are high, reflecting strong organizational commitment to sustainability. Cabin crew members completed the new module with a 99.8% rate, and engineering staff achieved a 79% completion rate for training initiated in 2023. **Single Engine Taxiing:** The airline uses single engine taxiing wherever possible, as does many other carriers. **New entrant course for cabin crew:** they receive training on waste segregation and recycling. 58.5% of the materials generated during a flight are recyclable (EasyJet Press Office, 2022).
	MORE RESPONSIBLE CATERING **Reducing Single-Use Plastics:** EasyJet removed 36 million single-use plastic items from its flights and is committed to recycling residual waste and reducing environmental impact further. **Sustainable Uniforms:** Crew uniforms made from recycled plastic bottles, diverting 2.7 million bottles from landfills and oceans in the next 5 years. The uniforms use a sustainable fabric produced with renewable energy. **Sustainable Supplier Selection**: EasyJet prioritizes sustainability in supplier partnerships for onboard offerings, preferring brands committed to reducing plastic usage and carbon emissions. **Food Production:** EasyJet has shifted food production closer to its operation points, reducing the distance products travel, lowering the carbon footprint associated with transporting onboard food items (EasyJet Press Office, 2022).

Table 14 Strategies in EASYJET operations air traffic management (ATM).
Source: Own elaboration based on information from EasyJet Press Office. (2022).

NEW TECHNOLOGIES & FLEET REVOLUTION

EasyJet possesses a modern and energy-efficient fleet of narrow-body jets, which are among the newest in Europe. As a matter of fact, EasyJet is the second biggest operator of A320neo family planes in Europe, (LG is the first). These aircraft are 15% more fuel-efficient than their predecessors and generate 50% less noise (EasyJet Press Office, 2022).

FLEET	336 Short Hauls (Statista, 2024c)
TYPES	AIRBUSES (EasyJet Press Office 2022).
AVERAGE AGE	10.7 YEARS (Airfleets, 2024)

Table 15 EASYJET's Fleet 2024
Source: Own elaboration based on information from EasyJet Press Office. (2022).; Airfleets. (2024).; Statista. (2024).

EasyJet has become a prominent player in the European short-haul air travel market, offering travellers economical flights to the most popular destinations on the continent for the past 25 years (EasyJet PLC, 2024). The oldest aircraft model in the fleet is the Airbus A319, which has been in service for 18 years. On the other hand, there are five brand new Airbus A320neo aircraft, delivered in 2024, making them the youngest additions to the fleet. Additionally, new aircraft orders are scheduled for delivery in the same year, indicating the company's continued efforts to modernize the fleet with more efficient and environmentally friendly options (Planespotters, 2024a). The company is also investing in new technology and fleet revolution, Table 16 summarizes the key point that the company is taken to reduce CO2.

NEW TECHNOLOGIES & FLEET REVOLUTION	**Fleet renewal with NEO:** EasyJet has secured the delivery of 213neo (New Engine Option) Airbus aircraft, which will allow it to complete its fleet replacement program and replace half of its older A320ceo aircraft (between year 2029-34). The upcoming airplane will have a higher level of technological advancement, leading to significant fuel and carbon efficiencies. This will aid in achieving net zero pathway. **Rolls-Royce – hydrogen propulsion systems:** EasyJet, in partnership with Rolls-Royce and endorsement of Airbus' ZEROe program, is working on developing hydrogen turbofans and a hydrogen-powered combustion engine. The main objective is to work on the modification of existing aircraft engines to run on hydrogen (EasyJet PLC, 2024). The modification can be achieved either by burning hydrogen in a turbofan or by adapting a gas turbine for green hydrogen combustion (Alden-Hull, 2023a). **Implemented AI with Descent profile optimisation:** EasyJet is now the world's largest operator of Descent Profile Optimization (DPO) technology, with 332 of its aircraft equipped with the system. DPO reduces fuel consumption, carbon emissions, and noise pollution around airports, demonstrating. **Advanced analytics with Sky Breathe fuel management tool:** It is an eco-flying software that analyses flight data to identify fuel-saving opportunities throughout different stages of a flight: - Aircraft save fuel by using single-engine taxiing during arrival and departure instead of using both engines for ground operations. - Real-time route adjustments are made using advanced weather data to avoid bad weather conditions and take advantage of favourable winds. - Engine washing improves air turbine performance by removing debris, leading to better fuel efficiency and reduced emissions. **Electric vehicles:** Working in Berlin on a project to establish electric charging stations and transition the entire vehicle fleet in the city to electric power by the end of 2024. The replacement of vehicles with electric alternatives will be phased in as per their availability. The UK is also collaborating to shift towards electric vehicles with the supplier (EasyJet Press Office, 2022).

Table 16 EASYJET New Technologies & Fleet Revolution

Source: Own elaboration-based information from EasyJet PLC. (2022).; Alden-Hull, M. (2023, Jul 20).; EasyJet PLC. (2024).

ECONOMIC STRATEGIES

EasyJet is a significant player in the aviation industry and operates in a complex economic and regulatory landscape. The company has taken a significant step towards sustainable aviation by working closely with diverse stakeholders. This collaboration has enabled EasyJet to drive real change, aligning with its economic interests and its commitment to reducing its environmental impact (EasyJet Press Office, 2022). Table 17 provides a summary of the economic strategies that EasyJet has implemented.

DIALOGUE WITH STAKEHOLDERS

Leadership in the Hydrogen in Aviation (HIA) Alliance: As part of the HIA alliance's founding members, EasyJet is working together with distinguished UK organizations such as Airbus, Rolls-Royce, GKN Aerospace, Bristol Airport, and Ørsted (operating under Cranfield Aerospace Solutions) to promote aviation with zero carbon emissions (project HEAVEN and LH2GT). They aim to improve infrastructure, policies, and safety frameworks for the widespread adoption of hydrogen aviation.

Founding Board Membership of Hydrogen Southwest (HSW): EasyJet is partnering with HSW to explore the potential of Bristol Airport as a central hydrogen hub. They are evaluating local and international hydrogen supply chains, assessing the demand for hydrogen-powered aircraft, and investigating the feasibility of using Bristol Airport's hydrogen supply for various transportation needs. The partnership aims to promote sustainable energy sources across multiple modes of transportation (EasyJet, 2023a).

Fuel and Emissions Savings Initiatives: Fuel and emissions can be reduced through operational initiatives in partnership with Skywise and SESAR (Single European Sky ATM Research), Airbus, and Collins Aerospace.

H2Zero initiative: EasyJet and Rolls-Royce have joined forces to launch this, which aims to investigate the potential of hydrogen as a fuel for aviation. The project is anticipated to be up and running by the mid-2030s (Alden-Hull, 2023a).

EasyJet holidays: It is a sustainability strategy for all consumers has three pillars: creating affordable and accessible sustainable travel, maximizing benefits, and minimizing negative impacts of tourism, and embedding sustainability into business decisions. the company offers sustainable holiday choices that don't compromise on affordability, allowing more people to make eco-friendly travel decisions. This is possible a collaborative effort:

- Partnered with the Global Sustainable Tourism Council (GSTC) to sponsor training for hotel partners in sustainable tourism practices (GSTC, 2023).
- Collaboration with the Travel Foundation and the University of Oxford to expand research, build partnerships, and enhance hotel certifications, with a focus on positively impacting destination communities.
- Partnered with UNWTO (United Nations World Tourism Organization) and Oxford Uni to create an ESG (Environmental, Social, and Governance) framework for tourism businesses. This tool will measure their impact on people, planet, and prosperity, and promote sustainable tourism practices (EasyJet, 2023b).

Industry Engagement: EasyJet Holidays works together with European and UK partners to tackle CO_2 emissions and encourage the development of zero-carbon aviation. This includes joining the **Jet Zero Council**, which promotes innovation towards this goal.

- EasyJet is utilizing cutting-edge software and AI technology to enhance its operational effectiveness and sustainability. The airline has established strategic collaborations with prominent aviation organizations such as Airbus, Collins Aerospace, NATS (National Air Traffic Services), and Eurocontrol to improve aircraft fuel efficiency, optimize flight routes, and minimize environmental footprints (EasyJet Press Office, 2022).

Single European Sky: which is essential for establishing a more environmentally friendly and efficient air traffic management system

Table 17 EASYJET Economic Strategies

Source: Own elaboration based on information from GSTC. (2023).; EasyJet. (2023).; EasyJet. (2023).; Alden-Hull, M. (2023, Jul 20).; EasyJet PLC. (2024).

POTENTIAL OBSTACLES

As a sustainability advocate, Jane Ashton acknowledges the many advantages that travel can bring, including fostering connections and cultural exchange and driving economic growth. However, she also recognizes the pressing need for the aviation industry, with high carbon emissions to address the challenge of reducing their carbon footprint amidst the escalating climate crisis. Ashton highlights the growing trend of investors, regulators, and consumers favouring environmentally friendly travel options, which makes it commercially viable to prioritize reducing the environmental impact. To this end, she recommends a strategic approach focusing on significant carbon reduction by adopting new technologies and innovative business practices (Alden-Hull, 2023a).

According to Ashton, SAF is a viable short-term solution for reducing emissions, but reaching "true zero" requires using hydrogen fuel. While SAF offers an impressive 80% decrease in emissions compared to conventional jet fuels, Ashton asserts that hydrogen's emission of mainly water vapor presents the ultimate solution for completely eradicating emissions within the aviation sector. She also recognizes the use of SAF or hydrogen, however, may present certain barriers to achieving net zero emissions (Alden-Hull, 2023a).

1. High Production Cost: Ashton is aware of the present state of sustainable aviation and acknowledges that although the cost of SAF is falling, it is expected to remain higher than traditional jet fuel until the mid-2030s. Despite this, she sees hydrogen as a promising long-term investment with benefits for the environment and the economy. Although, the initial costs of developing hydrogen are substantial, Ashton's strategic analysis is based on projections anticipating a significant reduction in the cost of green hydrogen up to 70% in the next decade. This could potentially make it a viable alternative to fossil fuels and position it as a competitive option (Alden-Hull, 2023a).

In line with these insights, Airbus's adoption of the NEO fleet (Table 16) is a concrete demonstration of its dedication to this investment strategy. Ashton's anticipation of the changing energy market indicates that the shift towards hydrogen is in line with the industry's environmental commitments and has the potential to generate significant financial returns as green energy market dynamics evolve (Alden-Hull, 2023a).

2. Limited Production Capacity: Addressing the constraint of limited production and maintain the ability to adapt to ensure sustainable growth. Ashton considers SAF a crucial solution in achieving immediate sustainability goals. For instance, in 2022, EasyJet entered into a five-year supply agreement with Q8Aviation to meet its medium-term SAF requirements (Table 13). In the future, Ashton predicts that between 2035 and 2040, advances in hydrogen technology could reduce the dependence on SAF to reduce CO2 emissions in aviation. This forward-thinking perspective highlights EasyJet's commitment to keeping up with technological advancements that align with its long-term vision for a more sustainable and efficient aviation industry (Alden-Hull, 2023a).

3. Feedstock Availability: EasyJet is currently exploring several options to obtain SAF. According to Jane Ashton, the airline's advocate for green hydrogen, it is crucial to achieve EasyJet's goal of transitioning to a sustainable and emissions-neutral future. EasyJet's sustainability agenda focuses on green hydrogen derived from renewable resources such as wind and tidal power. This approach guarantees environmental sustainability and resource abundance, resulting in long-term economic efficiency and aligning ecological objectives with financial prudence. As part of the H2Zero program (Table 17). Unlike grey or blue hydrogen, which is mainly extracted from natural gas and poses environmental and economic challenges, green hydrogen is generated from renewable energy sources (Alden-Hull, 2023a).

4. Technology Challenges: EasyJet is committed to sustainable aviation through technological innovation and strategic partnerships (Table 16 & 17), focusing on hydrogen as the primary fuel for the future. The airline also explores propulsion technologies, including electric options, in its hydrogen-centric approach. Wright Electric's high-power electric motors offer potential for a hybrid hydrogen propulsion system. According to Jane Ashton, EasyJet's focus on hydrogen as the cornerstone of its sustainability strategy means that a purely electric approach is currently not feasible for an airline of its scale (Alden-Hull, 2023a).

5. Infrastructure Requirements: The aviation industry heavily relies on a solid infrastructure for efficient operations. EasyJet, being proactive, collaborates with airports and regulatory bodies to improve infrastructure capabilities (Table 17). These collaborations have resulted in significant improvements, such as reducing operational delays, lower fuel consumption, and minimizing the environmental impact of aviation. Ashton state *"as the [net zero] Technologies become clearer, we need the regulatory infrastructure and incentives to enables them to scale''*. This highlights the importance of regulatory infrastructure and incentives to promote the application and growth of sustainable aviation technologies (Alden-Hull, 2023a).

6. Regulatory & Policy Support: Within the aviation sector, the impetus towards sustainable practices is significantly influenced by regulatory frameworks and policy mechanisms. EasyJet exemplifies proactive engagement in this domain, collaborating with policymakers and endorsing key sustainability initiatives, as evidenced in specific collaborative efforts detailed in Table 17. Ashton praises Jet Zero Council's efforts towards sustainable aviation and EasyJet's transparent sustainability communication strategy. She also advocates for a unified European methodology to measure and communicate the carbon footprint of flights, promoting environmental accountability and customer engagement. For instance, EasyJet's recent move to offset all carbon emissions, which will cost about £25m annually, represents a significant financial commitment to sustainable practices. However, instead of continuing with this broad-based offsetting program, the airline has changed its approach to offer customers the option to offset their emissions voluntarily.

To sum up, EasyJet has adopted a thorough sustainability plan that includes measures to reduce carbon emissions, implement technological advancements, and partner with industry leaders to address the challenging sustainability issues that confront the aviation sector.

4.3 INTERNATIONAL AIRLINES GROUP (IAG)

Established in January 2011, International Airlines Group (IAG) is a parent company that comprises some of the world's leading airlines. These include British Airways, Iberia, Vueling, Aer Lingus, LEVEL, IAG Loyalty, and IAG Cargo. IAG is headquartered in London, UK, and is registered in Spain, with its shares traded on the London and Spanish stock exchanges. The aim of merging airlines in the UK, Ireland, and Spain is to strengthen their presence in the aviation market while maintaining their brands and operations. Through this merger, customers benefit from an expanded network for passenger and cargo transport and the ability to invest in new products and services, thanks to improved financial stability (International Airlines Group (IAG), 2024). These airlines collectively operate 649 aircraft and fly to over 90 countries, 250 destinations worldwide. With more than 71,000 employees, the group serves approximately 115 million passengers annually as of 2023 (IAG, 2023).

The aviation industry faced unparalleled challenges due to the outbreak of COVID-19. IAG acted swiftly by employing various tactics, such as optimising expenses, modifying flight schedules, and temporarily grounding planes to reduce financial pressure (Rokou, 2020). Despite the impact of the pandemic, IAG exhibited strength and effective financial management, disclosing a revenue of $22.5 billion and an operational profit of $1.2 billion in 2023 (IAG, 2023).

IAG has pledged to become net zero emissions. The group has identified four key areas to achieve this goal: enhancing operational efficiency and investing in new aircraft, utilising SAF, carbon removal, and implementing market-based measures and offsets. Among these, the use of SAF is the most important, especially in the near future and following disruptive technologies (Hydrogen powered aircraft) (Badola, 2024). *IAG's comprehensive approach reflects its determination to lead the aviation industry toward a more sustainable and eco-friendly future through new aircraft and operation, using SAF, Carbon removal and market-based measure and offsets* (IATA, 2023).

ROADMAP BY 2050

IAG is dedicated to driving innovation to achieve its objectives, promote decarbonization, and encourage more extensive progress towards a sustainable industry. By 2030, IAG plans to reduce emission intensity by 27% by implementing various tactics such as CORSIA/ETS/OFFSETS, SAF, New Aircraft, and operations. Furthermore, a new strategy will be introduced by 2035 to achieve a 39% reduction involving Carbon Removals (IAG, 2023a). Ultimately, IAG aims to attain a net-zero emissions target by 2050 and will execute its roadmap using the strategies mentioned above:

1. New aircraft and operations (37%): Aircrafts of the new generation use significantly less fuel, ranging from 15-40%, compared to the older models (Table 21).

2. SAF (33%): IAG committed to achieving a target of 10% SAF by 2030 (Table 18).

3. Carbon removal (30%): Carbon removal solutions are capable of extracting CO_2 that is already present in the atmosphere and storing it biologically or geologically. Starting from 2050, IAG has pledged to rely solely on carbon removal techniques to mitigate any residual emissions that may result from its operations (Table 22).

4. Market-based measures and offsets (minimum percentage less than 10%): IAG airlines are involved in the EU, UK, and Swiss ETS programs and back the worldwide CORSIA scheme aimed at restricting net emissions from aviation(IAG, 2023a).

The IAG sustainability roadmap offers a comprehensive plan that combines internal improvements, industry partnerships, and new fuel technologies with economic measures to tackle emissions (Annex 8). The following points will present a thorough analysis of the strategies employed by Refuel EU and IAG.

GREEN FUEL SAF

IAG aims to incorporate 10% SAF into its fuel mix by 2030, surpassing the Refuel EU initiative's 6% aim. To achieve this, IAG engages in supply agreements and strategic investments, such as with Nova Pangaea Technologies, a UK-based company that converts waste into fuel. IAG has also secured SAF from Phillips 66 Limited's Humber Refinery, using feedstock of waste materials such as used cooking oil, municipal waste, or waste wood (IAG, 2023b). Reinforcing its commitment to environmental responsibility and setting a benchmark for the aviation sector (Informa Markets, 2023). Table 18 provides a summary of the company's achievements and goals in the use of SAF.

YEAR	MILESTONE
2019	The aviation group has made a groundbreaking commitment to reach net zero emissions.
2020	IAG invested in ZeroAvia to develop a hydrogen-electric powertrain program for zero-emission aviation. The investment was increased in 2022 to accelerate the program (IAG, 2024).
2021	The LanzaJet Freedom Pines project, in partnership with IAG, has opened as the first-ever plant to convert alcohol into jet SAF (Informa Markets, 2023).
2023	IAG and Microsoft have collaborated to jointly finance the acquisition of 14,700 tonnes of SAF in 2023. This amount of fuel will be adequate to power approximately 300 flights connecting London and Seattle, which will be operated by British Airways (BA). BA, LanzaJet, and Nova Pangaea signed an agreement to accelerate Project Speedbird for developing affordable SAF for commercial use in the UK (IAG, 2024).
2024	IAG has signed its biggest-ever SAF purchase agreement with Twelve, an innovative e-SAF producer which produces advanced PtL SAF made from CO2, water, and renewable energy. The agreement secures one-third of the SAF volume required to achieve its goal of incorporating 10% SAF into its fuel mix by 2030. (Hydrogen Central, 2024).
2025	IAG's '5 by 2025' sustainability plan aims to reduce waste and promote recycling across five waste streams and five business units. The plan adopts a zero-based approach towards single-use plastic (SUP) and sets targets for reducing on-board, office, cargo, and maintenance waste. Additionally, IAG aims to reduce carbon intensity by 11% to 80gCO2/pkm (IAG, 2023).
2030	SAF use will decrease emission intensity by 27% compared to 2019 baseline, accounting 10% SAF into its fuel mix.
2035	The objective is to decrease the intensity of emissions by 39%.
2040	Hydrogen aircraft will be introduced to the fleet
2050	SAF at 70% to cover of total fuel. IAG plans to reduce CO2 emissions by adopting fuel-efficient aircraft and optimizing operations, cutting emissions by 42%. SAF will contribute to a 41% reduction, and carbon removal methods will achieve a 17% reduction. = net zero emissions.

Table 18 SAF Milestones In IAG

Source: Own elaboration based on information from Hydrogen Central. (2024).; Informa Markets. (2023).; IAG. (2024).

IMPROVING OPERATIONS AIR TRAFFIC MANAGEMENT (ATM)

IAG has made a commitment to improve its operational efficiency and enhance its customers' experience. The company also supports the SES initiative which promises to reduce flight times as well as fuel consumption, thus reducing CO2 emissions. To achieve this, the company is undertaking a series of strategic initiatives, which include implementing responsible catering practices, providing comprehensive training programs for its staff, and optimizing ATM to ensure smoother and more efficient flights during the transition to SAF (IAG, 2024). Table 19 provides a summary of the strategies that IAG is implementing to optimize ATM.

AIR TRAFFIC MANAGEMENT	**Senior Leadership Sustainability Events:** Organize sustainability events for senior leadership team awareness. **Operational Emissions Reduction:** Incorporate sustainability into daily operations and business colleagues' s areas of colleagues using dashboard. **Sustainability Roadshows:** Promote sustainability strategy and encourage colleagues to take proactive actions by conducting roadshows in engineering, engagement centres, and crew areas. **Pilot Engagement on Sustainability:** specialized sustainability training module during 6-month simulator check. This will contain training on reduced engine taxi techniques, which have contributed to a 57% increase in reduced engine taxi out (before take-off) and 15% increase in reduced engine taxi (after landing) across all fleets at outstations. **Cabin Crew Sustainability Module:** Cabin crew training will include a sustainability module that aims to promote the Better World initiative and provide education on how to reduce environmental impact (BRITISH AIRWAYS, 2024).
	MORE RESPONSIBLE CATERING **"5 by 2025" plan:** targeting five waste streams and business units to decrease waste generation and increase recycling across various categories. The plan includes a zero-based approach to single-use plastic and properly disposing of hazardous waste. - Pre-flight services at airports: In airport lounges, renewable electricity is provided. To minimize food waste, pre-order meal service is offered along with vegan menus. - On-board impacts: Customers can contribute to carbon removal projects, choose vegan food, recycle onboard and option for SAF voluntarily. The airline uses SAF which is supported by IAG investment (IAG, 2024).

Table 19 Strategies in IAG Operations Air Traffic Management (ATM).
Source: Own elaboration based on information from BRITISH AIRWAYS. (2024); IAG. (2024).

NEW TECHNOLOGIES & FLEET REVOLUTION

IAG has a broad range of 649 airplanes that cover long-haul, medium-haul, and short-haul categories. The company has allocated a significant €12 billion between 2024 and 2028 to purchase 178 new, environmentally friendly planes (PLanespotters, 2024b). Table 20 provides a summary of IAG's present fleet composition.

FLEET	105 Wide-Body	105 Medium-Haul	412 Narrow Body	27 Cargo Aircraft
TYPES	AIRBUSES, BOEING	AIRBUSES	AIRBUS, BOEING, BOMBARDIER	AIRBUS AND BOEING
AVERAGE AGE	20 Years	8.9 Years	12.3 Year	6.2 Years

Table 20 IAG's Fleet 2024
Source: Own elaboration based on information from PLanespotters. (2024).

The airline has an aircraft fleet that includes a Boeing 777 which is around 27.5 years old. Recently, they added the Airbus A350neo, and Boeing which was launched in 2024 (PLanespotters, 2024b). Table 21 provides more information about IAG's ongoing initiatives and accomplishments as they move towards modernizing its fleet and adopting new technologies.

NEW TECHNOLOGIES & FLEET REVOLUTION	**Fleet renewal:** the airline has placed orders for 181 new short and long-haul (Boeing and airbus) aircraft to enhance the capacity and efficiency of their fleet. These new planes are expected to offer up to 20% more fuel efficiency as compared to the models they are replacing (Piscopo, 2022)(RYTIS BERESNEVIČIUS, 2024) **ZeroAvia (hydrogen-electric engines):** IAG has included ZeroAvia in its strategy, a company specializing in developing hydrogen-electric powertrains for aircraft. The technology employed uses hydrogen fuel cells to produce electricity, which powers the electric motors responsible for the aircraft's propulsion. **Ground transport at airports:** - Electric Buses for Passenger Transport: Emissions will be reduced by replacing diesel-powered buses with e- buses for transportation between terminals and aircraft. - Electric Mototoks for Aircraft Movement: Compact and battery powered, E- Mototoks are tugs that can tow aircraft from gates to runways. They provide a greener alternative for short-distance aircraft movement, replacing fuel-powered tugs. Also enhances operational efficiency. - Trialling Electric Trucks: Trialling electric trucks for cargo and baggage handling operations at airports to reduce CO2 emissions and achieve sustainability targets. - Renewable Electricity for Ground Power: Replaces the need for jet fuel/diesel generators. This reduces fuel consumption and emissions during ground operations. **Fuel efficiency programme:** Each airlines increase fuel efficiency and support flight planning through: - NAVlink Wind Updates: British Airways and Vueling deployed it services to plan a more efficient descent trajectory and reduce CO2 emissions per descent. - Honeywell Forge (fuel efficiency software): Improve flight planning and increase fuel efficiency. Integrates its data for real-time insights and efficient decision-making. - Pilot App: Vueling implemented it to track CO2 emissions saved during each flight and enhance decision-making. - I6 (fuel management software): It can optimize fuel usage, reduce waste, and lower emissions. - NAVflight services (flight planning services): help airlines optimize routes and flight profiles for efficient and fuel-saving operations (IAG, 2024).

Table 21 IAG New Technologies & Fleet Revolution

Source: Own elaboration based on information from Piscopo. (2022).; IAG. (2024).; RYTIS BERESNEVIČIUS. (2024).

ECONOMIC STRATEGIES

IAG collaborates with various industry stakeholders and organizations to enhance global ATM standards, which not only SAF practices but also improve the overall travel experience for passengers (IAG, 2024). Table 22 is presented to provide a summary of its economic strategies.

DIALOGUE WITH STAKEHOLDERS	**Partnerships with LanzaJet and Velocys:** IAG is investing $400 million in SAF development over the next two decades, in partnership with LanzaJet and Velocys. The collaboration will establish Europe's first facility for converting household waste into jet fuel in the UK (Polek, 2021). **SAF partnership:** IAG has collaborated with several SAF producers worldwide, including BP, Neste, Phillips 66, Repsol, CEPSA, LanzaJet, Twelve, Lanza Jet/Nova Pangaea, Aemetis, Gevo, LanzaTech, and Velocys. These partnerships ensure a secure and diverse supply of SAF, such as HEFA, Alcohol-to-Jet, PtL, and FTs (IAG, 2024). - NOVAONE: Nova Pangaea Technologies (NPT), a UK-based firm that converts agricultural waste and wood residues into bioethanol, has received investment from IAG. NPT will use IAG's backing to establish its inaugural commercial-scale waste-to-fuel production plant, making it the first such enterprise in the UK. - IAG and Microsoft have reached a co-funding agreement to purchase 14,700 tonnes of SAF produced by Phillips 66 Limited at the Humber refinery in England. The SAF is made from recycled cooking oil and food waste (Badola, 2024). **Carbon removals:** partnership with Heirloom (carbon capture start-up) and UR8 (carbon removal platform) - CO_2LLABORATE: IAG has partnered with CHOOOSE to launch a platform that enables passengers to offset the CO2 emissions from their flights. Customers can calculate their flight's carbon footprint and invest in SAF, certified carbon offsets, or carbon removal projects (BRITISH AIRWAYS, 2022; IAG, 2024). **Government-** The group is involved in the non-CO2 working group of the UK Jet Zero Council and supports research initiatives by the Rocky Mountain Institute. IAG's airlines are engaged in specific projects reducing non-CO2 climate impacts, including identifying flight paths that intersect with Ice Super-Saturated Regions, participation in the IAG'S project, conducting trials aimed at reducing contrails, and preparing for future EU ETS requirements (IAG, 2024). - UK – Jet Zero Council (JZC): is a partnership between the aviation industry and the UK Government, launched to achieve net zero -emission flights. The council comprises ministers and CEO-level stakeholders who hold regular meetings and subgroups to drive innovation to cut aviation emissions. - Spanish Alliance for Sustainable Air Transport: AST is an initiative aiming to promote sustainable aviation in Spain through collaboration of air transport industry, academia, and NGOs. Iberia played a major role in establishing AST and both CEOs of Iberia and Vueling serve as members. - Ireland: IAG and Aer Lingus are actively engaging with the Irish Government and at a European level to receive policy support and incentives for SAF production in Ireland (IAG, 2024). - IAG's participation in global initiatives like the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and its commitment to achieving net-zero CO2 emissions by 2050 (Badola, 2024). **Investors:** SAF plants' progress relies significantly on investors who provide the necessary capital for construction. IAG aims to establish 14 SAF plants in the UK within the next decade, which requires an estimated capital investment of $14 billion. To meet the demand for SAF production capacity, 250 plants are projected to be established globally, which will require a total capital investment of $250 billion. (Badola, 2024).

Table 22 IAG Economic Strategies

Source: Own elaboration based on information from IAG. (2024).; Badola. (2024).

POTENTIAL OBSTACLES

There are some possible obstacles that the company face, including:

1. High Production Cost: IAG tackles this problem by giving priority to cost optimization techniques such as effective management of the fleet, initiatives to save fuel, and streamlining its operations (Table 19). However, the cost-reduction efforts face persistent challenges due to unpredictability in fuel prices, maintenance expenses, and unexpected operational disruptions (Badola, 2024).

Jonathon Counsell, who serves as the Group Head of Sustainability at IAG, explains the financial implications that come with transitioning to SAF, which are 3-5 times more expensive than regular jet fuel. Counsell suggests that the additional cost associated with SAF, also known as "*green premium,*" will be passed on to the airline's passengers, which is critical to the industry's economic dynamics of carbon reduction. According to Counsell, *"Ultimately, the consumers of carbon-intensive products should bear the costs associated with their usage. Nevertheless, it is crucial to manage a streamlined transition free of any competitive distortions within the industry, ensuring that the costs of decarbonization are shared equitably among the airline customers.".* The goal is to distribute the costs of decarbonization fairly while maintaining a level playing field across the sector (Badola, 2024).

2. Limited Production Capacity: Currently, the aviation industry is facing a significant challenge due to SAF's limited production capacity, which is hindering its growth and operational flexibility. The Counsell has confirmed it as a pressing issue concerning the scarcity of SAF supply and the associated logistical problems with its distribution. These challenges are major hurdles in achieving universal adoption, especially in view of the global supply shortfall. This situation contrasts airlines' ambitious decarbonization objectives, creating a significant gap between aspirations and feasibility. There is an urgent need to increase its production and devise a well-planned distribution strategy to ensure the widespread availability of SAF across various operational locations. The Counsell has stressed the importance of establishing local SAF production facilities to reduce the barriers posed by geographical distribution challenges (Table 22). By doing so, airlines, including those associated with IAG, can obtain the necessary fuel to achieve their sustainability targets and facilitate the industry's transition towards lower CO2 emissions (Badola, 2024).

3. Feedstock Availability: According to Counsell, there are currently eight recognized pathways for SAF production (ANNEX 3), and six more are expected to emerge. This diversity allows for the utilization of various feedstocks and technologies, which can vary depending on the location. The use of various SAF production methods can help overcome the challenges associated with feedstock availability, making it easier to incorporate SAF into aviation operations. Counsell also emphasizes the practical benefits of SAF, noting that it is compatible with existing fueling infrastructure and aircraft. This compatibility is crucial because it eliminates the need for costly and time-consuming modifications to the current infrastructure(Badola, 2024).

4. Technology Challenges: IAG is of the view that sustainable aviation can be achieved by means of technological innovation. For this reason, the company is fully committed to undertaking extensive research and development (R&D) (Table 21 and 22). Counsell did not mention the technology challenges involved, but IAG has publicly acknowledged the obstacles associated with adopting SAF. In order to transition to SAF, it is necessary to overcome fuel compatibility issues, obtain certification, and scale up production, all of which require advanced technological solutions and significant costs. Counsell has emphasized that investors play a crucial role in promoting the adoption of sustainable aviation technologies (Table 22). This is because the production of SAF requires substantial capital investment. By maintaining frequent dialogues with investors who demand accurate and effective carbon management strategies, the company can advocate for policy advancements (Badola, 2024).

5. Infrastructure Requirements: Efficient infrastructure is essential for smooth operations in the aviation industry. Although it takes time to establish universal regulations, Counsell acknowledges the significance of interim regional and national regulations in creating facilities that produce SAF. However, such regulations must not create any disparities among airlines. IAG's primary strategic objective in this regulatory landscape is to accelerate the commercial-scale production of SAF and lower its associated costs. This demonstrates a concerted effort to navigate the complexities of regulatory environments and infrastructure demands in pursuing sustainable aviation advancements. He also recognizes the challenge of synchronizing global regulations such as the ICAO to ensure competitive equity across the aviation sector (Table 22) (Badola, 2024).

6. Regulatory & Policy Support: According to Counsell, the challenge lies in creating consistent global policies on carbon pricing and SAF mandates, which vary significantly by region. In the US, the production of SAF has been incentivized by a combination of state and federal policies. This has made the production of SAF economically feasible. In contrast, Europe has adopted a different approach, relying on carbon pricing mechanisms, such as the EU ETS, to encourage airlines to use SAF. These policy differences play a crucial role in shaping the SAF market and influencing its production and adoption. Through the establishment of strategic alliances, particularly in regions with favorable policy frameworks like the US, IAG endeavors to expedite the implementation of SAF and make significant strides towards its objective of attaining net-zero emissions. This underscores the significance of considering geographical factors when embarking on sustainability endeavors (Badola, 2024).

According to Cousell (2024), mitigating climate change for IAG is a risk management endeavor requiring diversified approaches to reducing emissions. One potential solution to achieve this is SAF, which provides inherent diversification across multiple production pathways, including municipal solid waste, alcohol to jet, HEFAs, and PTOs. This approach effectively spreads the risk associated with relying on a single methodology for emissions reduction. By embracing a multifaceted strategy that aligns with investor preferences, IAG can establish itself as a leader in pursuing ambitious environmental goals (Badola, 2024).

4.4 LUFTHANSA GROUP

The Lufthansa Group (LG), founded in 1926, has evolved into a renowned aviation conglomerate that operates globally and is recognized for its leadership in the European airline industry (Lufthansa Group, 2024b). LG's Airlines comprises of various airlines such as regional airlines, Germanwings, and Discover Airlines (LH), SWISS which includes Edelweiss (LX), Austrian Airlines (OS), Brussels Airlines (SN), Eurowings (EW), and Lufthansa Cargo (LCAG). The Group employs a strategic multi-hub system with global hubs in Frankfurt, Munich, and Zurich and national hubs in Vienna and Brussels. Moreover, Lufthansa Airlines works in closely with regional partners like Lufthansa CityLine, Lufthansa City Airlines, Air Dolomiti, and Discover Airlines - the Group's holiday airline. Edelweiss, SWISS's sister company, is known as the top Swiss holiday airline (Lufthansa Group, 2024d).

The COVID-19 pandemic presented various challenges for the LG. However, the company responded by implementing strict infection protection measures, digital document verifications, and changes in flight operations. To maintain their global competitiveness post-crisis, they embarked the "ReNew" restructuring program. Unfortunately, this program required them to make tough decisions, including cutting down 22,000 full-time positions within the LG and reducing the fleet by at least 100 aircraft (Deutsche Lufthansa AG, 2020a). Despite these significant adjustments, the LG remains committed to matching its 2024 capacity to the levels of 2019, which demonstrates their resilience and determination to recover (Deutsche Lufthansa AG, 2020b).

The company has a fleet of 721 airplanes, and the fleet's average age is 13.4 years. In the previous year, the Group accommodated over 120 million passengers and had a global workforce of 96,677 individuals, highlighting its significant role in linking approximately 310 destinations in 101 countries around the world (Lufthansa Group, 2024c). Furthermore, The Group performed well financially, generating revenues of 35.4 million euros and operating profit of 2.7 billion euros, mainly due to increased demand for air travel and excellent results from Lufthansa Technik (Lufthansa Group, 2024a).

Finally, the airline is firmly committed to environmental sustainability, as evidenced by its comprehensive strategy incorporating SAF and exploring innovative technologies such as PtL and StL. The Group invested 250 million euros in SAF procurement and actively participated in projects to increase SAF availability. *The strategy of the Lufthansa Group's is focus on the use of SAF, shift to new generation aircraft/engines, improving Operation and the use of carbon offsetting* (Lufthansa Group, 2024e).

ROADMAP BY 2050

LG has developed a comprehensive plan to become carbon neutral by 2050, which includes reducing CO2 emissions per passenger/km by 50% by 2030(Lufthansa Group, 2024b). The airline plans to achieve this by the following strategies:

1. Sustainable Aviation Fuel (65%): SAF is a great alternative to fossil jet fuels (Table 23).

2. Shift to new generation aircraft/engines (30%): LG is committed to investing in a fleet that is modern and highly fuel-efficient. The company is constantly making such investments.

Incremental changes to propulsion systems will be introduced. As well as Revolutionary technologies such as electric and hydrogen propulsion systems will be available at an industrial level starting in 2040 (Table 26) (Lufthansa Consulting, 2022).

3. Operational Excellence (3%): This area has significant potential for improvement and should be made mandatory by law to encourage airlines. It does not require significant investment and would not put financial strain on airlines (Table 24).

4. Carbon offsetting (2%): Neutralizing aviation's carbon emissions in the short and medium term can be achieved through carbon offsetting (Table 27).

It is important to understand that the percentages mentioned in this context have not been officially confirmed by the airline and are based on investigative efforts. As a result, these figures may differ from the actual ones. To gain a more in-depth understanding of the situation, a comprehensive analysis will be conducted aligning with the strategies of Refuel EU and LG.

GREEN FUEL SAF

The LG has positioned itself as one of the biggest purchasers of SAF worldwide. The company has decided to invest about 250 million dollars in the next few years to acquire an eco-friendly fuel. This fuel uses SAF that is produced from biogenic residues, including used cooking oils. Additionally, LG is implementing significant measures by expanding its supplier and partner network and establishing long-term collaborations to boost SAF production. A vital aspect of their plan involves collaborating with a top PtL crude oil production plant located in Werlte, Germany, wherein they act as a test customer. The plant manufactures PtL crude oil, which is then transformed into e-Fuel—an innovative and eco-friendly substitute for aviation fuel (Lufthansa Group, 2024e). This information is reflected in Table 23, which lists the notable accomplishments of the company in utilizing SAF.

YEAR	MILESTONE
2021	LG has partnered with the PtL crude oil production plant in Werlte, Germany. The plant is recognized for its pioneering role in producing SAFs, making it one of the first in the world to do so. As part of this partnership, LG has offered its support as a pilot customer, contributing to the plant's efforts to manufacture SAFs (Lufthansa Group, 2023).
2022	LG and Swiss Energy Group VARO Energy have signed a Memorandum of Understanding (MoU) to collaborate on the production and supply of SAF (Lufthansa Group, 2023). SAF utilization: The amount of SAF used was around 13,000 tons, which accounts for about 0.2% of the total fuel demand (Lufthansa Group, 2024e).
2023	LG and HCS Group are partnering to produce and distribute SAF. The plant will have a capacity of 60,000 metric tonnes per year and is expected to start operating in 2026 (Informa Markets, 2023).
2024	LG has partnered with Swiss firm Synhelion to produce StL fuel and is actively involved in projects to increase SAF market ramp-up and availability (Lufthansa Group, 2022).
2030	LG has set a target to decrease its net carbon emissions by 50% by 2030 when compared to the emission levels recorded in 2019.
2050	The objective is to attain CO2 neutrality (Lufthansa Group, 2024a).

Table 23 SAF Milestones in LUFTHANSA GROUP

Source: Own elaboration based on information from Lufthansa Group. (2022).; Lufthansa Group. (2023). ; Lufthansa Group. (2024).; Lufthansa Group. (2024).

IMPROVING OPERATIONS AIR TRAFFIC MANAGEMENT (ATM)

LG aims to maintain its leading market position by implementing a multi-traffic system, which includes hubs, point-to-point traffic, and intermodal offerings. The airline, as same as previous airlines, supports the SES initiative in advocating for the fast implementation of the measures throughout the EU. This system is designed to provide passengers with flexible travel options and extensive route networks. A summary of the ways to enhance the performance of ATMs is presented in Table 24.

AIR TRAFFIC MANAGEMENT	**The OPS Sustainability Program:** Improves sustainability by using a single engine during taxiing, reducing aircraft weight with lighter loading aids, and having a database for uniform emission reduction reporting. **Underground:** The company has sustainability ambassador programs on their flights. Cabin crew members are selected to increase awareness of sustainability issues among colleagues and suggest improvements. Dedicated spaces for discussions on sustainability, such as "Fly Greener briefing rooms" and "Green Corners," have been created to encourage broader employee engagement and foster a culture of sustainability.
	MORE RESPONSIBLE CATERING **Single-Use Waste Reduction:** Efforts to reduce disposable plastic and aluminium use include transitioning to reusable alternatives, innovative recycling projects like "Closed Loop" for PET bottles and replacing packaging with renewable materials. Suppliers are being involved to increase sustainable options. **Food Waste Management:** Implement a system and use AI pilot tests to optimize food loading processes. Strategies like the "to go" scheme and passenger pre-ordering options have reduced food waste significantly. **Reusable Waste Initiatives:** Efforts to promote circular resource use include successful textile recycling with SWISS. The program repurposes passenger blankets and other textiles, reducing waste and enhancing environmental sustainability.

Table 24 Strategies in LUFTHANSA GROUP Operations Air Traffic Management (ATM).
Source: Own elaboration based on information from Lufthansa Group. (2024).

NEW TECHNOLOGIES & FLEET REVOLUTION

The LG operates a varied fleet of 721 planes, which include both long and short-haul planes, apart from 29 planes dedicated to cargo. The planes range from the older Airbus A320, which has been in service for almost 29 years (Hardiman, 2024) to the newer Boeing 78, which has an average age of 4.1 years. LG is one of the largest and most experienced A320NEO Family operators worldwide and the first in Europe. In Table 25, a detailed overview of the entire fleet (Lufthansa Group, 2024c).

FLEET	396 Long-haul	325 medium- narrow body	29 Cargo
TYPES	AIRBUSES	AIRBUS, BOEING & BOMBARDIER CRJ	BOEING
AVERAGE AGE	13.6 years	13.4 year	6.2 years

Table 25 LUFTHANSA GROUP'S Fleet 2024
Source: Own elaboration based on information from Planespotters. (2024).; Lufthansa Group. (2024).

LG is investing significantly in modern, fuel-efficient aircraft and engine technologies to reduce CO2 emissions and improve the sustainability of flight operations. The company aims to add a new airplane to its fleet every ten days throughout 2024. To learn more about the new technologies and fleet revolution that the company is investing in, please refer to the following table (26) (Lufthansa Group, 2024a).

NEW TECHNOLOGIES & FLEET REVOLUTION	**Fleet Renewal and Sustainable Technologies**: This program entails a considerable expenditure on SAF, with a keen interest in green hydrogen and electric propulsion systems. The objective is to replace older, less effective models with modern aircraft that offer up to 30% better fuel efficiency and lower emissions and noise reduction. Involved in projects to accelerate the development of next-generation SAF, focusing on PtL and StL technologies. This investment includes 108 aircraft among Airbus A220, A320neo, and Boeing 737 MAXs, valued at approximately EUR 9 billion at list prices and expected to be delivered between 2026 - 2032(Lufthansa Group, 2023; Planespotters, 2024a) **Engine Management Initiative:** The goal is to increase the life of engines, enable airlines to share spare engines, and negotiate collectively for MRO (Maintenance, Repair, and Overhaul) services to improve operational efficiency and reduce costs. **AeroSHARK Surface Coating:** Lufthansa Technik and BASF have collaborated to create AeroSHARK, which replicates the drag-reducing characteristics of shark skin. The exterior of an aircraft can be physically modified to improve its aerodynamic properties using AeroSHARK app. The technology is used to improve aircraft aerodynamics, decreasing fuel consumption by approximately 1%. **Operations Decision Support Suite (OPSD):** OPS-D is a tool for managing flight operations developed in collaboration with Google Cloud. It leverages AI to optimize operational aspects, including aircraft allocation, maintenance scheduling, and seat occupancy. This tool is designed to help reduce CO2 emissions. **Electric and Alternative-Powered Vehicles:** Ground fleet operations are being improved with the use of electric and zero-emission vehicles. This includes the adoption of electric and hybrid aircraft tugs, indicating a move towards eco-friendly ground operations. **Underground Sustainable Mobility Offerings:** Encouraging employees to use electric vehicles, broadening the charging infrastructure, and promoting public transportation and bicycle leasing programs are all crucial components of a thorough approach to electromobility (Lufthansa Group, 2024a).

Table 26 LUFTHANSA GROUP New Technologies & Fleet Revolution

Source: Own elaboration based on information from Lufthansa Group. (2024).

ECONOMIC STRATEGIES

The LG recognizes the importance of engaging with stakeholders as a vital aspect of its economic strategy, particularly in integrating SAF and other sustainability initiatives. Collaboration with a wide range of stakeholders is essential in navigating the complex challenges of sustainable aviation. By promoting the adoption of SAF through partnerships and joint projects, the Group aims to align its sustainability goals with the broader industry and societal objectives and reduce the carbon footprint of air travel. Table 27 summarizes the current economic strategies of the company.

DIALOGUE WITH STAKEHOLDERS	**Green Fares and Carbon Offset Initiatives:** LG offers "Green Fares" that allows passengers to contribute to CO_2 reduction either by purchasing SAF or offsetting emissions through quality climate protection projects via platforms like Compensaid and Squake. This initiative extends to LG employees' business travels as well. **Hydrogen Technology Project:** Lufthansa Technik and the Hanseatic City of Hamburg are working together on a project to develop and test maintenance and ground processes for handling hydrogen technology. An Airbus A320 is being retrofitted with a fuel cell for onboard systems and a liquid hydrogen (LH2) distribution and monitoring unit as part of this project. This will be a major step forward in establishing a fully operational stationary field laboratory. **Atmospheric Data Collection through IAGOS:** Partnering with research institutions, the LG equips selected passenger aircraft with instruments to collect atmospheric data during scheduled flights. This data contributes to global scientific understanding of atmospheric conditions and climate change. **Contrail Avoidance Research:** The Group is involved in research initiatives such as D-KULT and the EU-funded CICONIA project with the aim of creating and testing flight planning tools that can prevent the formation of contrails, a non-CO_2 climate impactor. This involves evaluating the effectiveness of rerouted flights in avoiding contrail formation using satellite observations. **Procurement and Use of SAF:** The team procures SAF from reliable Eu suppliers, including OMV and NESTE, and combines it with fossil kerosene to utilize it at their primary airports, particularly Frankfurt. However, present regulations restrict blending of SAF to only 50%, underscoring the regulatory hurdles associated with moving to 100% SAF consumption. **SES initiative:** The organization has advocated for a unified European airspace, campaigned across the EU to safeguard overflights during air traffic control strikes, and organized 'Europe's journey to sustainable aviation' in collaboration with Boeing and Enav at the Eu Parliament. This aims to improve air traffic control efficiency across the EU and reduce CO2 emissions, fuel consumption, and flight delays.

Table 27 LUFTHANSA GROUP Economic Strategies

Source: Own elaboration based on information from Lufthansa Group. (2024).

POTENTIAL OBSTACLES

The aviation industry requires a significant increase in SAF production to meet its extensive operational demands. Currently, SAF is scarce and more expensive than traditional fossil kerosene, accounting for only 0.1 percent of the aviation industry's fuel consumption (Lufthansa Group, 2024e). The company has identified certain obstacles that need to be addressed as following:

1.High production cost: The LG is facing sustainability challenges due to various factors, such as economic instability, regulatory intricacies, and operational barriers. One of the primary regulatory obstacles is using SAF, which is affected by production capacity and high expenses. Changes in fuel prices can significantly impact earnings. This makes it difficult for European airlines to compete globally. Furthermore, legislative measures like ReFuelEU Aviation and talks about a European kerosene tax add to the disadvantage of EU-based airlines. Regulatory adjustments are necessary to maintain the competitiveness of EU-based airlines and prevent carbon leakage. To address economic uncertainties, the Group has implemented a robust fuel hedging strategy that covers gas oil, crude oil, and option combinations to mitigate the adverse effects of fuel price volatility (Lufthansa Group, 2024a).

Additionally, The LG recognizes the importance of consumer protection policies, such as insolvency protection for flights and restrictions on advance payments and no-show clauses. However, these regulations come at a cost for the Group and its clients. Despite this, the Group remains committed to upholding its environmental and operational sustainability standards and recognizes the need to navigate a complex regulatory landscape to do so (Lufthansa Group, 2024a).

2.Limited production capacity: Currently the LG is facing a pressing issue of limited production capacity. The company is aware of the necessary increase of production to meet the target which it is three times every five years for thirty consecutive years. This level of production increase is unprecedented and extremely challenging. As a result, it is unlikely that SAF will be available on an industrial scale in the near to medium-term.

To make matters worse, supplier risks resulting from the current geopolitical climate and disruptions in global supply chains are compounding the problem. These risks include factors such as the energy crisis, raw material scarcity, labor shortages, and supplier insolvency, which all threaten the Group's ability to receive uninterrupted supplies of goods and services, potentially jeopardizing business operations. The Group is also anticipating significant price hikes and, as a result, has shifted its focus towards vigilant supplier risk management practices. To tackle these challenges, the LG regularly identifies and assesses suppliers crucial to business continuity. The Group engages in ongoing dialogues to prevent supply interruptions and takes strategic measures, such as adjusting payment terms, conducting regular contract reviews, and implementing a risk visualization and management system for supply chain disruptions (Lufthansa Group, 2024a).

3. Feedstock availability: LG CEO Carsten Spohr has raised concerns about the aviation industry facing significant challenges related to feedstock availability. He worries about the feasibility of meeting blending quotas due to current limitations and he has also expressed concerns about the potential financial implications for passengers due to the increased cost of SAF. To overcome these obstacles, LG is actively researching innovative SAF technologies, including PtL and StL processes (Table 26), which are still in the early stages of development. Despite this, these technologies represent a forward-thinking strategy to overcome the scarcity of feedstock and the high costs associated with conventional SAF production methods (Reuters, 2023).

4. Technology challenges: By modernizing its fleet (Table 26), the Group can increase profits, take advantage of favourable purchasing options, and address the supply chain bottlenecks of SAF. However, incorporating digitalization and sustainability into its services while modernizing its fleet may pose cybersecurity risks. To address potential cyber threats, LG needs help in its efforts to digitize its business processes. The airline has developed a robust cybersecurity program to mitigate these risks and regularly monitors its performance using external cybersecurity ratings (Lufthansa Group, 2024a). Another different barrier is Hydrogen has a higher energy density and is an excellent replacement for SAF, but it requires high capital investment for storage and delivery. Despite short-haul electricity-powered flights are a viable option, large-scale electric flights are not feasible due to low energy density.

5. Infrastructure requirements: The future growth of the aviation industry is closely linked to global politics and macroeconomic trends. The supply-side challenges, such as limited infrastructure and supply chain restrictions, the geopolitical tensions resulting from the Russian-Ukrainian conflict, and the increasing focus on climate change, have led to a significant shift in demand. The aviation sector's historically high expansion rates are expected to be more moderate in the long run, resulting in even more intense competition in the airline market. Adapting to the changing market environment will challenge the LG and the industry (Lufthansa Group, 2024a).

6. Regulatory & policy support: The LG faces challenges in complying with the EU's climate agenda, which may lead to higher operational costs and affect the competitive balance. The Group needs to be strategically agile to navigate the increased fuel costs, investment requirements in SAF, and the broader implications for global competitiveness. Additionally, the draft regulation for the SESS (Table 27) can be affected by ongoing political deliberations may hinder the implementation of these benefits, adversely affecting the punctuality and regularity of European air traffic (Lufthansa Group, 2024a).

Furthermore, the LG is facing operational challenges due to a surge in flight demand. To address this, the company is taking measures to improve working conditions, recruitment processes to boost employer attractiveness and sustain workforce morale. As the demand for sustainable travel options and carbon offsets continues to grow, LG anticipates continued growth in the airline industry despite global challenges like resource shortages and inflation. In response to climate concerns and regulatory demands, they need to accelerate the transition to low or zero-emission technologies due to the resurgence in market consolidation within the European airline sector. As part of its ongoing efforts to achieve sustained profitability, the airline fosters a culture of cooperation and efficiency. Regarding financial stability and reduced costs, the Group is well-positioned to take advantage of favourable market conditions, including fuel price and exchange rate changes. By combining market adaptation, technological advancement, internal efficiency, and financial prudence, the LG targets growth and profitability in the evolving aviation market(Lufthansa Group, 2024a).

4.5 RYANAIR

Ryanair Holdings PLC is a major player in the airline industry, with its headquarters in Swords, Dublin, Ireland. The airline has the highest number of passengers in Europe, making it the largest airline group on the continent. Ryanair was founded in 1984 and was renamed Ryanair Holdings PLC in 1996. Its strategic approach to ultra-low-cost air travel has enabled it to expand from being a regional airline to a significant force in the aviation market. This business model has not only revolutionized air travel affordability but has also significantly impacted the dynamics of the aviation industry (Informa Markets, 2024).

Additionally, Ryanair Holdings is a large conglomerate that comprises multiple subsidiaries such as Ryanair DAC, Malta Air, Buzz, Lauda Europe, and Ryanair UK. The company operates a vast fleet of over 500 aircraft, which serves more than 240 destinations across 40 countries in Europe, North Africa (including Morocco), and the Middle East (including Israel and Jordan). Ryanair Holdings' primary operational hubs are strategically located at Dublin, London Stansted, and Milan Bergamo airports to facilitate its extensive network (Ryanair, 2024a).

The company has demonstrated exceptional adaptability and resilience throughout its history, particularly during the COVID-19 pandemic. To effectively manage the pandemic's unprecedented challenges, the airline took decisive actions such as grounding surplus aircraft, deferring capital expenditures, freezing recruitment, and providing voluntary leave options. Despite reducing seat capacity by up to 80% in 2019 and facing the possibility of a full grounding of the fleet, Ryanair was on the path to recovery and restored flights to 80% of pre-pandemic levels by July 2021 (Jolly, 2021; Ryanair, 2020).

In the fiscal year 2022/23, Ryanair demonstrated an impressive performance by carrying 169 million passengers, representing a 74% increase from the previous year. With a workforce of approximately 19,000 employees, the airline achieved a revenue of €11.221 billion and a net income of €1.314 billion, showcasing its strong recovery and growth trajectory (Statista, 2023; Zacks Investment Research, 2024).

The airline is leading the aviation industry in sustainability by committing to power 12.5% of its flights with SAFs by 2030. According to this approach, Ryanair seeks to shift its focus to greener technologies and practices in its main strategies. *These strategies include increasing SAF usage, technological and operational improvements, and offsetting and other economic measures* (Ryanair, 2024b).

ROADMAP 2050

As part of its commitment to achieve a net zero goal by 2050, Ryanair has established carbon intensity targets for the upcoming years (FY26 and FY31) to monitor its progress. The main objective is to ensure the company's ability to continue facilitating travel across Europe for business, pleasure, and personal connections while simultaneously operating sustainably in line with the goal of limiting global warming to 1.5°C. Based on its prior successes in implementing efficient measures, Ryanair has developed a plan that outlines the actions it is currently undertaking and will take in the future to support this goal. According to the map, the airline aims to reduce CO2 emissions per pax/km by 50% by 2031. The company is utilizing technological advancements, implementing SAF, introducing air traffic reform, and offsetting to reach its target. In the coming years, Ryanair has pledged to develop these four pillars further as part of its commitment to achieving sustainability and meeting its target by 2050 (Ryanair Group, 2023).

1. **Use of SAF (34%):** Ryanair considers SAF as a key factor in the aviation industry's shift to becoming more sustainable (Table 28).
2. **Technological and Operational Improvements (32%):** This approach includes investments in modern aircraft, optimized flight routes, and refined maintenance practices (Table 29 and 31).
3. **Introduction of the Single European Sky Initiative (10%):** The company believes collaboration with regulatory bodies is essential to bring about structural changes and accomplish environmental objectives on a larger scale (Table 32).
4. **Offsetting and Other Economic Measures (24%):** The airline is taking measures to address its carbon footprint by implementing carbon offset programs and other economic strategies. This approach helps them to achieve their overall sustainability goals (Table 32) (Ryanair Group, 2023).

In synthesizing these components, Ryanair's sustainability roadmap presents a holistic strategy that integrates internal advancements, sector-wide collaborations, and innovative fuel technologies with economic mechanisms to address emissions (Annex 9). A more detailed analysis will be provided in accordance with Refuel EU and Ryanair's strategies.

GREEN FUEL SAF

Ryanair recognizes the significance of SAFs in mitigating environmental impact and aims to have SAF contribute approximately 34% towards achieving its 2050 net-zero emissions target. The airline has been procuring SAF from OMV. The fuel is produced by co-processing sustainable and regional raw materials, which include used cooking oil. (Ryanair Group, 2023). Table 30 presents a comprehensive overview of the significant progress in using SAFs throughout the years.

YEAR	MILESTONE
2021	**Sustainable Aviation Research Centre (SARC):** Ryanair and Trinity College Dublin have launched the SARC. The centre will research SAF sustainability, accelerate certification, evaluate zero-carbon propulsion systems, and develop noise maps for low-noise aircraft (Ryanair, 2024b).
2023	The airline has signed agreements with suppliers to provide SAF at airports across Europe with major suppliers like Neste (Schiphol), OMV (Austria, Germany, and CEE) and Shell (in London and Dublin) by announcing a multi-year Memorandum of Understanding (MOU) with Repsol to supply Ryanair bases in Spainn and Portugal, providing up to 155,000 tonnes of SAF between 2025 and 2030. All Ryanair flights departing from Amsterdam will be powered by a blend of 40% SAF and traditional fuel supplied by Neste (Informa Markets, 2023).
2030	Ryanair targets 12.5% SAF (Informa Markets, 2023)
2050	34% SAF: Ryanair plans to increase the use of SAF. = Ryanair Path to Net Zero emission (Ryanair Group, 2023).

Table 28 SAF Milestones in RYANAIR GROUP

Source: Own elaboration based on information from Ryanair Group. (2023); Informa Markets. (2024); Ryanair. (2024).

IMPROVING OPERATIONS AIR TRAFFIC MANAGEMENT (ATM)

In order to reduce CO2 emissions and enhance operational efficiency, Ryanair has adopted several ATM improvements. Ryanair has implemented or supported some key strategies to achieve these goals, as shown in Table 29

<table>
<tr><td rowspan="2">AIR TRAFFIC MANAGEMENT</td><td>Sustainability team: Responsible for sustainability at Ryanair oversees and executes the company's sustainability strategy, ensuring they meet the requirements of carbon trading schemes, procure SAF blends, track emission savings for new projects, and provide frequent updates to the Sustainability Committee. They report to the CFO of the Group and have a secondary reporting line to both the Board and Audit Committee.
Continuous Descent Operations (CDOs) and Continuous Climb Operations (CCOs): Optimized descent and climb profiles minimize fuel burn and emissions by maintaining continuous, smooth descents and climbs, reducing unnecessary level flight phases.
Direct Flight Routes and SES: The airline favours the SES initiative to reform European airspace to reduce flight distances and times (Ryanair Group, 2023).
Fuel-Efficient Flight Operations: Pilots can be trained in fuel-efficient flying techniques that significantly reduce CO2 emissions. These techniques include managing optimal altitude and speed (Ryanair Group, 2021)</td></tr>
<tr><td>REDUCING WASTE
Ryanair is taking steps to reduce waste on its flights by using biodegradable cups and wooden cutlery and increasing the use of paper packaging. The aim is to reduce the use of plastics in various in-flight products, contributing to waste reduction and environmental conservation (Climate Action, 2018).</td></tr>
</table>

Table 29 Strategies in Ryanair Group Operations Air Traffic Management (ATM).
Source: Own elaboration based on information from Climate Action. (2018).; Ryanair Group. (2021).; Ryanair Group. (2023).

NEW TECHNOLOGIES & FLEET REVOLUTION

Ryanair possesses a varied fleet that comprises 622 airplanes used for long, medium, and short-haul flights, including cargo transport. The oldest plane in their fleet is the Boeing 737, with a remarkable 19.6 years of service. In contrast, the newest addition to their fleet is the Boeing 737 MAX 8, which is less than a year old (Planespotters, 2024). The company has also placed orders for more brand-new planes. For a comprehensive insight into the fleet composition and the corresponding average age, please refer to Table 30.

FLEET	105 Long-haul	105 Medium-haul	412 narrow body	20 Cargo
TYPES	AIRBUSES, BOEING	AIRBUSES	AIRBUS, BOEING, SERIES	AIRBUS, BOEING
AVERAGE AGE	20 years	8.9 Years	12.3 year	6.2 years

Table 30 RYANAIR's Fleet 2024
Source: Own elaboration based on information from Planespotters. (2024).

Ryanair is investing in greener, more efficient aircraft to reduce carbon and noise emissions (Ryanair Group, 2023). Table 31 displays Ryanair's latest technological advancements and fleet upgrades for better comprehension.

NEW TECHNOLOGIES & FLEET REVOLUTION	**Fleet Renewal with Advanced Aircraft:** The company has committed $40 billion to purchase 300 new Boeing 737'Gamechanger' planes and Boeing 737 MAX 10 aircraft, which are equipped with advanced technology winglets and efficient engines. This aircraft consumes up to 20% less fuel than their predecessors, emitting fewer emissions, producing 50% less noise and increase 21% greater passenger capacity. Delivery expectation end of 2034 (Ryanair, 2024c). **Technological Enhancements:** Ryanair and Aviation Partners Boeing (APB) have agreed to equip their 409 Boeing 737-800NG aircraft fleet with retrofit technology. The installation of this upgrade is expected to result in a reduction of carbon emissions and fuel burn by around 1.5% and decrease take-off noise by 6.5% and NOx emissions by 8%. **Vehicle Electrification:** Ryanair works with its handling partners to implement the use of electric vehicles. In recent years, the air company has been introducing electric ground handling at more and more airports it services. **Operational Efficiency in Flight:** Single-engine taxi (SETI) and Continuous Descent Approach (CDA). SETI involves taxiing with only one engine running after landing, saving fuel, and reducing emissions. CDA allows for a continuous, smooth descent from cruising altitude to landing, minimizing fuel burn and noise pollution, with SETI used in 77% of flights and CDA in approximately 80% (Ryanair Group, 2023). **Ryanair Labs**: operates as a technology hub, which in turn supports Ryanair's initiatives to reduce CO2 emissions using digital transformation and technological innovation. The Labs works towards developing software that optimizes flight routes, improves fuel efficiency, and utilizes data analytics to identify operational efficiencies, all of which help to reduce the airline's carbon footprint.

Table 31 RYANAIR New Technologies & Fleet Revolution

Source: Own elaboration based on information from Ryanair Group. (2023). ; Ryanair. (2024).

ECONOMIC STRATEGIES

Ryanair plans to achieve carbon neutrality by 2050 by collaborating with the European Commission, national governments, the Fuelling Flight Project, and fuel suppliers to invest in SAF. The airline is utilizing various approaches, such as policy advocacy, strategic partnerships, and economic incentives to encourage the adoption of SAF and establish itself as a leader in environmental sustainability in the aviation industry (Ryanair Group, 2023). The economic frameworks and partnerships Ryanair is employing are outlined in Table 32.

DIALOGUE WITH STAKEHOLDERS	**Aerodynamic Improvements:** Ryanair collaborated with Boeing's aviation partners (APB) to equip its fleet of 409 Boeing 737-800NGs with split scimitar winglets installed to minimize drag and lessen fuel consumption. **SAF initiatives:** The airline is a key player in the fuelling flight project, advocating for adopting SAF. This involves lobbying the European Commission, national governments, and fuel suppliers for supportive policies and investments in SAF to accelerate the industry's progress towards net-zero carbon emissions by 2050. **SAF supplier:** Ryanair has established agreements with several SAF suppliers, enabling the airline to access SAF at major airports. The agreements are in place with Shell, OMV, Repsol, and Neste. Ryanair expects to fulfil 70% of the airline's SAF usage goal, which aims to achieve 12.5% SAF usage by 2030. **Operational advocacy for overflights:** Ryanair is promoting policy changes that allow overflights during air traffic control strikes to keep EU skies open and reduce unnecessary emissions. Throughout the petition "Protect Passengers - Keep EU Skies Open''. **SES initiative:** The organization has advocated for a unified European airspace, campaigned across the EU to safeguard overflights during air traffic control strikes, and organized 'Europe's journey to sustainable aviation' in collaboration with Boeing and Enav at the Eu Parliament. The initiative aims to improve air traffic management, resulting in reduced emissions, optimized flight routes, and improved airspace usage. **Customer sustainability awareness:** Ryanair provides for its customers to offset their carbon emissions by participating in the Ryanair Customer Offset Scheme. The scheme includes several offsetting initiatives such as methane capture in Bulgaria, a wind power plant project in Turkey, distribution of cookstoves in Nepal, and reforestation in Portugal. **Sustainability committee**: Led by the director of sustainability. This committee, which includes members from various sectors, meets once a month at the executive level to ensure a comprehensive approach to environmental stewardship. Among its major accomplishments are significant reductions in emissions through initiatives like the adoption of dynamic flight plans and the implementation of single-engine taxi-in policies. **Research and development:** Ryanair and Trinity College Dublin are collaborating on sustainability initiatives to reduce the airline's environmental impact. They have developed a pre-screening tool to simplify the SAF certification process and improved aircraft fuel burn prediction models. They have also created a simulation model to assess and improve noise reduction strategies at Dublin Airport.

Table 32 RYANAIR Economic Strategies

Source: Own elaboration based on information from Ryanair Group. (2023).

POTENTIAL OBSTACLES

In its efforts to integrate SAF into its operations, Ryanair encounters several obstacles that mirror broader challenges facing the aviation industry in its transition to more sustainable practices.

1. **High production cost:** Ryanair admits that SAF pricing is currently uncompetitive, posing a challenge to producing advanced types of SAF in large quantities. To bridge the price gap between SAF and jet kerosene, Ryanair recommends financial measures such as providing financial aid for SAF production research and innovation, utilizing ETS auction revenue to encourage airlines to use SAF (when sufficiently funded), and implementing contracts for difference (when reasonably funded) to support SAF commercialization and create price certainty to encourage more investment (Ryanair Group, 2021, 2023).

Furthermore, the company recognizes that the implementation of the Fit for 55 regulations may lead to higher costs in the air travel industry within the EU. Nevertheless, Ryanair's fuel efficiency and pioneering efforts in reducing carbon emissions provide it with a competitive edge over other airlines, enabling it to uphold the most economical prices in the market (Ryanair Group, 2023).

2. **Limited production capacity:** Obtaining necessary supplies has become a challenge due to limited production capacity and the effects of global warming. Climate change impacts such as extreme temperatures and insufficient fresh water supplies make the supply chains vulnerable, leading to higher costs and reduced profits. However, the company has a broad range of suppliers and can mitigate challenges by switching to different supply lines (Table 32) (Ryanair Group, 2023).

3. **Feedstock availability:** Ryanair is facing the challenge of limited feedstock availability in its sustainability efforts. At present, SAF availability represents a small portion of the aviation industry's needs. A typical SAF fuel can cost four times as much as normal jet kerosene, depending on its feedstock and country of uplift. The Group is at risk of not being able to meet requirements for SAF blending due to prohibitive prices or a lack of availability. To address this, the airline is having a strong relationship with leading SAF producers and carrying out research via its Sustainable Aviation Research Centre. Additionally, Ryanair supports draft amendments to Annex IX of the RED II and advocates excluding palm fatty acid distillates (PFAD) from eligible feedstocks under the ReFuel EU initiative (Table 32). The company insists that SAF production should not be at the expense of food supplies or contribute to deforestation(Ryanair Group, 2023).

4. **Technology challenges:** Ryanair has a plan to modernize its fleet (Table 31), but there are challenges to implementing new technology, such as the high cost. However, the airline has strong cashflows, investment grade ratings, and access to capital markets to support this plan (Ryanair Group, 2023).

5. **Infrastructure requirements:** Ryanair has demonstrated its commitment to sustainable aviation by setting ambitious SAF usage targets exceeding regulatory requirements. This sends a clear message to our fuel suppliers that there is a growing demand for new refining infrastructure and technologies to scale up SAF production. In addition, Ryanair actively engages with airport partners to ensure that future aviation infrastructure demands will be met (Table 32).

It is worth noting that over 70% of Ryanair flights operate to airports that have set a net zero goal (Ryanair Group, 2023).

6. Regulatory & policy support: The certification process for SAF is a significant challenge, as it takes many years for SAF to become commercially available for use in the aviation market. This process also involves high investment costs. Ryanair is currently backing research that aims to create pre-screening tools to accelerate the certification process of SAF candidates. Such tools could lessen regulatory barriers. Additionally, the airline is working closely with the European Commission, national governments, the Fuelling Flight Project, and fuel suppliers to encourage investment in SAF and provide incentives for its usage (Ryanair Group, 2023).

Furthermore, the company is in favour of the "Single European Sky" initiative to reform air traffic management in Europe and decrease CO2 and non-CO2 emissions. A more efficient ATM network would result in 10% decrease carbon emissions. Currently, Ryanair initiated a petition calling for EU legislation to safeguard overflights during national ATC strikes, which can lead to reduced additional emissions. It is an urge for legislation to respect the strike rights of ATC unions while protecting 100% of overflights during strikes, allocating cancellations to domestic/short-haul flights, enforcing binding arbitration for ATC disputes, and mandating advance notice of strike action and employee participation (Ryanair Group, 2023).

In conclusion, Ryanair is dedicated to promoting sustainable aviation and fully supports the implementation of SAF mandates. However, the airline acknowledges many challenges in scaling up the production of SAF, such as the scarcity of feedstock, the uncompetitive pricing compared to conventional jet fuel, and the long certification processes. Addressing these challenges requires a collaborative effort from the aviation industry, regulatory bodies, and the broader energy sector, where Ryanair is committed to actively fostering a more sustainable future for aviation (Ryanair Group, 2023).

This investigation provides a comprehensive assessment of the efforts made by leading European carriers as they work to adopt SAF and adhere to the EU's sustainability guidelines for aviation (REFUEL EU agreement). It is worth noting that the study's results are based on the most up-to-date data available and may not fully reflect each airline's complete sustainability plan.

In the upcoming chapter, a comparison will be made between the strategic approaches of the "Big 5" airlines towards adopting SAF and other sustainability measures. The evaluation will scrutinize each airline's strategy to identify best practices, shared objectives, and potential areas for collaboration or policy support that could enhance the aviation industry's collective progress toward its environmental goals. The assessment will also lay the groundwork for discussing future directions and the implications for the broader aviation sector's sustainability journey.

CHAPTER 5 RESULTS THE IMPACT OF REFUEL EU AVIATION INITIATIVE IN THE BIG 5

Refuel EU Aviation's initiative requires an incremental rise in SAF blend, with a target of at least 70% by 2050. This challenging goal compels airlines to enhance their integration strategies of SAF. The initiative highlights the importance of expanding SAF production, exploring various feedstocks, and innovating in SAF-compatible technologies, all while balancing economic viability and market dynamics. A thorough analysis of the SAF methodologies utilized by the leading "Big 5" European airlines, which are AF-KLM, EasyJet, IAG, LG, and Ryanair, is presented in this chapter. The assessment examines the effectiveness and eco-friendliness of these methodologies and discusses their possible consequences for the aviation industry. In order to move forward, consult Figure 16 for a summary of the Big Five.

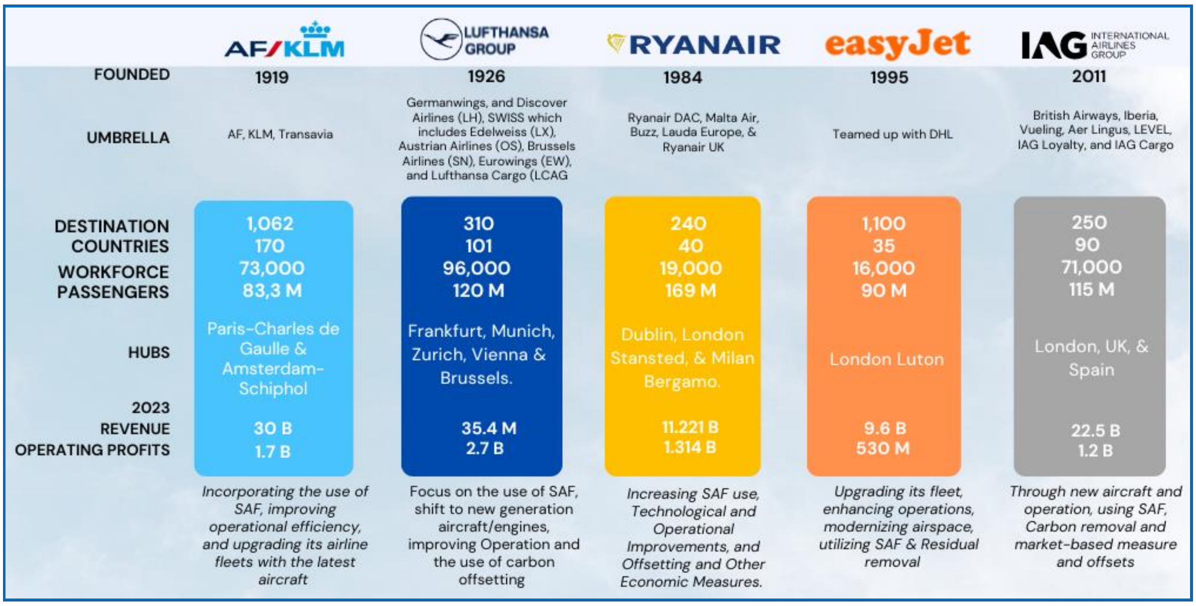


Figure 16 Summary of The Big Five

5.1 CROSS-COMPARISON OF STRATEGIES

The strategies of the top five airlines for SAF are evaluated based on specific measures, including the use of environmentally friendly SAF, improving operation ATM, making investments in modern technology and fleet, and adopting an economic strategy.

5.1.1 ROADMAPS TOWARDS BY 2050 AND MEETING GLOBAL CLIMATE TARGETS

The "Big 5" European airlines are making significant strides towards achieving net-zero emissions by 2050 by setting ambitious targets to reduce CO2 emissions per passenger-km. Each airline has its course charted for a sustainable future. By achieving those goals, the airlines will align with the EU's goal of making Europe the world's first climate neutral continent by 2050. Figure 17 shows us the roadmap goals of the Big 5.

Figure 17 Airlines Emission Reduction Roadmap by 2050.

Ryanair and LG are committed to reducing emissions and plan to cut emissions by 50% per passenger-km by 2030-31. IAG has outlined a comprehensive approach to lower emission intensity by 27% by 2030. Moreover, AF-KLM has set a more extended timeline goal to reduce CO2 emissions per passenger km by 50% by 2035. Like EasyJet, but with a minor percentage, the company has articulated a multifaceted strategy to slash well-to-wake CO2 emissions by 35% by 2035. Although there have been percentage variations, the aim of decreasing emissions by 55% by 2030 is unlikely to be met, which goes against the objectives of the "Fit 55" campaign. Nonetheless, it should be kept in mind that this data provided by airlines may require an update since the legislation was adopted and implemented this year.

Each airline has developed customized strategies that align with its distinct operational needs and sustainability objectives. Although Refuel EU has stipulated minimum requirements for SAF and the supply of e-kerosene, companies must exhibit greater transparency regarding their usage. Using SAF in aviation can reduce up to 80% of CO2 emissions, but companies need to address the remaining 20% to achieve net zero emissions. As a result, the regulation significantly impacts the entire company, including its management strategies, such as adopting improvements in ATMs, implementing new technologies and fleet revolution, and economic strategies. Mind map 18 provides a summary of the strategies employed by the big five.

Figure 18 Mind Map Strategies Employed by The Big 5.

Their strategic roadmaps, as revealed by a comprehensive study, indicate a collective commitment towards addressing climate change in the aviation industry:

The Big Five recognize the importance of SAF in mitigating their carbon footprint. They have established measurable objectives to increase the use of SAF. For example, LG aims to reduce its emissions by 65% by focusing on SAF as the foundation of its environmental endeavours. Ryanair intends to lower its emissions by 34% and IAG by 33%. Meanwhile, EasyJet's plan involves cutting emissions by 26%. In contrast, AF-KLM has not outlined SAF as a specific strategy, but they have incorporated it into their core commitment to sustainable development strategies, recognizing it as the driving force behind a 45% reduction in emissions.

Furthermore, the big Fives are striving to reduce emissions by adopting various initiatives aimed at achieving operational excellence. A significant percentage of AF-KLM Operations is targeting a 45% reduction in C02 emissions, and to achieve this, the airline plans to train pilots in fuel-efficient flying techniques. In contrast, LG aims for a minor 3% reduction by optimizing ground and flight operations. EasyJet want to achieve a 8% improvement in operational efficiency by implementing initiatives such as washing and using single-engine taxis to save fuel. Ryanair has included the reduction of emissions as part of its overall technological and operational improvement efforts, which account for 42%. Similarly, IAG is integrating operational excellence into its broader strategy for new aircraft and operations, intending to achieve a 37% reduction in emissions.

There is a noticeable trend toward investing in modern airplanes, prioritizing fuel efficiency. As an example, EasyJet is taking a proactive approach by aiming to be an early adopter of fleet transitions. Their NEO fleet, which is expected to reduce emissions by 44%, is a notable example of this. LG is also embracing transformation by exploring next-generation engines and electric and hydrogen propulsion systems. Their goal is to reduce CO_2 emissions by 30%. Meanwhile, IAG and Ryanair have incorporated this strategy into their technological and operational plans. IAG aims to reduce emissions by 37% by acquiring more efficient aircraft, complementing broader operational improvements. Conversely, Ryanair is allocating a 42% reduction to technological advancements and operational efficiencies. Similarly, AF-KLM focuses on operational improvements, which account for 45% of its strategy. They have a vision for hydrogen-powered planes in the post-2035 future.

Regarding economic strategies, carbon offsetting and removal strategies vary among different airlines. For example, IAG aims to remove 30% of its carbon emissions, while EasyJet focuses on eliminating 22% of residual emissions. Ryanair, on the other hand, is committed to allocating 24% of its efforts to carbon offsetting and other economic measures. AF-KLM includes carbon compensation as a tangible component, with 10% directed towards this effort. However, LG views carbon offsetting as a temporary measure, with a 2% impact attributed to it.

Moreover, Ryanair places a great emphasis on implementing the Single European Sky initiative (This percentage is included on the ATM), which they attribute to a 10% reduction in emissions. EasyJet has also incorporated SES into its plans for modernizing airspace, resulting in a 7% decrease in emissions. Although other airlines have included SES in their strategies for reducing CO_2 emissions, it is not their primary focus.

Airlines have highlighted the significance of SAF, modernized fleets, and operational efficiencies while developing a customized plan according to their operational capabilities and strategic goals. However, there are variations in their approach towards prioritizing these measures and utilizing innovative technologies to achieve their objective of reaching net-zero emissions. Moreover, each strategy will be thoroughly assessed in accordance with Refuel EU.

1. GREEN FUEL SAF

The sustainable practices of the EU aviation industry are advancing significantly as demonstrated by major airlines such as AF-KLM, EasyJet, IAG, LG, and Ryanair. These airlines have outlined comprehensive milestones that transparently showcase their commitment to reducing CO2 and embracing eco-friendly solutions, which include the adoption of SAF and other green technologies. An overview of the SAF milestones achieved by these leading airlines can be found in Figure 19.

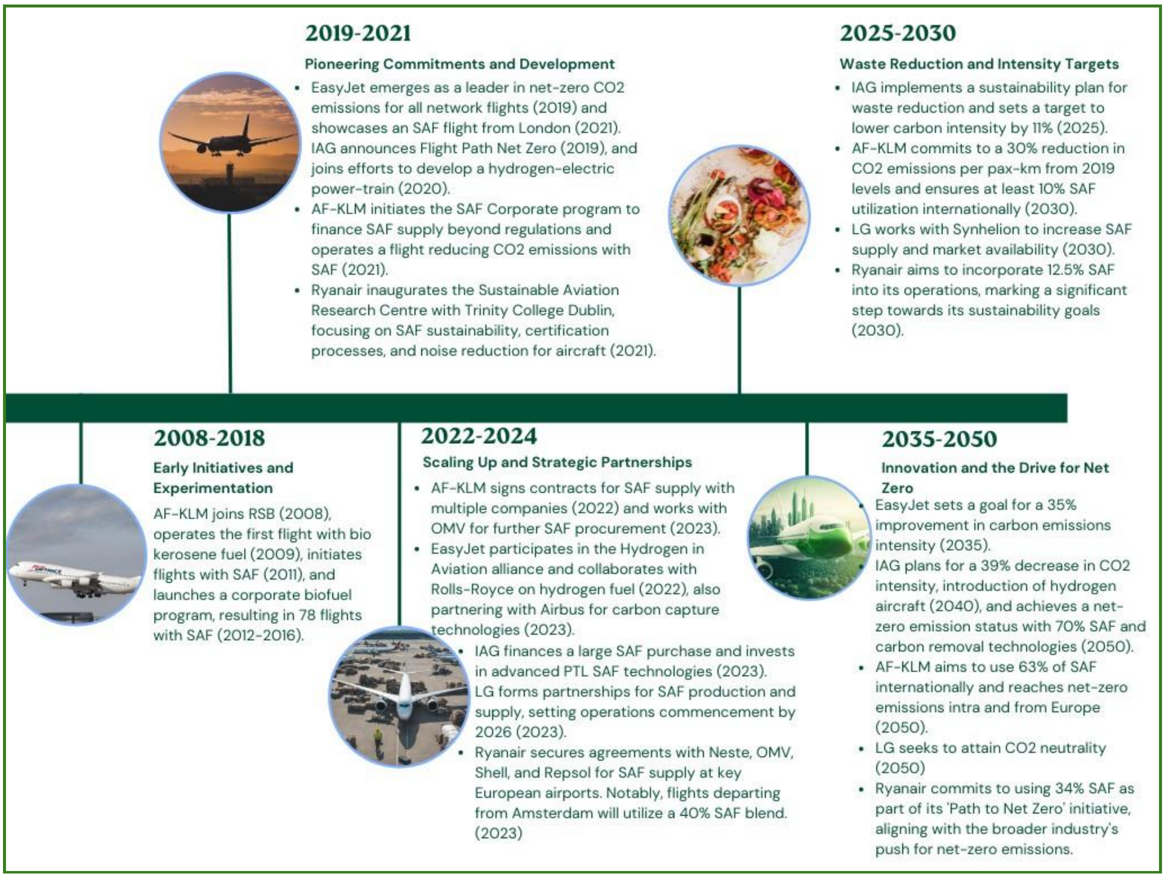
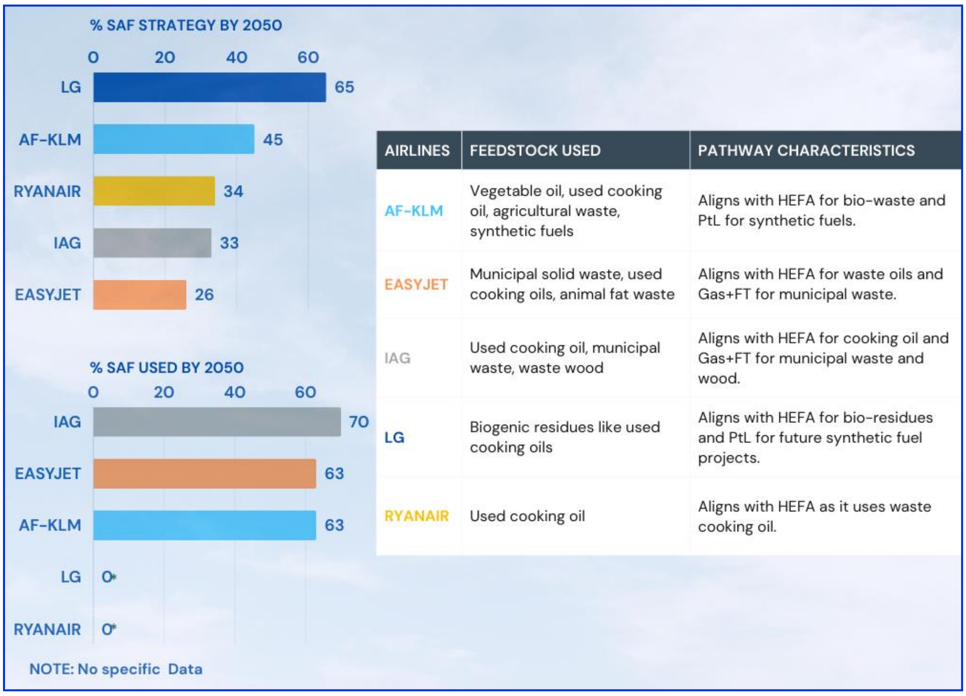


Figure 19 SAF MILESTONE'S TIMELINE OF THE BIG 5.

The Eu aviation industry's leading airlines progressively incorporate SAF into their operations, demonstrating their commitment to tackling environmental issues within the EU's 'Refuel EU' initiative. The move towards sustainability is characterized by varying degrees of adoption and pace among the airlines. AF-KLM has been a pioneer in the use of biokerosene since 2009 and now aims to integrate 63% SAF into its operations by 2050. This aligns with EasyJet's target, while IAG has set its sights higher at 70%. Ryanair and LG have fewer specific goals in the use in percentage of SAF, with a general ambition to reduce CO2 emissions by 34%,65% through SAF. Interestingly, IAG's targets align with the Refuel EU initiative's requirements, which mandate increasing shares of SAF in the fuel mix, reaching a minimum of 70% by 2050, focusing on the transition to e-kerosene. The Refuel EU agreement has widened the scope of SAF, enabling airlines to investigate a wider range of biofuels and synthetic fuels. This expansion of fuel options offers a multifaceted approach to meeting the minimum share requirements and making progress towards the EU's climate goals. AF-KLM and EasyJet currently use only a small proportion of SAF, but this information may be incomplete and require updating with the latest version of Refuel EU. A different case is in Ryanair and LG, where this information is not currently available online.



AIRLINES	FEEDSTOCK USED	PATHWAY CHARACTERISTICS
AF-KLM	Vegetable oil, used cooking oil, agricultural waste, synthetic fuels	Aligns with HEFA for bio-waste and PtL for synthetic fuels.
EASYJET	Municipal solid waste, used cooking oils, animal fat waste	Aligns with HEFA for waste oils and Gas+FT for municipal waste.
IAG	Used cooking oil, municipal waste, waste wood	Aligns with HEFA for cooking oil and Gas+FT for municipal waste and wood.
LG	Biogenic residues like used cooking oils	Aligns with HEFA for bio-residues and PtL for future synthetic fuel projects.
RYANAIR	Used cooking oil	Aligns with HEFA as it uses waste cooking oil.

Figure 20 SAF Strategy of the Big Fives Comparative analysis.

Figure 20 provides insights into how an airline's selection of feedstock corresponds to different SAF pathways, as well as their limitations and cost drivers. For instance, AF-KLM, EasyJet, IAG, LG, and Ryanair use feedstocks that place them in the HEFA category, which has limitations such as feedstock availability and market-driven prices. In contrast, airlines exploring synthetic fuels are investigating the PtL pathway, which has higher costs and the potential for unlimited feedstock availability through carbon capture. These airlines also examine other advanced technologies, such as Gas+FT and AtJ, which present additional operational and economic challenges like high capital requirements and technological integration.

All the mentioned airlines have progressively begun to blend SAF into their operations, underscoring their dedication to slashing life-cycle CO2 emissions. The adoption of SAF by these industry players is likely to encourage wider usage and demand for SAF, which could lead to more innovative ways of producing the fuel, reduction in costs through economies of scale, and influence more robust regulatory frameworks to encourage a more sustainable aviation industry.

By analysing feedstocks and pathways, we can see that airlines are selecting pathways based on the sustainability and availability of feedstocks and the technological maturity and cost implications of each pathway. This evaluation can assist in comprehending the strategic choices made by airlines in their quest to reduce carbon emissions by employing SAF.

As of today, these airlines continue to increase their use of SAF, with notable agreements being signed with suppliers like Neste for the acquisition and partnerships to develop SAF production facilities. Further, the Big 5 have entered into strategic partnerships with fuel suppliers, energy companies, and technology innovators to ensure SAF supply. They are demonstrating their dedication to research and development by adopting SAF and working closely with technology and fuel partners. These efforts are part of a broader initiative to align with global climate objectives, which is a difficult challenge given the complexities of the Refuel EU Aviation Initiative. The ability of those airlines to effectively integrate these innovations and achieve their sustainability goals may result in competitive advantages.

2. IMPROVING OPERATIONS AIR TRAFFIC MANAGEMENT (ATM)

The "Big 5" airlines are dedicated to improving operations and reducing emissions towards achieving net-zero emissions. The information in Table 21 provides a summary of the main points and percentage of how each airline has implemented the strategy. The strategy aims to reduce CO_2 emissions by 45% for AF-KLM, whereas LG has the lowest percentage of 3%. They have implemented strategies that involve improving operational efficiency, optimizing routes, Sustainability Training and Engagement, and effectively managing waste employed in ATMs:

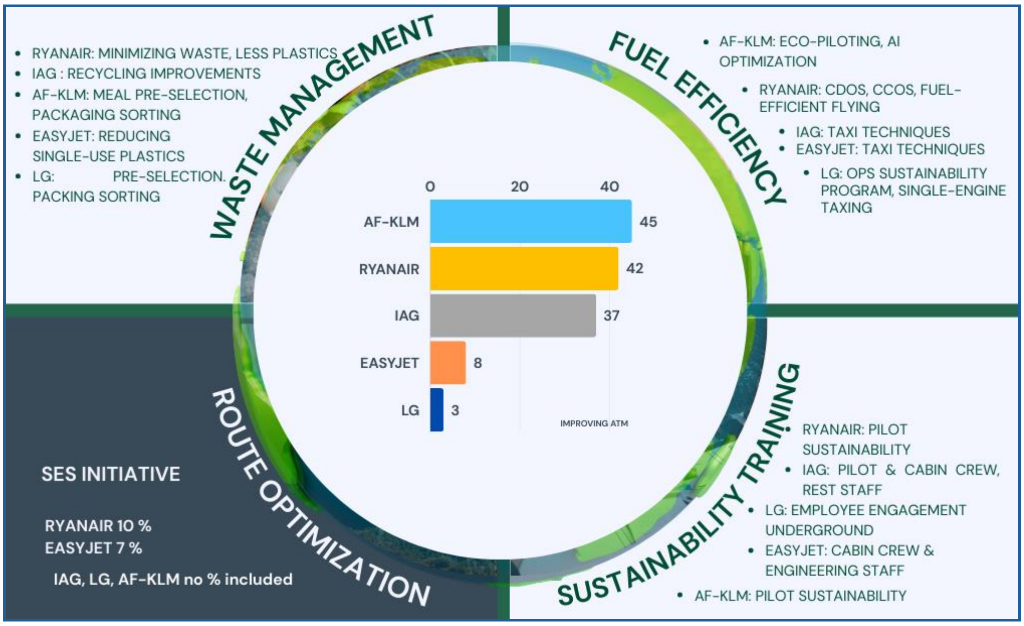


Figure 21 Operations Air Traffic Management of The Big Fives.

Ryanair, AF-KLM, and LG have adopted various strategies to enhance the fuel efficiency of their flight operations. LG's OPS Sustainability Program focuses on measures such as single-engine taxiing and reducing aircraft weight to save fuel. AF-KLM emphasizes eco-piloting strategies, which involve optimized ground operations and AI tools to optimize flight trajectories. Meanwhile, IAG and EasyJet employs taxiing methods to save fuel And Ryanair incorporates CDOs and CCOs and employs fuel-efficient flying techniques for pilots.

In order to Route Optimization, Ryanair (10%) And EasyJet (7 %) endorses the SES initiative, which aims to restructure European airspace with the goal of decreasing flight distances and duration, thereby conserving fuel and decreasing emissions. This is a shared objective that is supported by other European airlines (LG, AF- KLM, & IAG) as the SES initiative provides advantages to the entire industry. Nevertheless, they do not consider this to be a main strategy like Ryanair and EasyJet do.

Ryanair and EasyJet prioritize providing sustainable training to their employees. EasyJet is firmly committed to sustainability, as evidenced by the high completion rates of its sustainability training modules. Ryanair also offers specialized sustainability training for pilots. Similarly, AF-KLM offers pilot training in Eco piloting. Other airlines, such as LG and IAG, are also committed to engaging their staff and pilots in sustainability practices in training. This includes educating them on fuel-saving practices and raising awareness about the airline's environmental commitments.

The Big Five have pledged to reduce waste during their flights, particularly in the context of waste management. To achieve this, they are taking measures such as reducing the use of single-use plastics and improving recycling programs. The benefits of these efforts are twofold: they are not only good for the environment but also align with a growing industry trend of reducing the ecological impact of air travel. Similarly, LG has implemented strategies to reduce weight and save fuel, such as pre-selecting meals in the business cabin, and they are also taking steps to sort their in-flight packaging.

Additionally, the airlines are trying to reduce negative impact on the environment in many ways for example Ryanair and AF-KLM have both demonstrated their commitment to embracing sustainable materials and technologies. Ryanair has stated that it aims to utilize biodegradable cups and cutlery, whereas AF-KLM plans to shift towards bio-sourced materials and also intends to install water fountains with the objective of reducing plastic consumption.

After a thorough examination of their approaches, it is clear that all sides are working towards making their operations and ATMs more sustainable, which are fundamental aspects of broader sustainability initiatives in the aviation industry based on the baseline scenario to reduce CO2. By implementing such measures, airlines are making a significant contribution to the ultimate objective of decreasing the aviation industry's environmental impact and moving towards a more sustainable future.

3. NEW TECHNOLOGIES & FLEET REVOLUTION

The 'Big five' leaders are implementing advanced technologies and pursuing operational efficiencies to achieve their objectives. A key aspect of their strategy involves a comprehensive transformation of their traditional fleets, along with the implementation of pioneering technologies that enhance fuel efficiency and minimize environmental impact. Figure 22 illustrates the percentage of companies expecting to reduce CO2 emissions with this strategy.

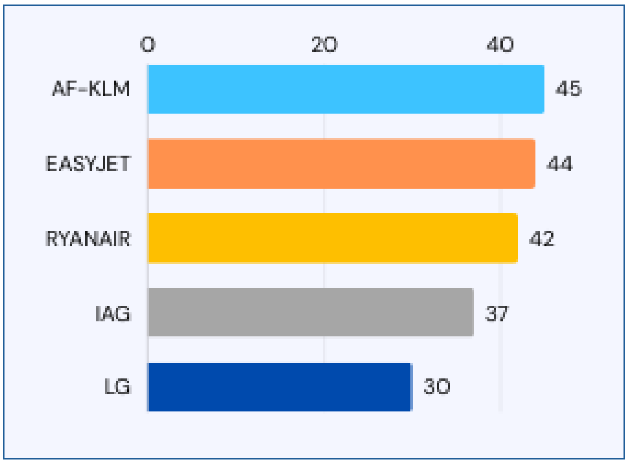


Figure 22 New Technologies & Fleet Revolution in percentage of the Big Five by 2050

- **Fleet Renewal and Modernization:** LG has the largest fleet, with 721 aircraft, mainly consisting of newer planes that are 4.1 years old. Even though the overall age of its fleet is around 11 years, its strategy includes transitioning to 108 new aircraft (Airbus and Boeing) that provide up to 30% better fuel efficiency. IAG, on the other hand, has a collection of 649 planes with a median age of 12 years. Recently, IAG added the Airbus A350 in 2024 and additionally, 181 (Boeing and airbus) will receive in the coming years, which is a step towards next-generation aviation. IAG's approach is noteworthy for exploring the potential of hydrogen-electric powertrain technology, a leap towards carbon-free aviation.

Simultaneously, Ryanair and AF-KLM have traditional and modern aircraft in their fleets. Ryanair has a fleet of 622 airplanes with an average age of 12 years. Ryanair is currently upgrading its fleet with newer and more fuel-efficient, which will have a higher passenger capacity and will improve operational efficiency. Similarly, AF-KLM has a fleet of 505 airplanes with an average age of 13.5 years and plans to renew 70% of its fleet with new-generation aircraft by 2030, which will help to reduce fuel consumption to less than 3 liters per passenger by 2030.

Contrastingly, EasyJet's fleet consists of 336 airplanes designed explicitly for short-haul flights, unlike the older fleets of AF-KLM, LG, and IAG. The average age of EasyJet's fleet is 10.7 years, including the oldest 18years, which is relatively the youngest compared to other airlines. EasyJet's strategy is focused on fleet modernization, as demonstrated by its recent addition of the new neo models models24 and additionally 213 Neo model will be delivered in the coming years. These aircraft are equipped with the latest technological advancements to enhance fuel and carbon efficiency. This approach allows EasyJet to establish itself as a forward-looking and innovative player in the European aviation industry. A summary of the fleet of the Big 5 is in Figure 23.

	FLEET	AV. AGE	OLDEST	NEWEST	F. DELIVERY	TYPES
LUFTHANSA GROUP	721 Long-Medium Short haul	11	28	4.1	108	AIRBUS* BOEING* BOMBARDIER
IAG INTERNATIONAL AIRLINES GROUP	649 Long-Medium Short haul	12	29	MONTHS	181	AIRBUS* BOEING* BOMBARDIER
RYANAIR	622	12	19.6	MONTHS	300	AIRBUS BOEING*
AF/KLM	505 Long-Medium Short haul	13.5	29	MONTHS	353	AIRBUS* BOEING* BOMBARDIER EMBRAER
easyJet	336 Short Hauls	10.7	18	MONTHS	213	AIRBUS*

Figure 23 Fleet Renewal and Modernization of the Big Five.

Despite their differences, each airline displays a dynamic approach to fleet management and is committed to utilizing the latest aeronautical technology to move towards a sustainable future.

- **Technological Enhancements:** The Big Five airlines, including AF-KLM, IAG, LG, Ryanair, and EasyJet, are actively seeking ways to enhance their in-air and ground operations by investing in modern technologies. Figure 24 provides an overview of the technological improvements that the airlines are currently pursuing.

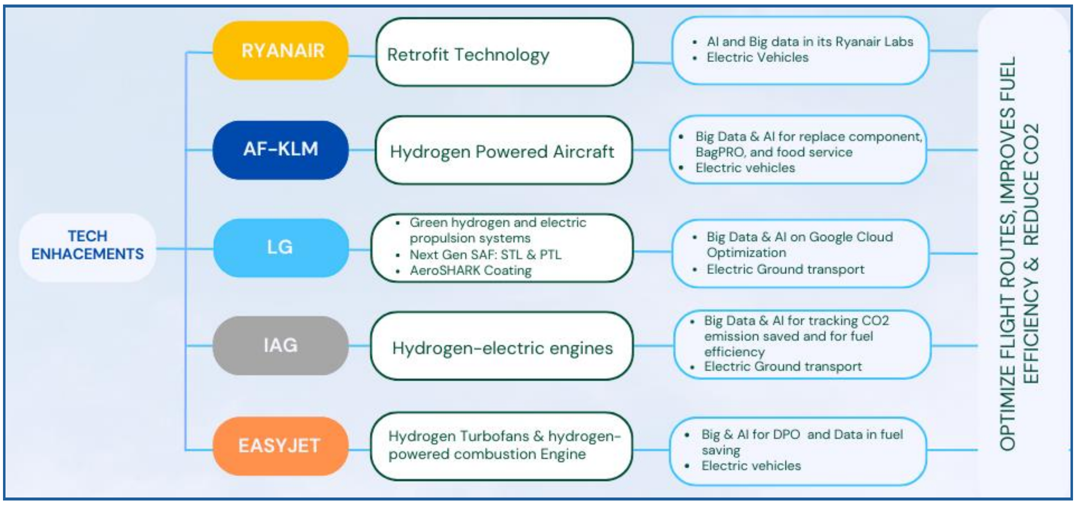


Figure 24 Technological Enhancements of the Big Fives.

EasyJet is currently exploring hydrogen turbofans and combustion engines, while IAG is investing in ZeroAvia's hydrogen-electric powertrain technology. The approach of IAG is different from EasyJet's. AF-KLM is also making progress with its HPA project to explore hydrogen-powered aircraft. On the other hand, LG is primarily focused on SAF and integrating green hydrogen in its production through PtL and StL technologies. Its primary use of hydrogen is for SAF production rather than direct propulsion systems like those investigated by EasyJet and IAG. Meanwhile, Ryanair is committed to reducing its carbon footprint and is upgrading its fleet with more fuel-efficient aircraft and retrofitting technology from Aviation Partners Boeing to meet their environmental objectives.

All the Big Five utilize digital optimization, AI, and big data to reduce unnecessary expenses and improve effectiveness, which are common themes in their operational enhancements. AF-KLM is embracing inventive solutions, such as BagPRO, to optimize luggage routing, predict and replace components before they fail with big data, and adopt AI to decrease waste in their food service operations. Likewise, EasyJet has implemented AI and advanced analytics in endeavors like the Digital Pilot Office (DPO) and the Sky Breathe fuel management tool to reduce fuel consumption. IAG is also making use of AI and Big Data to save fuel. LG is deploying a tool built with Google Cloud to streamline flight operations. Meanwhile, Ryanair is prioritizing digital transformation for operational efficiency with Ryanair Labs, performing operational tactics such as single-engine taxiing and continuous descent approaches to save fuel and decrease emissions.

In order to reduce their carbon footprint, airlines are incorporating electric vehicles into their ground operations. AF KLM is making the transition to electric ground support equipment with the goal of minimizing emissions. EasyJet is leading the way in electrifying its underground vehicle fleet. Ryanair is collaborating with airport authorities to help facilitate the usage of electric vehicles and support infrastructure development that aligns with net-zero objectives. IAG is integrating electric buses for passenger transport and e-Mototoks for efficient aircraft towing, testing electric trucks, and moving towards renewable electricity for their ground operations. LG also embraces sustainability by incorporating electric and alternative-powered vehicles into their ground operations and promoting eco-friendly transportation methods among their employees.

Although all airlines share similar goals and approaches, such as renewing their fleets and improving efficiency, each airline is pursuing its unique path when it comes to integrating new technologies and optimizing operations to meet its targets. This commitment showcases their dedication to achieving environmental goals while setting a positive example in an eco-friendly market.

4. ECONOMIC STRATEGIES

Major 5 airline companies are adopting unique and diverse strategies to minimize their impact on the environment. AF-KLM is incorporating train services to decrease short-haul flights and exploring the use of hydrogen at airports, as demonstrated by their initiatives such as the H2 HUB AIRPORT. EasyJet, on the other hand, is committed to hydrogen as the primary fuel source for future aircraft and has established hydrogen hubs at airports, participating in the Hydrogen in Aviation Alliance. IAG has invested in various forms of SAF production technologies and carbon capture initiatives, showing a broad approach to sourcing and technology adoption. LG prioritizes atmospheric research and contrail avoidance, with a focus on tackling non-CO2 emissions alongside their commitment to SAF. Finally, Ryanair is driving sustainability through operational efficiencies and customer engagement, advocating for policy changes supporting SAF and better ATM. The economic strategy of the big Five is summarized in Table 33.

A	STRATEGY HIGHLIGHTS	SUSTAINABILITY INITIATIVES	COLLABORATIONS & PARTNERSHIPS
AF-KLM	Focus on intermodality, hydrogen technology, multi-stakeholder engagement	• H2 HUB AIRPORT initiative for hydrogen in airports • Project Phoenix, focusing on hydrogen-powered aircraft. • SkyTeam Sustainable Flight Challenge, Corporate SAF Programme, • Train + Air service to reduce short-haul flight emissions	• Customers, Employees, Shareholders, Airbus, Groupe ADP, Choose Paris Region. • Collaboration with NGOs for carbon offset projects. • Corporate SAF Programme with multiple stakeholders
EASYJET	Collaboration & technological innovation in hydrogen technology and operational efficiencies	• Hydrogen in Aviation Alliance • AI for operational efficiencies • EasyJet Holidays' sustainability strategy	• Global Sustainable Tourism Council, Travel Foundation, UNWTO, Rolls-Royce, GKN Aerospace, and Airbus • Founding member of Hydrogen in Aviation Alliance like Hydrogen Southwest.
IAG	Investments in diversification SAF, carbon capture technologies, emphasizing customer engagement to manage the green premium associated with SAF.	• Investment in various SAF production technologies • Carbon removals and offsets through partnerships • Engagement in non-CO2 climate impact reduction efforts • CO2LLABORATE, Heirloom partnership, Jet Zero Council involvement.	• LanzaJet, Velocys, UK's Jet Zero Council, Heirloom, and Nova Pangaea Technologies. • Collaboration with governments and institutions like the UK Jet Zero Council and the Rocky Mountain Institute • Co-funding agreements with Microsoft for SAF procurement.
LG	Scientific approach to sustainability with a focus on atmospheric research and contrail avoidance, alongside robust investments in SAF and hydrogen technology. Also focus on consumer centric.	• "Green Fares", atmospheric & contrail avoidance research projects, SES initiative • Atmospheric data collection through IAGOS	• Hanseatic City of Hamburg, OMV, NESTE • Collaboration on the SES initiative to improve air traffic management efficiency
RYANAIR	Policy advocacy, customer engagement	• Fueling Flight Project, SES initiative, SAF agreements at airports • Aerodynamic improvements with split scimitar winglets • Customer sustainability awareness programs • Research and development in SAF and noise reduction strategies	• Academic institutions, Boeing, Shell, and various SAF suppliers. • Participation in policy advocacy with the European Commission and the Fuelling Flight Project. • Partnerships with Trinity College Dublin for sustainability research

Table 33 Economic Strategy of the Big Fives.

The multi-stakeholder engagement strategy that Air France has developed stands out for its ability to leverage feedback from all stakeholders to refine its sustainability actions, from customers and employees to shareholders and NGOs. In particular, they have participated in the SkyTeam Sustainable Flight Challenge to encourage innovation and established a Corporate SAF Programme emphasizing a collective approach to sustainability. Their commitment to sustainable aviation is strengthened by their efforts in intramodality and hydrogen strategy collaboration, such as Project Phoenix.

In order to advance its economic strategy, EasyJet places a high priority on collaboration with industry and technological innovation. By joining groups such as HSW, aiming to convert Bristol Airport into a hydrogen hub. Using strategic partnerships with technology giants and aviation experts, EasyJet is bringing AI to the forefront of operational efficiencies. As well as catering to affordable travel and environmental conservation, EasyJet Holidays' sustainability strategy draws upon collaborations with organizations such as the GSTC, the Travel Foundation, and the UNWTO. And commitment to promoting the SES initiative is indicative of their efforts to influence sustainable aviation by means of policy transformation.

Among IAG's economic strategies are significant investments in SAF, with partnerships such as investors, LanzaJet and Velocys demonstrating its forward-thinking approach to fuel innovation. Through CO2LLABORATE and the partnership with Heirloom, IAG is demonstrating its commitment to consumer engagement and futuristic technology in carbon management. A strong commitment to driving policy and fostering a collaborative environment for sustainable aviation advancement is illustrated by their involvement with the UK's Jet Zero Council and other national alliances.

A major focus of LG's economic strategy is consumer-centric initiatives such as "Green Fares" and the pursuit of technological advancements in hydrogen technology, which has been demonstrated by the company's partnerships with the Hanseatic City of Hamburg. Through their commitment to atmospheric research and contrail avoidance research, they emphasize a science-driven approach to sustainable development. Moreover, LG procures SAF from reliable European suppliers, including OMV and NESTE.

As part of Ryanair's strategy, the airline advocates for policy changes that facilitate sustainable aviation practices. Engaging in policy lobbying for the Fuelling Flight Project and promoting the SES initiative with the goal of influencing SAF development through strategic partnerships and economic incentives. Ryanair, as well, has established agreements with several SAF suppliers at major airports. Through their operational advocacy activities, customer sustainability awareness programs, and research collaborations with academic institutions, the company demonstrates a holistic economic strategy emphasizing consumer engagement, policy advocacy, and scientific research.

Although all these airlines are dedicated to sustainable aviation, their approaches for example, EasyJet and AF-KLM are more aggressive in prioritizing hydrogen than the others. Additionally, there are differences in integrating customer involvement and policy advocacy. Ryanair places a strong emphasis on influencing policy through direct engagement. IAG relays in Investments in diversification SAF and LG in research of the next generation of SAF. Despite the nuances in each airline's strategy, the overarching commitment to reducing CO2 emissions through SAF, hydrogen technology, and operational efficiencies is evident. These strategies combine immediate actions and long-term investments, reflecting the sector's dynamic approach to addressing the challenges posed by the Refuel EU Aviation Initiative.

6. EFFECT OF REFUEL EU AVIATION INITIATIVE ON THE “BIG 5” AND POTENTIAL OBSTACLES

The Refuel EU Aviation Initiative has set ambitious targets for the adoption of SAF, including minimum supply quotas and transitioning the industry towards e-kerosene. This policy has significant implications for the "Big 5" aviation companies, as they must navigate various challenges in order to meet these targets, including. How the airlines are overcoming this obstacle is summarized in Table 34.

	AF-KLM	EASYJET	IAG	LG	RYANAIR
HIGH PRODUCTION COST	Actively secures SAF supply and encourages demand growth.	Focuses on hydrogen as a cost-effective alternative. Sees SAF as an interim solution while advocating for hydrogen fuel.	Transferring cost premium to customers	Implements a solid hedging strategy.	Advocates for financial measures to support SAF affordability such as providing financial aid for SAF production research and innovation. Focuses on affordability and commercialization of SAF.
LIMITED PRODUCTION CAPACITY	Forms strategic partnerships and off-take agreements to scale up production.	Includes hydrogen in SAF agreements to reduce reliance on traditional SAF. Adapts strategies to future technological developments.	Urging local SAF production increase	Intensifies supplier risk management and dialogue. Uses diverse supplier base to address supply-related challenges.	Uses diverse supplier base to remain flexible.
FEEDSTOCK AVAILABILITY	Seeks feedstocks with minimal environmental impact. Explores alternatives like waste, agricultural residues, and synthetic fuels.	Pivots towards green hydrogen for long-term sustainability.	Diversifying SAF production methods including municipal solid waste, alcohol to jet, HEFAs, and PTOs,	Exploring PtL and StL technologies	Strengthens partnerships with SAF producers. Seeks feedstocks with minimal environmental impact and explores alternative sources like waste, agricultural residues
TECHNOLOGY CHALLENGES	Upgrading fleet and testing new technologies	Upgrading fleet & Banks on hydrogen and complementary electric propulsion technologies	Upgrading fleet Committed to R&D to tackle technological challenges. Recognizes the role of investors in promoting sustainable aviation technologies.	Upgrading fleet Acknowledges cybersecurity risks and technological challenges.	Upgrading fleet & Supports modernization with strong financial capabilities.
INFRASTRUCTUR E REQUIREMENTS	Develops biofuel production and improves flight procedures. Invest in SAF industry through Corporate SAF Programme. Improving infrastructure for SAF	Collaborates with airports and regulators to enhance infrastructure	Recognizes the importance of adequate infrastructure. Follows regulatory protocols to facilitate SAF production	Prepares to adapt to a changing market environment while increasing SAF production through off take agreement.	Encourages development of refining infrastructure. Collaborates with airport partners to meet future sustainable aviation demands.
REGULATORY & POLICY SUPPORT	Works with policymakers to support sustainable aviation. Engages in sustainable policy advocacy with partners like 'Train+Air'.	Emphasizes the importance of regulatory frameworks. Adapts to customer needs with carbon offset options.	Implements consistent worldwide policies to promote SAF integration. Expedite large-scale SAF production with local regulations.	Advocates for unified European airspace. Engages in campaigns and collaborations to reduce CO2 emissions and improve air traffic efficiency.	Supporting studies for SAF certification; advocating for 'SES' initiative

Table 34 Comparative Obstacles analysis across the Big Fives.

Integrating SAF into the operations of all airlines is a challenge and a barrier due to its high price. This confirms the statement mentioned earlier in point 2.13 challenges and barriers of SAF. Each airline has adopted distinct approaches to address these costs and mitigate their impact. While AF-KLM is aware of the difficulties, it secures its supply and encourages demand growth to commit to SAF. EasyJet focuses on hydrogen as a cost-effective and sustainable alternative for the future despite its current development expenses. Although SAF is a viable short-term solution for reducing emissions, reaching "true zero" requires hydrogen fuel, according to this company. IAG has adopted a customer-focused approach transferring "green premium" to passengers, aiming to ensure a fair transition without disrupting competition. In contrast, LG is implementing a solid hedging strategy. On the other hand, Ryanair is advocating for financial measures to support the affordability and commercialization of SAF.

The second hurdle for all airlines is the restricted capacity to produce SAF, which is a major obstacle in achieving demands of the aviation industry and sustainability goals. All airlines have recognized the issue and are acting by forming strategic partnerships and off-take agreements to meet the demand for SAF, which they consider crucial for scaling up production with special focus enhancing supplier management. AF-KLM and LG is taking steps to intensify its supplier risk management and dialogue, and Ryanair is using diverse supplier bases to remain flexible and address any supply-related challenges that may arise. IAG emphasizes the urgent need to increase local SAF production to overcome distribution barriers. In contrast, EasyJet is showing its confidence in the potential of hydrogen technology to reduce its reliance on SAF.

The Big Five are grappling with the challenge of ensuring a sustainable future in aviation by securing the availability of SAF feedstock confirming the point 2.13 challenges and barriers of SAF. To overcome this challenge, AF-KLM and RYANAIR actively seeks feedstocks with minimal environmental impact and explores alternative sources like waste, agricultural residues, forestry residues, and combinations of CO2 and renewable hydrogen. Similarly, EasyJet is also sourcing SAF while pivoting towards green hydrogen, derived from renewable sources, as a long-term sustainable and economical alternative. Similarly, IAG is focused on diversifying SAF production methods, including municipal solid waste, alcohol to jet, HEFAs, and PTOs, effectively spreading the risk associated with relying on a single methodology for emissions reduction. Meanwhile, LG is exploring innovative production technologies like PtL and StL processes.

The Big Five are determined to modernize their fleet despite the. One of the biggest challenges is to develop zero-emission aircraft, which could take decades to accomplish and require high expenses. Further, the industry is also struggling with integrating digitalization and sustainability in modernizing its fleet, and it must follow strict testing protocols to demonstrate the efficacy of its innovations. These challenges are similar to the main challenges mentioned by The Big Five in adopting the Refuel EU. However, this challenge and barriers of SAF were not anticipated.

The infrastructure challenges that must be addressed as seen in point 2.13 challenges and barriers of SAF. For instance, AF-KLM is taking an active approach to improve infrastructure investing directly in the SAF industry through its Corporate SAF Programme. This program enables corporate customers to assess and contribute towards their travel-related CO2 emissions by investing in SAF procurement. In the meantime, EasyJet & IAG collaborates with airports and regulators to enhance infrastructure, with a focus on net-zero technologies. They emphasize the significance of regulations and incentives in scaling up these technologies. Through their partnerships, they strive to simplify operations and promote the development of sustainable aviation technologies. LG understands that the outlook for aviation is linked to worldwide political and economic movements. LG is preparing to adapt to a changing market environment while increasing SAF production. On the other hand, Ryanair has established ambitious goals for using SAF and is communicating these targets to fuel suppliers. The airline is also encouraging the development of new refining infrastructure and collaborating with airport partners to ensure that future infrastructure meets the growing demand for sustainable aviation.

Those airlines are confronted with various obstacles in terms of sustainability owing to regulatory and policy support. These challenges include time-consuming certification procedures for SAF, staff involvement, intricacies of intramodality, disparities in global policies, communication with investors, and compliance with the European Union Climate Agenda. They also need to advocate for changes that will allow them to confront these challenges directly as seen in point 2.13

challenges and barriers of SAF. AF-KLM is placing great emphasis on using SAF and collaborating with policymakers to promote regulations that support sustainable aviation. Recognizing the challenges of intramodality, the airline is adopting a comprehensive working in partnership with other companies such as those involved in the 'Train+Air' program. Meanwhile, EasyJet involve adapting to meet the needs of customers by providing the option to offset their carbon emissions. This shows a policy engagement approach that is responsive and adaptable. Moreover, IAG plans to expedite large-scale production of SAF and push for local regulations to streamline this transition, showcasing its dedication to policy-driven sustainable progress, also the company gives a lot of importance to investors for the production of SAF. On the other hand, LG is adjusting to the evolving market conditions and managing operational difficulties due to changes in demand and regulations and also investing in SAF and Ryanair is actively supporting studies to accelerate the certification process of SAF and advocating for the 'SES' initiative to reform air traffic management, which aligns with their efforts to reduce emissions.

In conclusion, the Five major EU airlines have started using SAF to address environmental issues and comply the Refuel EU Aviation Initiative, which presents several opportunities and challenges, including high production costs, limited production capacity, feedstock availability, technological challenges, infrastructure development, and regulatory and policy support, as revealed by the findings. To overcome these hurdles, airlines are taking several measures, such as forming strategic partnerships for SAF development and procurement, exploring alternative and innovative feedstocks and production techniques, upgrading their fleets with newer and more efficient aircraft, welcoming digital and AI technologies for operational optimization, and engaging in policy advocacy and regulatory dialogue. These airlines demonstrate a collective commitment to combat climate change and lead the aviation industry toward a sustainable future while balancing sustainability goals with economic realities. They are pursuing immediate and long-term strategies to meet the environmental expectations of stakeholders and regulatory bodies. Achieving the net-zero emissions goal by 2050 will require adherence to existing plans and continuous adaptation and responsiveness to new technological developments and regulatory changes.

Although SAF reduces emissions in the short term, achieving carbon neutrality could rely on hydrogen as a fuel. The importance of this non drop in fuel as a sustainable fuel is gaining recognition due to its economic and environmental benefits among airlines.

Furthermore, airlines are using a managed risk approach to reduce emissions. They are implementing various techniques to distribute risk and improve operational resilience. This approach is consistent with ventures that mitigate risk and pave the way for future innovations and adaptations in the industry. The ability of the top 5 EU airlines to maintain their leadership in the industry depends on their effective risk management and innovation capabilities. An academic exploration is needed to investigate whether they can maintain their dominant positions. These airlines' strategies will significantly impact their future and the success of the EU's climate goals, potentially setting a precedent for the global aviation industry.

CHAPTER 6 CONCLUSION, LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

This thesis assessed how the "Big 5" European airlines- AF-KLM, EasyJet, IAG, LG, and Ryanair- are incorporating SAF into their operations to achieve net-zero emissions by 2050. This aligns with the European Union's climate neutrality objectives under Regulation (EU) 2021/1119. The analysis started by thoroughly examining the existing literature to identify the primary challenges and strategies associated with adopting SAF in the aviation industry.

From the beginning, the "Big 5" airlines have demonstrated remarkable resilience despite facing challenges such as the COVID-19 pandemic, impacting air traffic and revenue. These airlines' traffic levels and CO2 emissions have almost returned to pre-pandemic levels. However, they are now faced with new challenges in reducing CO2 emissions, as the EU has set strict targets through the Refuel EU initiative. This study provides an in-depth analysis of the various strategic approaches these airlines took, their past and current implementation, and the resulting impact on sustainability objectives in the future.

Subsequently, a comparative analysis was carried out to compare the methods used by airlines to implement SAF. Despite facing numerous challenges, such as expensive costs, limited production capacities, and complex regulations, the airlines have made significant strides. The analysis indicates that major airlines have embraced SAF to varying degrees, driven by the need to meet global climate targets and the EU's aim for a carbon-neutral future by 2050. Their dedication is evident in their attempts to enhance operational efficiencies, modernize their fleets and strategic partnership.

The theoretical implications of this study suggest that the transition to SAF necessitates more than just technological changes—it requires a strategic realignment in which economic and environmental goals converge. This thesis contributes to the academic discourse by explaining how major carriers deal with these dual challenges in a competitive and environmentally scrutinized industry.

The thesis has been consistent with the research questions stated in the introduction, enabling a thorough investigation of the emerging issues while remaining loyal to the research objectives. The subsequent sections will revisit these questions to offer a definitive summary and analyse the restrictions and potential future research opportunities.

QUESTION 1: How have the major European airlines, collectively known as the "Big 5," historically, currently, and in their future plans, implemented SAFs in response to environmental issues under the mandates of the Refuel EU initiative?

The "Big 5," the major European airlines, have been actively integrating SAF into their operations to tackle environmental issues and adhere to regulatory mandates.

- **Historical Efforts:** Historically, "The Big 5" has previously conducted pilot programs and utilized SAF on a small scale to gain better insight into its technical and operational implications. For instance, AF-KLM started experimenting with biokerosene between 2008-

2009 and has been increasing its use of SAF. Despite the slow adoption rate of SAF due to limited production capacity and higher costs compared to conventional jet fuel, progress has been made. In 2019, EasyJet and IAG started their SAF flights, while Ryanair and LG joined in 2021, with Ryanair focusing on research to explore more feedstock options and LG securing partnership agreements for future supply. Despite high-profile SAF milestones, the broader adoption across those airlines remains limited. Precise quantitative data detailing the specific percentages of SAF usage by each airline in the past is unavailable. This gap in data highlights the challenges in assessing the aviation sector's progress toward integrating more sustainable fuel options.

- **Current Practices**: In late 2023, the EU enacted the ReFuelEU Aviation legislation, which is part of the comprehensive "Fit for 55" package. This legislation requires a gradual increase in blending SAF with kerosene, starting at a minimum of 2% in 2025 and reaching 70% by 2050. Currently, AF- KLM, IAG, EasyJet, Ryanair, and LG airlines are committed to reducing their carbon footprint by increasing integration SAF into their operations. Used cooking oils are the most commonly used feedstock for SAF due to their availability and cost-effectiveness. Furthermore, these airlines are researching alternative feedstocks, such as solid and animal fat waste, that are consistent with the approved sources under the RefuelEU regulations.

Nowadays, airlines are taking measures to ensure that they have a reliable supply of SAF, improving operational efficiency through training and optimizing routes and fleet management to reduce fuel consumption. They are also adopting new fleets and technologies that support fuel efficiency and operational optimization. This proactive transition to SAF emphasizes their dedication to meeting environmental goals and regulatory requirements, which is essential for achieving a greener aviation industry.

- **Future Plans:** Looking ahead, LG and Ryanair have pledged to decrease their CO2 emissions by 50% by 2030-31. AF-KLM intends to accomplish this objective by 2035, while IAG and EasyJet are targeting a reduction of 27% and 35%, respectively, by the same year. Nevertheless, all these airlines share a common goal of achieving net-zero emissions by 2050.

At present, there is no confirmed data to suggest that the "Big 5" airlines will be using 70% SAF in their operations by the year 2050. However, IAG has publicly announced its intention to do so. EasyJet and AF-KLM have expressed a desire to achieve 63%, which is slightly less than the Refuel EU mandate. It's worth noting that the information may not be fully up to date, given the recent approval and revision of the agreement.

Meeting Refuel EU targets necessitates the strategic implementation of SAF, despite the challenges. This involves not just the adoption of SAF, but also the development of stable economic strategies and partnerships that will ensure sufficient supply. The reduction of CO2 emissions will be significantly aided by more fuel-efficient fleets and better fuel utilization through operational efficiencies. Airlines are planning to increase their use of SAF, explore alternative feedstocks to expand the supply base, and promote advances in biofuel production technologies.

These endeavours are expected to make significant contributions to meeting EU climate targets and advancing sustainability in aviation.

Question 2: How have these airlines been implementing SAF, and meeting global climate targets?

The literature review shows that the main impact of the aviation industry on the environment, causing 3.8% of total European CO2 emissions, is generated by aircraft, support vehicles, and ground transportation. Ryanair was the most polluting airline until 2021, followed by EasyJet, LG, IAG, and AF-KLM, according to verified emissions under the EU ETS. Nevertheless, the "Big 5" airlines have been progressing towards their climate targets by implementing SAF progressively since 2008-9, as part of the Refuel EU scheme to limit global warming to 1.5°C - 2°C. Various factors will be needed to achieve net-zero emissions by 2050, with SAF playing a vital role in all three scenarios. Market-based measures will significantly supplement SAF, followed by aircraft technology and ATM systems.

The five airlines have established targets to decrease CO2 emissions by 2050. Each airline has implemented unique approaches to achieve these goals through using SAF.

- LG is targeting a 65% reduction.
- Ryanair aims for a 34% reduction,
- IAG targets a 33% reduction.
- EasyJet plans a 26% reduction in emissions.
- While not specifying SAF as a standalone strategy, AF-KLM integrates it into broader sustainable development efforts, aiming for a 45% reduction.

As part of their plan, they aim to obtain newer airplanes that consume less fuel and emit fewer pollutants. This involves procuring modern aircraft that are designed to provide better fuel efficiency.

- EasyJet with its NEO fleet expected to reduce emissions by 44%.
- Lufthansa Group's goal is a 30% reduction,
- IAG targets a 37% reduction,
- Ryanair aims for a 42% reduction.
- AF-KLM include this strategy with SAF (45%)

EasyJet, LG, IAG and AF-KLM are also exploring green hydrogen technology, noted for its potential as a zero-emission fuel, differing from Ryanair's focus on retrofit technologies. Green Hydrogen, emitting only water vapor upon combustion, represents a more radical shift from SAF, requiring new technology and infrastructure.

ATM is being enhanced to improve operational efficiencies while flight routes are optimized, and fuel-saving techniques are implemented.

- AF-KLM aims for a 45% and is planning to train pilots in fuel-efficient flying techniques.
- LG targets a modest 3% by optimizing ground and flight operations.
- EasyJet seeks an 8% improvement in operational efficiency through measures such as washing and using single-engine taxis.

- Ryanair has included the reduction of emissions as part of its overall technological and operational improvement efforts, which account for 42%.
- IAG is integrating operational excellence into its broader strategy for new aircraft (37%).

All airlines recognize the significance of training in all levels in the organization not only on board and underground. Most airlines prioritize training their pilots to optimize fuel efficiency during taxing and artificial intelligence utilization. Moreover, airlines aim to reduce waste during flights, which helps decrease weight and reduce CO2 emissions. This initiative is also a part of SES initiatives, which are among the primary goals of Ryanair and EasyJet to reduce CO2 emissions. However, IAG, LG, and AF-KLM agree with the SES initiative. This is not their primary strategy.

Collaborating with technology providers, fuel suppliers, and other stakeholders is essential to achieve the target RefuelEU sets. In their economic approaches, the companies involve carbon offsetting and removal strategies.

- IAG plans to remove +30% of its emissions, including investing in various forms of SAF production technologies and carbon capture initiatives, showing a broad approach to sourcing and technology adoption.
- EasyJet focuses on eliminating 22% of residual emissions and is committed to establishing hydrogen hubs at airports and partnerships.
- Ryanair allocates 24% of its efforts to carbon offsetting, including operational efficiencies and customer engagement, advocating for policy changes and research.
- AF-KLM includes carbon compensation, aiming for 10%, incorporating intermodality to decrease short-haul flights, and exploring the use of Hydrogen at airports.
- LG views it as a temporary measure with a 2% impact, prioritizing atmospheric research and contrail avoidance.

All of these airlines are dedicated to sustainable aviation, but there are differences in their approaches. For instance, EasyJet and AF-KLM prioritize Hydrogen more aggressively than the others. And they vary in how they involve customers and advocate for policies. Ryanair focuses on influencing policy directly through research and engagement. On the other hand, IAG invests in diversifying SAF and LG while researching the next generation of SAF.

Although SAF remains critical for reducing emissions in the short term, Hydrogen has the potential to play an integral role in achieving net-zero emissions in the long term. SAF is a readily available fuel that can be used with existing technology to reduce aviation fuel's carbon footprint by 80% significantly. In contrast, Green Hydrogen requires new technology and infrastructure but produces no CO2 emissions. While SAF is a more traditional and speedy approach to emissions reduction, could be that Green Hydrogen is the forward-looking strategy for achieving net-zero emissions?

Question 3: How does the Refuel EU Aviation Initiative's SAF trajectory affect the major five European airlines, including potential obstacles they face in adopting SAFs, and what initiatives do they have set up to address this challenge?

The Refuel EU Aviation Initiative significantly impacts the major Five EU airlines. This initiative sets a challenging course for these airlines, requiring them to adjust their fuel usage and environmental strategies. The initiative presents several effects and challenges for these airlines, and they have responded to it with various actions.

1. High Production Cost: SAF poses a significant financial burden for all airlines.

- AF-KLM actively secures SAF supply and encourages demand growth to manage costs.
- Easyjet focuses on hydrogen as a cost-effective alternative for the future as they see SAF as an interim solution while advocating for hydrogen fuel.
- IAG transfers the cost premium to customers. They advocate for financial measures to support affordability.
- LG uses a hedging strategy to stabilize fuel costs.
- Ryanair advocates financial measures to support the affordability and commercialization such as providing financial aid for SAF production research and innovation.

2. Limited Production Capacity: All Airlines are forming strategic partnerships and off-take agreements to scale up production. For instance, it is urging an increase in local SAF production to meet its needs and enhancing supplier risk management.

3. Feedstock Availability: There are a variety of feedstock, and the price also varies.

- AF-KLM and Ryanair seek feedstocks with minimal environmental impact, exploring alternatives like waste, agricultural residues, and synthetic fuels.
- EasyJet pivots towards green hydrogen for long-term sustainability.
- IAG explores the diversification of feedstocks.
- LG explores PtL and StL technologies and strengthens partnerships with SAF producers.

4. Technology Challenges: New tech, testing, and high expenses take time to accomplish. However, all five airlines are upgrading their fleets and testing new technologies to comply with future SAF requirements and improve efficiency.

5. Infrastructure Requirements: Fuel infrastructure may require modifications

- AF-KLM invests in biofuel production and SAF procurement.
- EasyJet and IAG collaborate with airports and regulators to enhance infrastructure.
- Through off-take agreements, LG is preparing for increased SAF production amid changing market conditions.
- Ryanair encourages the development of refining infrastructure by collaborating with airport partners.

6. Regulatory & Policy Support: The aviation sector must navigate varying national and international regulatory landscapes, which can complicate the widespread adoption of SAF. Include time-consuming certification procedures for SAF.

- AF-KLM works with policymakers to support sustainable aviation and engage in policy advocacy. Using strategies such as intramodality.
- Easyjet emphasizes the importance of consistent regulatory frameworks and provides carbon offset options to customers.
- IAG is pushing for policies that promote SAF integration and expedite production. They give massive importance to investors.

- Ryanair and LG advocate for regulatory support and engage in initiatives to improve air traffic efficiency and reduce emissions.

The five largest airlines are addressing these issues by taking direct action, forming strategic partnerships, and advocating for policies that support their goals. Their aim is to comply with the EU's climate objectives, decrease carbon emissions, and guide the aviation sector towards a sustainable future.

6.1 DISCOVERIES AND OBSERVATIONS

This thesis highlights the importance of SAF as an immediate transitional pathway towards achieving carbon neutrality and reducing CO2 emission by 80% in the EU aviation industry while also noting that green hydrogen fuel could be the ultimate solution for "true zero" emissions. This research emphasizes that the shift toward sustainability is not just a technological challenge but a strategic move that needs to be made within a regulatory and economic framework. The analysis also stresses the significance of a diversified approach to managing risks in emissions reduction, indicating that more than a single methodology may be required. The findings add to the broader conversation on sustainable aviation, providing ideas on how airlines can balance environmental targets with economic viability.

From a managerial perspective, this research provides some valuable suggestions for airline executives to consider:

1. Strategic Partnerships for SAF Development: Airlines need to increase their partnerships with fuel suppliers and technological innovators to guarantee a secure supply of SAF and examine fresh production approaches. The partnerships are essential for expanding the integration of SAF and reducing supply-side risks.

2. Policy Advocacy and Regulatory Engagement: Airlines need to engage with regulatory bodies to impact policy-making that promotes sustainable aviation positively. By advocating for consistent global regulations, airlines can facilitate fair competition and encourage more widespread use of environmentally responsible aviation practices.

3. Risk Management and Diversification: By combining innovative technologies, hydrogen, and SAF, airlines can avoid risks depending on a single emission reduction method. Diversifying emission reduction approaches is vital to ensure a sustainable and effective solution.

4. Innovation and Adaptation: Incorporating fuel-efficient aircraft and investing in innovative technologies like AI for operational optimization are crucial for upgrading fleets. Continuous innovation is essential to remain adaptable to new technologies and regulatory changes. While modernizing fleets and operational practices, there is a need to focus on optimization through digital and AI technologies. It is also recommended that investments be made in Hydrogen Technologies (non-drop in fuel).

The challenges on the road to sustainable aviation are many, including costly production of SAF, limited capacity for production, and strict regulatory requirements. Nonetheless, the "Big 5" are developing strong strategies to overcome these obstacles, demonstrating their unwavering commitment to both economic viability and environmental sustainability. Decisions that are made today play a key role in determining the future path of companies in this industry. Their success in this endeavour will determine their future in the aviation sector and will also make a significant contribution to the EU's climate goals. As technology advances and regulations change, it will be crucial for these airlines to adapt their strategies to maintain their industry leadership and achieve their environmental objectives. Exploring new academic and practical approaches will be essential as the landscape evolves, supporting these airlines through their transition and helping them to meet current and future sustainability challenges effectively.

6.2 LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

This research has some limitations related to its methodology and scope. Firstly, publicly available data and company reports may introduce bias, as these sources highlight positive achievements and downplay challenges in understanding the real-time challenges and innovations in SAF implementation. The aviation industry's progress and commitment to sustainability can be overly optimistic; for example, SAF is promoted as a key solution, but high costs and availability issues limit its widespread use, while SAF is a speedier approach to emissions reduction, Green Hydrogen could be the long-term strategy for achieving net-zero emissions. Additionally, all airlines focus on market-based efforts like carbon offsetting, which is a superficial way to show sustainability without making substantial operational adjustments. Additionally, the study primarily focuses on the "Big 5" European airlines, which may result in overlooking innovative practices and challenges faced by smaller or non-European carriers. These carriers could provide valuable insights into the broader application of SAF and green technologies in different market contexts and regulatory environments.

Given the limitations identified, several avenues for future research emerge. An in-depth comparative analysis involving a broader spectrum of airlines, including smaller carriers and those from outside Europe, would enrich the understanding of diverse strategies and challenges in integrating SAF and achieving sustainability goals. This could uncover unique approaches and innovations that are being implemented in different regulatory and market contexts. By integrating primary data, a comprehensive comprehension of the rationale behind adopting SAF can be achieved through interviews or surveys with airline executives and sustainability officers. Such conversations can offer valuable insights into the strategic decision-making processes in use for SAF implementation.

Moreover, exploring market research of the consumer perspective on airlines' sustainability efforts and their willingness to pay a premium for greener aviation options could offer valuable insights into market dynamics and potential obstacles in consumer acceptance.

Lastly, it is important to conduct thorough, extended studies to monitor the development and impact of incorporating SAF into those airlines over long periods of time. This could include assessing the long-term viability of non-drop-in alternatives like green hydrogen. Which would offer valuable insights into the long-term sustainability and environmental advantages of SAF, particularly its ability to decrease carbon emissions over periods of ten years or more and whether these airlines adopting SAFs sustain their position as Europe’s top five.

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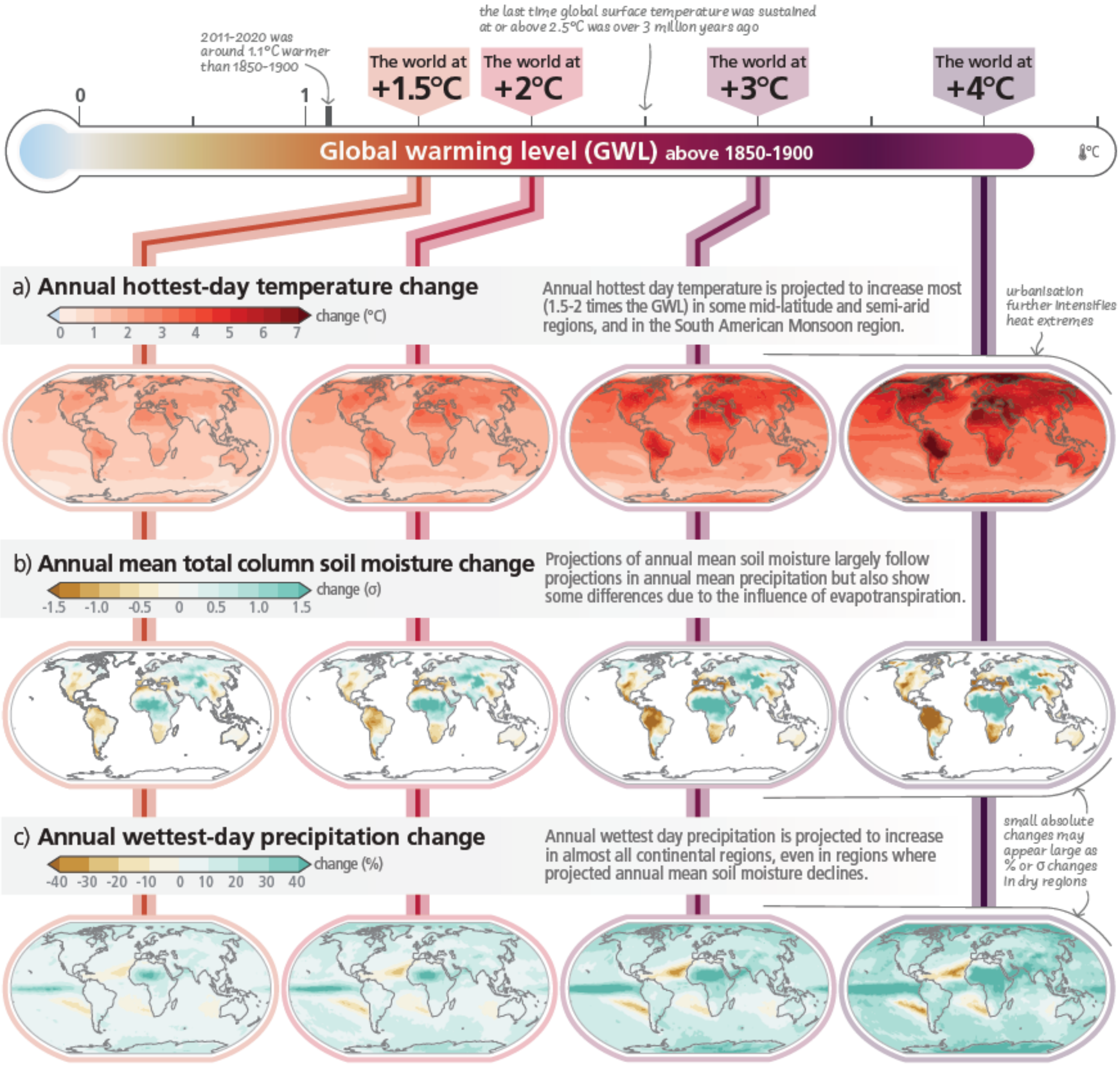
ANNEX

ANNEX 1 Projected Climate Variations at Different Global Warming Levels (1.5°C, 2°C, 3°C, and 4°C) Relative to 1850–1900.

Note: Projected increases in annual maximum daily maximum temperature, mean total column soil moisture, and maximum 1-day precipitation for global warming levels of 1.5°C, 2°C, 3°C, and 4°C compared to 1850-1900. From IPCC. (2023). Climate Change 2023 Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.



ANNEX 2 Main milestones of SAF

Note: Own elaboration in based on 1. ICAO. (2013). Sustainable Aviation Fuel User Group (SAFUG). ICAO ENVIRONMENT 2. Honeywell. (2022). Preparing for Liftoff: A Timeline of Sustainable Aviation Fuel (SAF) Milestones.

3.. IATA. (2023). Net zero 2050: sustainable aviation fuels.; Pilling, M. (2021). How sustainable fuel will help power aviation's green revolution.

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YEAR	MILESTONE
2007	It developed renewable military jet fuel exclusively for the United States military (Honeywell, 2022).
2008	The SAF Users Group (SAFUG) was formed with 25 member airlines (representing 33% of commercial aviation fuel demand), including Air France and Lufthansa, as well as 5 affiliate organizations from the aviation industry (Boeing, Airbus, Embraer), the fuel industry (UOP), and the supply of aviation fuel (ASA). A key goal of the group is to promote the adoption of SAF. The commitment includes assisting in SAF's development, certification, and commercial use as a drop-in fuel. Furthermore, the group has established stringent sustainability benchmarks to guide SAF's responsible development (ICAO, 2013). Same year Virgin Atlantic accomplished the first test flight using bio jet fuel. (IATA, 2023)
2011	Test flights began by accomplishing the first transatlantic flight using a 50/50 combination of biofuel and regular Jet-A fuel. (Honeywell, 2022).
2016	At Oslo Airport, the common hydrant system began to provide sustainable gasoline on a regular basis. Neste, SkyNRG, and Air BP collaborated on this venture (IATA, 2023). In addition, the aviation sector achieved an important milestone with the development of the world's first commercial SAF facility in USA. In the same year, United Airlines made a pioneering move by incorporating SAF into its regular operations (Honeywell, 2022).
2017	IATA members supported a resolution on SAF deployment, which included a demand for constructive government policies and a commitment to solely using fuels that protect ecological balance and prevent natural resource depletion (IATA 2023).
2018	The Renewable Energy Directive (RED II), legislative framework established by the EU to promote and regulate the use of renewable energy sources within the member states (EASA, 2023b).
2020	Norway became the first government in the world to implement a mandate, requiring that 0.5% of all fuel consumption be SAF (Pilling, 2021).
2021	A historic breakthrough an airplane fuelled solely by SAF landed successfully in Washington, DC. This milestone demonstrates the industry's continuous commitment to ecologically friendly air travel, paving the path for a more sustainable future. Furthermore, both the European Union and the United States have implemented substantial policy changes to encourage the use of SAFS. (Honeywell 2022; IATA 2023)
2023	EU adopted Refuel EU Aviation which completed the 'Fit for 55' (IATA 2023)

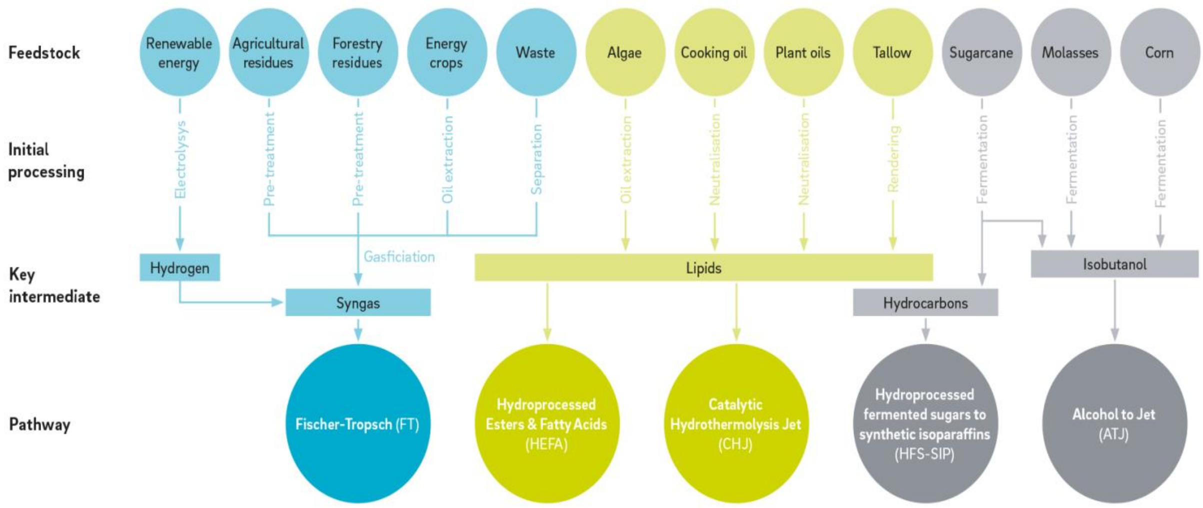
ANNEX 3 Production and co-processing process approved for manufacturing SAF.

Note: The table shows products pathways, feedstocks, certification name and TRL (Technology Readiness Level). From EASA. (2023). What are Sustainable Aviation Fuels?

PRODUCTION PATHWAY	FEEDSTOCK	CERTIFICATION NAME	TRL
Biomass Gasification + Fischer-Tropsch (Gas+FT)	Energy crops, lignocellulosic biomass, solid waste	FT-SPK (up to 50%)	7-8
Hydroprocessed Esters and Fatty Acids (HEFA)	Vegetable and animal fat	HEFA-SPK (up to 50%)	8-9
Direct Sugars to Hydrocarbons (DSHC)	Conventional sugars, lignocellulosic sugars	HFS-SIP (up to 10%)	7-8 or 5
Biomass gasification + FT with Aromatics	Energy crops, lignocellulosic biomass, solid waste	FT-SPK/A (up to 50%)	6-7
Alcohols to Jet (AtJ)	Sugar, starch crops, lignocellulosic biomass	ATJ-SPK (up to 50%)	7-8
Catalytic Hydrothermolysis Jet (CHJ)	Vegetable and animal fat	CHJ or CH-SK (up to 50%)	6
HEFA from algae	Microalgae oils	HC-HEFA-SPK (up to 10%)	5
FOG Co-processing	Fats, oils, and greases	FOG (up to 5%)	-
FT Co-processing	Fischer-Tropsch (FT) biocrude	FT (up to 5 %)	-

ANNEX 4 Mapping feedstocks to SAF pathways.

Note: The figure displays Mapping of feedstocks to pathways. From Berger. (2020). Sustainable aviation fuels key for the future of air travel.



ANNEX 5 Approved pathways in EU, Cost driver and Limitations.

Note: Table shows a summary of the SAF pathway used. Own elaboration in based on:

1. Soone & Claros. (2022) Sustainable aviation fuels. EPRS (European Parliamentary Research Service).

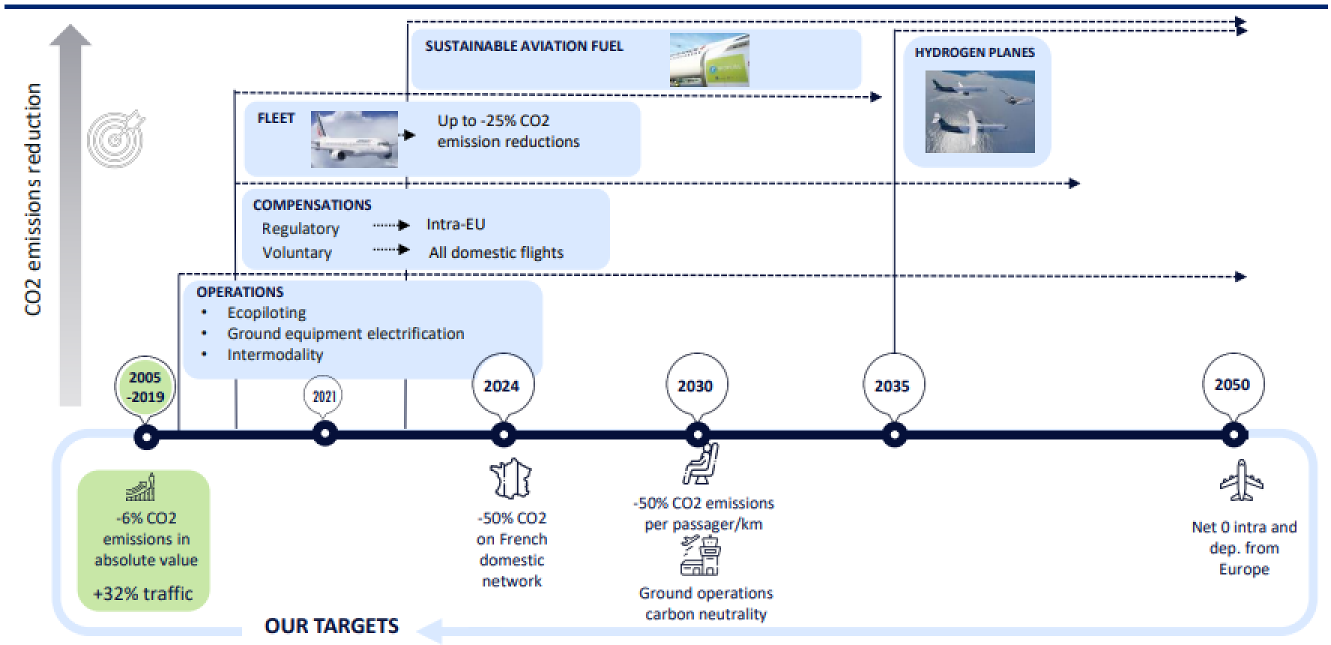
2. EASA. (2023). European Aviation Environmental Report; EASA ECO.

3. World Economic Forum. (2023). Sustainable Aviation Fuels: Offtake Manual.

SAF PATHWAY	DESCRIPTION	LIMITATIONS & COST DRIVERS
Hydro processed Esters and Fatty Acids (HEFA)	• Feedstocks for the process include waste and residue fats (e.g., vegetable oil) as well as plants grown specifically for the process (e.g., jatropha, camelina). • Hydrogen is utilized to remove oxygen from the feedstock, and the goal is to convert them into hydrocarbon fuel components (EASA, 2023a).	• Availability of sustainable feedstock. • Competition with other sectors (e.g., transportation) • Production capacity is limited (Soone & Claros, 2022). • Feedstock prices are market-driven and unlikely to decline. The cost is double that of fossil jet fuel (World Economic Forum, 2023)
Alcohol to Jet (AtJ)	• Fermentation is used to produce ATJ from lignocellulosic feedstocks (e.g., agricultural and forest residues) as well as sugar or starch crops (e, g. corn, sugarcane, wheat). • In some aromatic compounds can be produced. While decreasing fuel aromatic content benefits both air quality and the environment (EASA, 2023a).	• AtJ fuels without aromatics may affect aircraft engine components. This enables 100% SAF certification (for example, rubber seals) (Soone & Claros, 2022). • The most expensive option is to refine ethanol into aviation fuel. It needs significant capital investment (World Economic Forum, 2023).
Biomass Gasification + Fischer-Tropsch (Gas+FT)	• Involves producing Biogas (syngas) through the gasification of feedstock and then processed in a FT reactor. • Gas+FT and AtJ are both advanced biofuels that can use the same feedstocks mentioned in REDII, including municipal solid waste (EASA, 2023a).	• The cost of production is mostly determined by the capital cost. Cost is between 2-4 times higher of fossil jet fuel. • Versatility in feedstock types, indicating potential cost reductions (World Economic Forum, 2023) • Not yet commercially available in the EU. • Rivalry with the maritime transport industry (Soone & Claros, 2022).
Power-to-Liquid (PtL) (Synthetic kerosene, efuels, power-to-liquid, or synfuels, E-kerosene (Southern Green Gas., 2023).	• Hydrogen is produced by electrolysis of water, which is then mixed with CO2 to create syngas. This may be transformed into fuel using a FT reactor or methanol synthesis. • Unlimited availability: CO2 can come from industrial waste gases, biomass, or direct atmospheric capture (EASA, 2023a; Soone & Claros, 2022).	• Costs 3 to 6 times higher than fossil jet fuel (Soone & Claros, 2022). Synthetic fuel costs expected to decrease with lower-cost electrolysers and scale effect (World Economic Forum, 2023) • Green power costs vary, and there are uncertainties about carbon capture and diverse technologies. • Further study is needed (Murphy A. 2021).

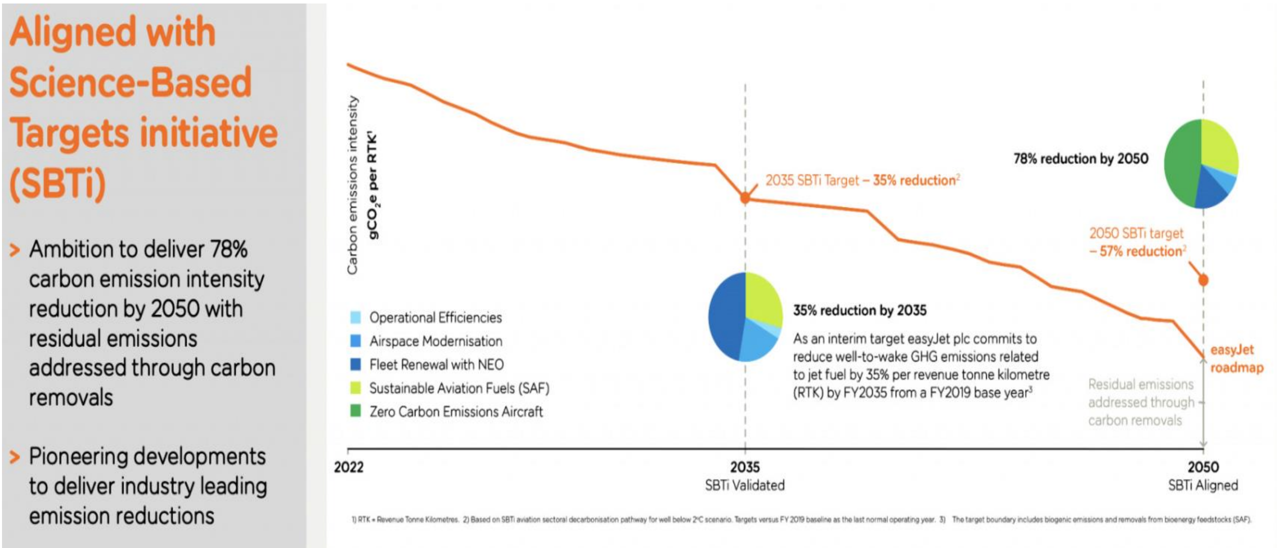
ANNEX 6 AIR FRANCE KLM Environmental Roadmap By 2050

Note: The roadmap is part of AIR FRANCE-KLM Sustainable Strategy. From: Etchebehere, V. (2020). ENVIRONMENTAL SUSTAINABILITY AT AIR FRANCE KLM. In A. FRANCE-KLM (Ed.).



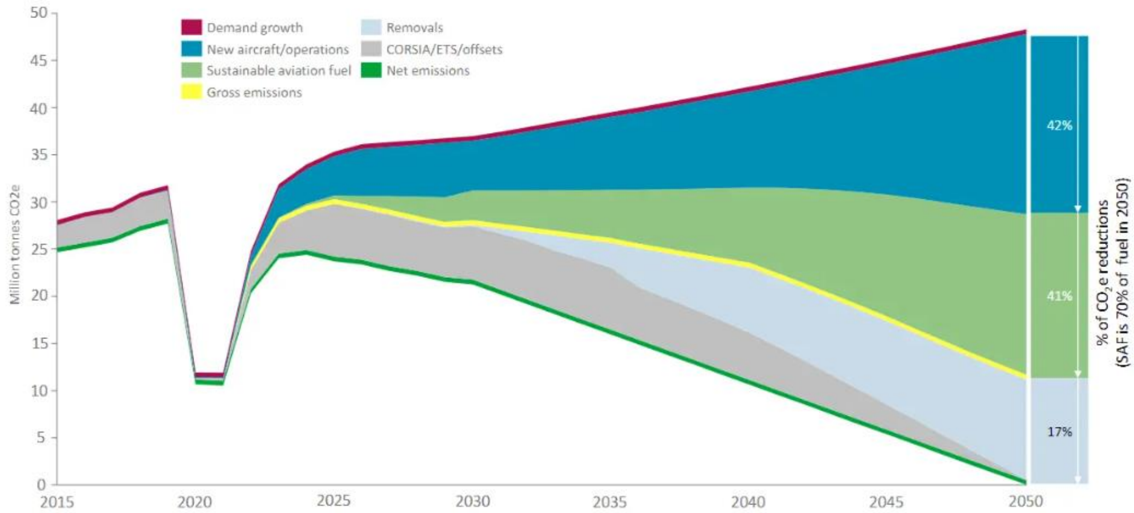
ANNEX 7 EASYJET Environmental Roadmap By 2050

Note: EASYJET roadmap to net-zero carbon emissions by 2050. From: EasyJet. (2022). Our roadmap to net-zero carbons emissions by 2050. EasyJet.



ANNEX 8 IAG Environmental Roadmap By 2050

Note: The roadmap is part of IAG, its latest roadmap to this goal every year since 2019. From: IAG. (2023). Roadmap 2050. International Airlines Group (IAG).



ANNEX 9 RYANAIR Environmental Roadmap By 2050

Note: The roadmap is part of RYANAIR REPORT. From: Ryanair Group. (2023). Ryanair Group Aviation with Purpose. 2023 3 SUSTAINABILITY REPORT. https://corporate.ryanair.com/wp-content/uploads/2023/07/Ryanair-2023-Sustainability-Report.pdf