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THE ENVIRONMENTAL COMMITMENT OF EUROPEAN COMMERCIAL AVIATION: THE CASE OF LOW-COST AIRLINES

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1. INTRODUCTION

Climate change has many widespread and irreversible effects, such as increases in global average air and ocean temperatures, changes in precipitation patterns, rising global average sea levels and increasing ocean acidity. Their impacts threaten the viability of social, environmental and economic systems, so nowadays every industry and sector is taking sustainability into account in each of their daily actions. According to the Intergovernmental Panel on Climate Change, known by its acronym IPCC, global sea levels have risen by about 20 centimetres since 1900. It is rising faster than at any time in at least the last 3,000 years, and this rate is accelerating. In addition, the ocean has absorbed 90% of the additional heat associated with global warming, and is also warming faster than at any other time. Regarding precipitation, rainfall over the Earth's surface has increased since the 1950s. In tropical regions, more rain falls during wet seasons and less during dry seasons than before. Finally, the average land surface temperature between 2011 and 2020 was 1.1°C (2°F) higher than the average temperature in the 19th century. Each of the last 4 decades has been warmer than the previous decade. The planet is warming faster than at any time since at least the last 2000 years (Climate Change 2021: The Physical Science Basis, n. d.).

For its part, the aviation industry has a clear negative impact on the environment (Hinnen et al., 2017; Qiu et al., 2021; Vespermann & Wittmer, 2011), especially in relation to carbon emissions as aircraft produce large amounts of carbon dioxide (CO_2), the main greenhouse gas. Such emissions contribute to climate change by increasing greenhouse gas concentrations in the atmosphere (Intergovernmental Panel on Climate Change, 1999). Carbon dioxide (CO_2) emissions from international aviation accounted for about 3% of global and EU inventories in 2004 (Enerdata, 2009). The growth of CO_2 emissions from international aviation in EU countries was 85% between 1990 and 2009 (European Environment Agency, 2007). In addition, aircraft contribute to climate change by emitting nitrogen oxides, sulphur dioxide, soot and water vapour. Less well known warming effects of aircraft emissions include the formation of contrails and cirrus clouds.

Furthermore, apart from its contribution to global climate change, aviation is also linked to aircraft noise and noise pollution, as well as the high consumption of energy and water to meet passenger needs and the large amounts of waste produced (Paraschi and Poulaki, 2021). In particular, controlling and mitigating emissions from passenger air transport is vital for the achievement of global carbon emission reduction targets (Falk and Hagsten, 2020; Vespermann and Wittmer, 2011).

The main objective of this work is to study the commitment of European commercial aviation, more specifically low-cost airlines, to environmental sustainability as it is one of the highly polluting sectors that are at the centre of public opinion on sustainability. For this reason, it analyses how Europe and the different companies have reached the current situation and, above all, what objectives they have for the future and how to achieve them. The aim is to find out what the industry's initiatives are to reduce their environmental impact, whether through technological advances, the development of alternative fuels or other methods, in order to compare the airlines chosen and to understand the most significant differences, if any, in their corporate strategies in relation to environmental sustainability.

With regard to the methodology used to prepare this study, firstly, it is a case study, where several airlines are analysed and compared in order to understand how different variables can influence the results and to generate more contextualised knowledge. Secondly, the sources of information used to carry out this project include studies and works related to the aeronautical sector that offer a first contact with the current state of the industry. It should be noted that the reports and studies carried out by European organisations and institutions provide a clearer picture of the evolution of Europe in terms of aeronautical sustainability, as well as the guidelines and objectives for the coming years. Finally, and as the main source of information, the annual reports of the companies analysed have been used and, where available, the sustainability reports themselves from 2017 to 2022, which is the last year registered. The study focuses on the European low-cost airline segment where the following airlines are analysed: Ryanair, WizzAir, EasyJet, Norwegian and Jet2.

The paper is structured in several points where firstly the term sustainability itself is developed, explaining why it is important in the aviation sector and the different degrees depending on the airline's strategy, followed by the environmental impact of the commercial aviation industry where the current situation of European aviation is defined as well as its roadmap to achieve the objectives set for the future. Finally, the comparison of companies itself appears, showing the methodology used for the analysis, as well as the comparison of the results. Finally, the last section contains the conclusions drawn from this work.

2. LITERATURE REVIEW

2.1 Corporate sustainability

2.1.1 Concept and dimensions of corporate sustainability

Although the emergence of social and public responsibility associated with sustainability is a concept that seems very modern, it has a long history in society in general and in the business sector in particular. Terms related to corporate sustainability, such as sustainable development, sustainable business or sustainability, are complex concepts that have been used throughout history in different ways. Today, there are also some differences between expert definitions as there are multiple interpretations of the concept. It should be said that most studies identify corporate sustainability with both social and environmental issues and their relationship with economic sustainability (Montiel, I., & Delgado-Ceballos, J. (2014)).

The origin of this concept is mainly linked to the report's definition of sustainable development (WCED, 1987) as development that satisfies the needs of the present without compromising the ability of future generations to meet their own needs. Despite this, the concept first appeared in mainstream literature in 1995, when Kennelly, Gladwin and Krause (1995) described sustainable development as a process for achieving human development in an inclusive, connected, equitable, prudent and secure manner. Ten years later, it is also defined as a three-dimensional construct based on economic prosperity, social equity and environmental integrity (Bansal, 2005).

More recently, Hart and Dowell (2011) argue that sustainable development is one of the three key strategic capabilities of the natural resource-based vision and that it evolves in two distinct areas: clean technology and bottom-of-the-pyramid strategies. A sustainable development strategy does not simply seek to do less damage to the environment but to actually produce in a way that can be sustained indefinitely into the future. Sustainable development is not limited to environmental concerns, but also involves focusing on economic and social concerns (Hart & Dowell, 2011, p.1466).

The economic, industrial and social development that humanity has experienced in recent centuries has left a negative mark on the environment. The consequences of overexploitation of resources, global warming and climate change are already being felt, making it imperative that states take action to ensure environmental sustainability.

The term sustainability refers to corporate activities that maintain or enhance the company's ability to create long-term value (SASB Standards). That is, the ability to manage, maintain or preserve a balance in the use of natural and social resources derived from the production of goods and services to meet current needs without compromising the ability of future generations to meet their own needs. This definition describes the organisation as one that will not use natural resources faster than the rates of renewal, recycling or regeneration of those resources (Marshall & Brown, 2003).

A more recent definition is described as a move towards a proactive sustainability orientation. Businesses must find ways to interconnect social, economic and ecological systems through coordinated approaches that leverage the collective cognitive and operational capacities of multiple social, ecological and economic stakeholders operating as a unified network or system (Valente, 2012, p. 586).

As can be seen, the concept has never been fully accepted by society and there have always been some discrepancies as to whether corporate responsibility should be a three-dimensional construct, with some scholars identifying the concept exclusively as an environmental dimension (Marshall & Brown, 2003), as synonymous with environmental management, while others refer to social and environmental issues (Hall & Vredenburg, 2003), while a large proportion of scholars agree on the definition that encompasses all three dimensions: economic, social and environmental (Hart & Milstein, 2003).

To minimise such conceptual conflicts, it would be correct to use corporate sustainability for the three-dimensional construct and corporate environmental sustainability when focusing on environmental aspects (Shrivastava, 1995; Starik & Rands, 1995).

The three dimensions could be defined in a simple way. According to the economic perspective, production methods should be able to meet current consumption levels without compromising their ability to meet future demand. The social dimension deals with issues of equity, participation, accessibility, security and institutional stability. Finally, the environmental dimension refers to the natural environment and requires that resources be used at a rate no faster than they can be regenerated and that the waste it receives be emitted at a rate no faster than it can be assimilated.

2.1.2 Strategies and degrees of commitment to corporate sustainability

Having examined the different approaches to defining corporate sustainability, it is worth mentioning the existence of different levels, each of which identifies the elements that must be taken into account to achieve true corporate sustainability (Dyllick, T. and Muff, K. 2016). The four levels are:

1. Traditional businesses: those companies that are not committed to sustainability and their main objective is to maximise short-term profits.

2. Improved business: at this level companies have taken some steps to improve their sustainability, but still focus on maximising short-term profits.

3. Sustainable businesses: those organisations that have an overall perspective on sustainability, considering the economic, social and environmental impacts of their decisions. They aim to balance long-term profitability with social and environmental responsibility.

4. True corporate sustainability: At this level, companies have integrated sustainability into their core strategy and daily operations. They aim to create long-term economic, social and environmental value and contribute to solving global challenges.

It points out the importance of having a clear and well-defined typology of different levels of corporate sustainability to help understand how they can improve their sustainability performance. It also stresses the need for companies to adopt an approach that encompasses not only environmental, but also economic and social aspects. It underlines that corporate sustainability is not only a matter of compliance with legal and ethical requirements, but can also generate opportunities and enhance a company's reputation. Companies that take a proactive and strategic approach to sustainability can improve their long-term profitability and their ability to compete in an increasingly sustainability-conscious marketplace (Dyllick, T. and Muff, K. 2016).

To take this further, a comprehensive review of the corporate sustainability literature develops a framework of the "strong sustainability" perspective. This resulted in a multi-stage model differentiated according to the degree of sustainability of a company's practices (Landrum, 2018). It describes the following:

1. Non-participatory: no adoption of sustainability practices by companies.

2. Compliance: adoption of practices with the aim of complying with regulations.

3. Business-focused: they pursue sustainability for business profit.

4. Systematic: practices that go beyond the business case and seek cooperative efforts with the goal of systematic change.

5. Regenerative: They seek to repair, restore and regenerate practices and patterns with the aim of keeping them in place.

6. Coevolutionary: practices that go beyond and require constant evolution.

These stages show how involved a company is in terms of sustainability, where the first stage encompasses all companies that do not engage in any sustainable practices. As the stages change, the level of involvement increases, reaching a very strong sustainability position in the evolutionary stage.

Three fundamental aspects can be highlighted when talking about the future of corporate sustainability: technology and innovation, regulations and standards, and finally collaboration and commitment (de Oliveira, UR, Menezes, RP and Fernandes, VA. 2023).

Focusing on corporate sustainability, several studies analyse the importance of pursuing a strategy focused on technology and innovation, as they can provide opportunities and solutions to reduce the environmental footprint of companies in order to improve their sustainability. These can be useful in certain areas such as energy efficiency, waste management and the use of sustainable materials. In addition, technology can improve the monitoring and measurement of the environmental footprint of companies, setting more ambitious targets and being able to assess progress in implementing sustainability strategies.

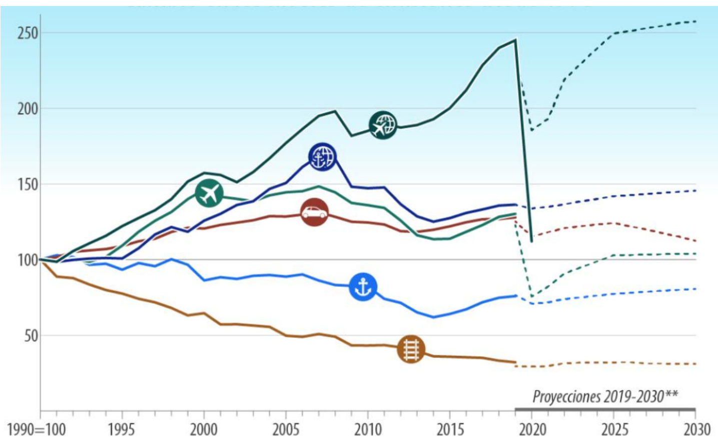
On the other hand, regulations and standards are necessary to ensure that companies are accountable for the impacts their operations have on the environment and society. Similarly, these regulations can provide incentives for companies to take sustainability measures, such as more sustainable technologies and practices, while ensuring transparency and accountability. However, it is important that these new regulations are consistent and that companies are supported to meet these standards.

Governments must establish stricter sustainability regulations, but in a clear and consistent manner, and enforce them effectively to encourage change towards more sustainable practices. Businesses need to take a more proactive role in implementing sustainable practices by setting ambitious and measurable targets to reduce their environmental impact.

2.2 Sustainability in the commercial aviation industry

Mobility is an essential human need and in today's society, the survival of humanity and social evolution depends on the ability to move people and goods in a safe, efficient and reliable way. The transport system is essential for European individuals and businesses while at the same time it is not without costs and damage to our society: emissions of polluting gases, noise, traffic accidents. In the years before the recent pandemic, transport emissions accounted for around a quarter of the EU's total greenhouse gas emissions, between 25 and 30% (European Environment Agency, 2020).

Figure 1: Changes in greenhouse gas emission levels from EU transport since 1990



Source: European Environment Agency (2022)

As can be seen in graphic 1, air transport is the type of transport that generates the most emissions, but it cannot be said that it is the most harmful to society, as it is not only this criterion that is assessed. According to Vicente Padilla, CEO and founder of AERTEC: "The environmental impact assessment of any type of transport must take into account the entire process involved, from the construction of the infrastructure to its maintenance and use. Air transport needs a runway of just over 4 km while rail transport needs thousands of km of infrastructure". (1st Aviation Climate Summit).

Air transport is one of the most popular and rapidly expanding businesses, offering a wide range of services and social benefits. The industry is an important economic force for the global economy, connecting people, facilitating the transport of goods and promoting tourism in a way that previous generations could only dream of. In recent years passenger traffic has experienced remarkable growth with both passenger numbers and operations reaching historic highs.

However, with this growth, the role of aviation and its environmental impact are now the subject of greater societal scrutiny. While climate change already enjoyed high visibility in Europe, the entry into force of the Paris Agreement undoubtedly helped to bring it to the top of the political agenda (United Nations Paris Agreement, 2015). So much so that the College of European Commissioners (2019-2014) itself, led by Ursula von der Leyen, recognises the opportunity to make Europe the first climate-neutral continent as the greatest challenge of the 21st century, as developed in the European Green Pact (European Green Pact and "Target 55", 2019). It seeks to initiate a drive for the transformation of transport to become more sustainable and competitive while this revolutionary change must leave nothing behind, be available and affordable for all as well as the connectivity of rural and remote areas with good conditions for the population (European Commission's Sustainable and Intelligent Mobility Strategy, 2020).

European airlines have committed to decarbonise air transport and to accelerate their efforts to make Europe the world's first carbon neutral continent by 2050 by reducing CO2 emissions in absolute terms and through CO2 mitigation. The EU's own aviation sector recently published its "Destination 2050" roadmap showing a clear path to achieving net emissions for intra-European flights. This report shows that the target is achievable, but is no guarantee of success as it depends closely on the ability of policy makers in European national governments, the EU and ICAO to support the sector's decarbonisation plans with regulatory, fiscal and investment incentives (Airlines for Europe, 2021).

Transport Commissioner Adina Vălean says that transport companies must be provided with a stable framework for the green investments they will have to make in the coming decades in order to encourage and incentivise change without fear of losing these investments due to changes in laws and regulations once they have started. The implementation of this strategy will create a more efficient and resilient system that is in line with the European Green Pact objectives.

With regard to environmental sustainability in aviation, it can be seen that in the early days of aviation, the concept of sustainability went unnoticed, but it has progressively gained importance and more and more sustainable and ethical parameters have been incorporated. So much so, that numerous organisations and programmes have emerged that try to take care and measure that the different airlines apply the measures correctly and that they are within the established parameters. It refers to the industry's ability to operate profitably and efficiently while minimising its impact on the environment and addressing climate change. It encompasses all developments in innovative sustainable technologies and practices aimed at improving competitiveness and environmental impact.

From Europe, sustainability is not only focused on the airlines and aircraft themselves, but also on the airport, its facilities and the handling companies operating in this sector, as it is a growing concern for the industry and it seeks to implement measures and technologies to address environmental challenges and ensure a sustainable future for aviation.

2.2.1 Importance of sustainability in commercial aviation

Previous studies have concluded that environmental impacts can be alleviated through operational strategies. Scotti and Volta (2015) assessed the CO2 sensitivity of EU aviation productivity and found that it was positively influenced by improved load factors and by the combination of increases in stage length and aircraft size. Simic and Babic (2015) noted that the environmental efficiency of airports can be improved through air traffic management, including the evolution of airport infrastructure. Pérez-Valls et al. (2016) stated that environmental capabilities can be established through teams, social controls, internal networks and horizontality of organisational design. Research by Hao et al. (2016) found that each additional minute of fuel used for continuous agencies could be induced by a one-minute increase in the standard deviation of flight time.

It can be seen that there is some relationship between possible measures and the achievement of more sustainable outcomes, so it could be assumed that achieving more sustainable aviation is feasible. However, few studies have developed database methods to investigate sustainability issues in aviation. Moreover, given the abundance of sustainability alternatives, it remains difficult to differentiate which are the most useful approaches or pathways to achieve environmental sustainability in this field (Wu, P and Yang, CK-K. (2021)).

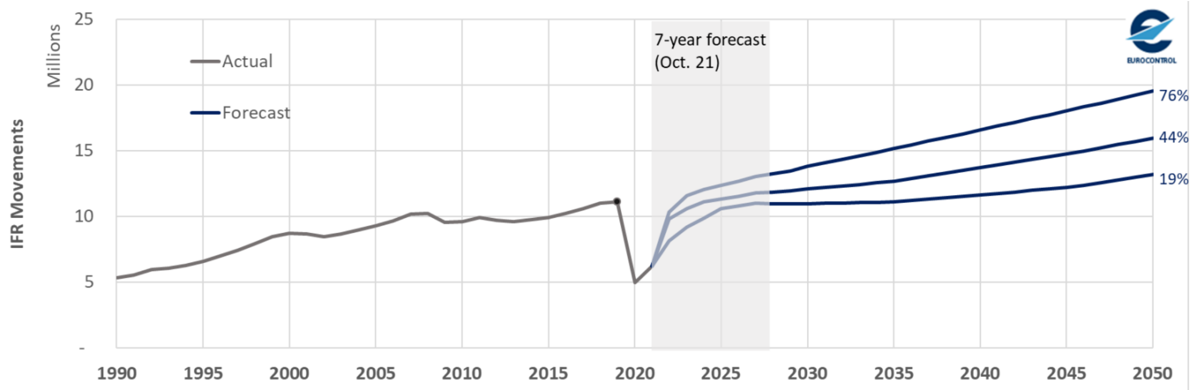
Despite this, the major environmental concern of aviation is that air transport is a major consumer of energy and leaves a considerable environmental footprint, which unlike other types of transport, not only has a direct impact on the surface of the earth, but also extends to the upper limits of the troposphere. The effects produced are difficult to control, especially the contribution of air transport to climate change, since as a consequence of its heavy dependence on hydrocarbon fuels, the airline industry generates a significant amount of emissions, the vast majority of which are in the form of carbon dioxide (CO2). The main source of greenhouse gas (GHG) emissions are due to the use of aircraft fuel, so its management is essential in reducing these emissions (Benito, A. 2014).

Carbon dioxide (CO2), a greenhouse gas produced by the combustion of aviation kerosene, absorbs heat released by the sun and the earth's surface and releases it into the atmosphere. High concentrations of greenhouse gases, in particular CO2, threaten to raise the world's average surface temperature to unbearable levels causing a range of life-threatening consequences. Carbon dioxide levels in the atmosphere have increased by more than 40% since the mid-17th century, and climatologists estimate that current levels are the highest in 14 million years.

On the other hand, if we focus on the positioning of aircraft with respect to other means of transport we see a clear disadvantage as non-CO2 emissions from aviation is much higher than the equivalent of other means of transport as they are formed at higher altitudes persist longer than at the surface and also have a stronger warming potential (Marais, E. 2019).

The need to implement greener policies and practices becomes important if we analyse the data (Figure 2 and 3) of European aviation where we can see how from the first years of records to the present day, both the number of flights and the amount of CO2 emissions have been progressively increasing. In a scenario that is considered possible (Base scenario), 44% more flights are expected than in 2019.

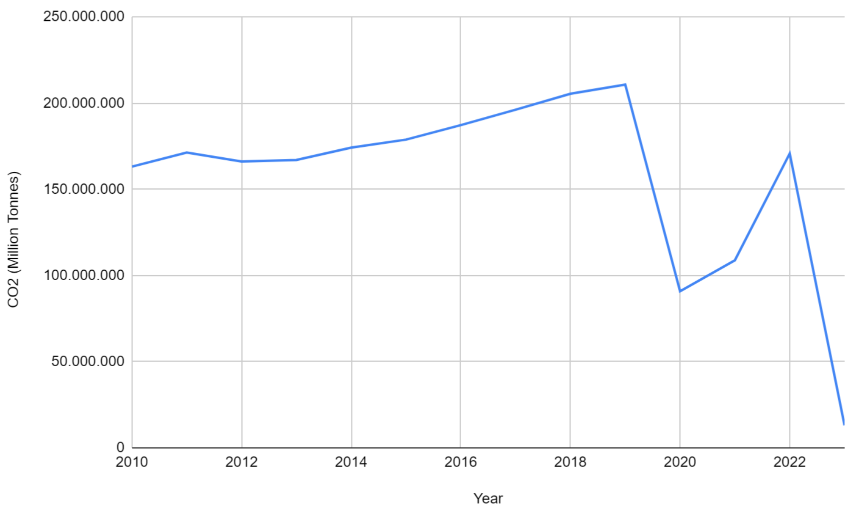
Figure 2: Flight forecast for Europe, with total growth between 2019 and 2050.



Source: Eurocontrol Aviation Outlook (2022)

This steady growth has prompted a wake-up call from Europe as pre-pandemic figures are expected to be reached very quickly and the growth momentum is expected to continue.

Figure 3: CO2 emissions in million tonnes per year in Europe (commercial flights)



Source: Own elaboration based on Eurocontrol data.

The concern is mainly about the CO2 emissions emitted by aircraft in their flights and, in the wake of the health crisis, European organisations have ruled that the time has come to take action to create a sustainable future for commercial aviation.

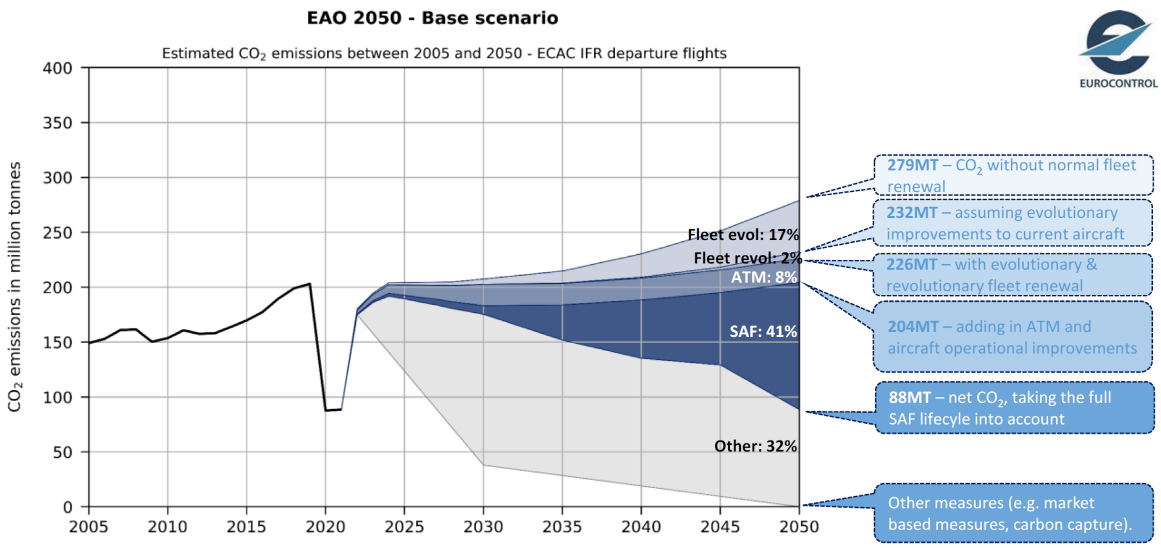
The European Union is committed to becoming the first climate-neutral block by 2050 and sustainability is high on the agenda. Its own organisations have been set up to combat this problem and agreements have been drawn up that set out the roadmap for achieving these goals. These can be achieved, although not easily, through joint and coordinated efforts by industry and mainly by regulations and government.

The roadmap for moving towards more sustainable commercial aviation is by following a path that combines four types of actions, known as the "four pillar theory", to try to reduce carbon emissions. They are as follows:

-Improved aircraft and engine technology
-Improvements in aircraft operations and traffic management
-Sustainable aviation fuel
-Economic measures

As shown in Figure 4, Eurocontrol has designed a study which reveals more concretely the importance of each of the above measures for the achievement of Net Zero CO2 by 2050.

Figure 4: Estimated CO2 emissions between 2005 and 2050 - ECAC (European Civil Aviation Conference) take-offs IFR (Instrument Flight Rules)



Source: Main Report - EUROCONTROL Aviation Outlook 2050 (april 2022)

This forecast for 2050 will be achieved through the reduction of around 280 million tonnes of CO_2 by 2050:

- (17%) More efficient commercial aircraft.
- (2%) Electric and hydrogen-powered aircraft.
- (8%) Commercial operational improvements and Air Traffic Management.
- (41%) Sustainable Aviation Fuel.
- (32%) Other measures.

The study also reflects three possible scenarios that differ significantly from one another depending on the degree of involvement and investment in the aviation sector. The higher the scenario, the more flights, the more investment and the greater the need to reduce CO_2 emissions.

In the most likely baseline scenario, net CO_2 emissions are reduced by around 40% in 2050 compared to 2005 levels. Most of this is achieved through the use of sustainable fuel (SAF). In addition, new emission-saving aircraft types with electric propulsion are also entering service over some distances. However, they are still relatively new and do not constitute a dominant share by 2050.

In the table below we see a summary of the results for each of the three scenarios showing the relative share of each measure to decarbonise aviation. In all scenarios, measures will still be needed in 2050 to fully decarbonise. As shown in Table 1, sustainable aviation fuel is by far the most important measure to achieve net emissions, so it is essential to develop SAF fuels.

Table 1: Importance of the different measures in the various scenarios

Net Zero CO2 can be achieved by 2050 via:	**Low Scenario**	**Base Scenario**	**High Scenario**
Required CO2 reduction for Net Zero	194 MT	279 MT	359 MT
Fleet evolution	17%	17%	17%
Fleet revolution	2%	2%	3%
Air traffic management (ATM)	6%	8%	9%
Sustainable Aviation Fuel (SAF)	34%	41%	56%
Other measures	41%	32%	15%

Source: Own elaboration based on EUROCONTROL Aviation Outlook 2050 data.

2.2.2 Key factors for moving towards sustainability in 2050

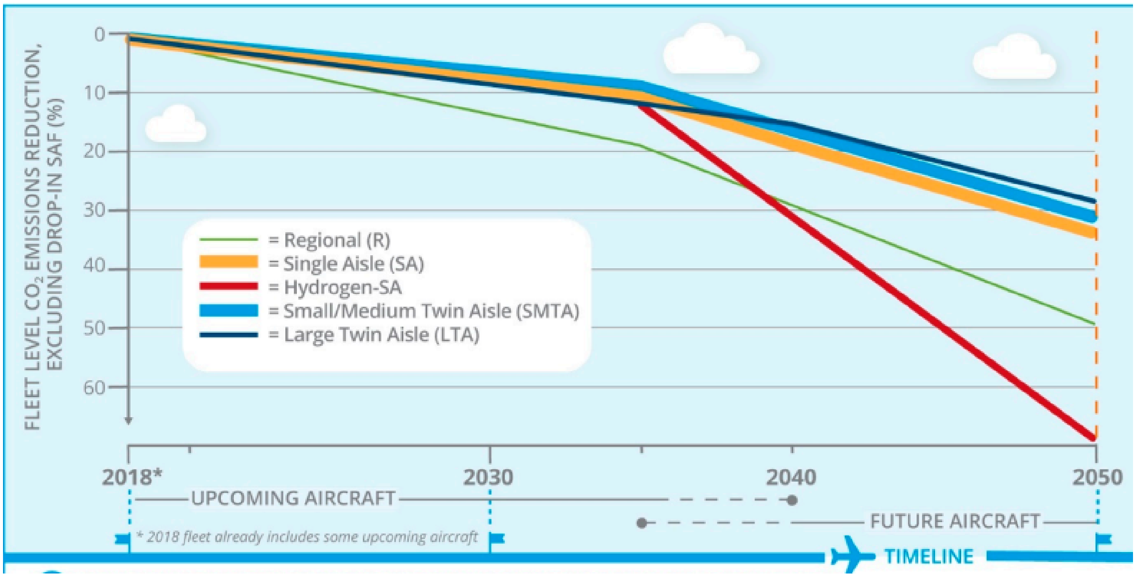
As mentioned in the previous paragraph, Eurocontrol has set out a roadmap identifying various approaches to reduce the effects of commercial aviation emissions, ranging from new fuel sources to operational and policy measures. These factors are key to moving towards a much more sustainable future and European airlines must take actions and measures to try to meet the estimated figures imposed. This section addresses and describes these different aspects, highlighting the most relevant information.

The different factors are: fleet and technology development, operational improvements, sustainable aviation fuels and other measures.

- Fleet and technological development:

The importance of technology through improvements to existing aircraft and engines, but also by introducing radical changes in aircraft design and propulsion. Mainly the development of new types of aircraft (water, hybrid electric, all-electric).

Figure 5: Improvements in aircraft and engine technology and their impact on CO2 emissions



Source: Destination 2050 - A route to Net Zero European Aviation

The main focus of this section is the potential ability to make a radical change in energy efficiency in order to reduce fuel consumption by around 30% compared to conventional engines. Also, the optimisation of the range and capacity of the aircraft will prevent them from reducing CO2 emissions.

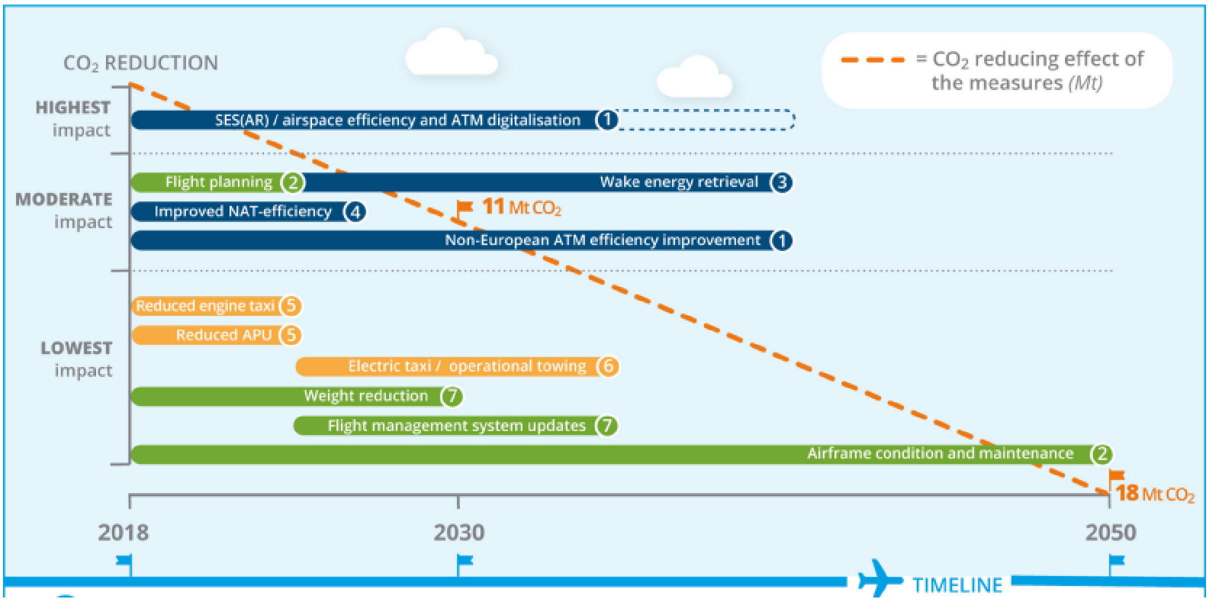
Figure 5 shows the evolution of future aircraft emissions by aircraft model over time. It can be seen how 2035 is estimated as a turning point due to the time required from today to implement sustainable measures in aviation.

- Operational improvements:

Optimisation of flight efficiency (more fuel-efficient trajectories), the introduction of specific operational measures that reduce fuel consumption (reduction of holding and taxing times) and minimisation of fuel consumption in aircraft operations in all phases of flight (better aircraft weight management and optimisation of fuel management practices).

Programmes such as SESAR 3 and Digital European Sky will help to achieve this goal.

Figure 6: CO2 reduction effect of measures



Source: Destination 2050 - A route to Net Zero European Aviation

Improvements in ATM are seen as a crucial opportunity to reduce CO2 emissions in the short to medium term.

As Figure 6 highlights, these improvements can be divided into three groups: air operations, air traffic and space management and ground operations.

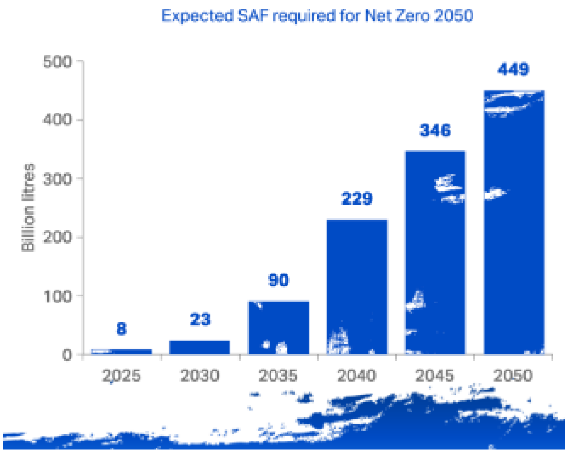
- SAF:

Sustainable aviation fuels are today's most promising pathway to decarbonisation. SAF is a liquid fuel currently used in commercial aviation that can reduce CO2 emissions by up to 80% compared to fossil aviation fuels. It can be produced from various sources (feedstock), including used oils and fats, green and municipal waste and non-food crops. It can also be produced synthetically through a process that captures carbon directly from the air. It is 'sustainable' because the feedstock does not compete with food crops or water supplies, nor is it responsible for forest degradation. While fossil fuels add to the overall level of CO2 by emitting carbon that had previously been locked up, SAF recycles the CO2 that has been absorbed by the biomass used in the feedstock over the course of its life.

One of the great advantages of using SAF is that it is a drop-in fuel, so no changes to airport infrastructure or aircraft are required.

This fuel type has already become very important in the context of sustainability in aviation but is expected to gradually become more important. This will require a massive increase in production to meet demand, as shown in Figure 7. The greatest acceleration is expected in the 2030s as policy support becomes important and global.

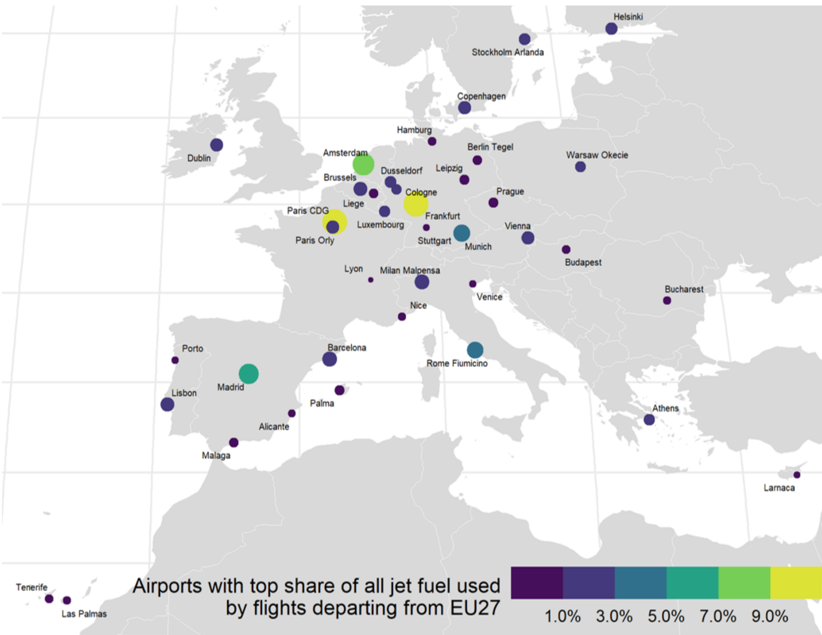
Figure 7: Projected ADC required for decarbonisation in 2050



Source: IATA

The European Union has launched the "Fit for 55" package of measures, which includes a fundamental impulse for the adoption of FFCs with the ReFuelEU Aviation proposal, where an obligation to blend from 2025 with 2% FFCs, gradually increasing to 63% in 2050, has been highlighted.

Figure 8: Use of sustainable aviation fuels at European airports



Source: Eurocontrol data on regulation and targeted logistics unlocking the availability of sustainable aviation fuels.

As can be seen in Figure 8, the most remarkable airports of all the European ones that use the highest percentage of SAF are Frankfurt Airport (Germany), Paris CDG (France), Amsterdam (Netherlands) and Madrid (Spain).

Table 2: Airports using the highest percentage of UFAS

Airport	***Percentage of PBS (%)***
Frankfurt	*10,06*
París CDG	*9,97*
Amsterdam	*7,26*
Madrid	*5,68*
Munich	*3,86*
Rome Fiumicino	*3,48*
Barcelona	*2,71*
Milán Malpensa	*2,68*

Source: Own elaboration based on Eurocontrol Data Snapshot No. 11.

If we look at table 2, we can take Frankfurt airport as an example, that for every 100 litres of aviation fuel refuelled, 10 litres are sustainable.

- Economic measures:

Unlike the other three measures described above, economic measures are not actions that airlines can take with the aim of reducing CO2 emissions, as they are only based on the acquisition of carbon offset credits to cover their CO2 emissions once their allocation of emission allowances has been exceeded. Some critics of the industry, including from the EU, argue that these offset credits do not always represent a real reduction in emissions and have allowed airlines to cover part of their emissions without making significant changes to their operation.

Among the most prominent programmes in this area are the EU ETS (Emissions Trading System) and CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation).

First, there is the emissions trading system that applies to flights operated in the European Economic Area (EEA). In 2012 CO2 emissions from aviation were included in this system and since then, all airlines must monitor, report and verify their emissions and surrender allowances for these emissions.

Airlines receive tradable allowances covering a certain level of emissions from their annual flights. The number of allowances issued to airlines is based on a cap on emissions set by the EU. This limit is gradually reduced over time to achieve emission reduction targets. They can buy or sell emission allowances on the EU ETS market, allowing them to tailor their emissions to their needs and targets. If they emit more greenhouse gases than they are allowed to, they can buy additional permits on the market. In the opposite case, it can sell its surplus permits on the market.

Secondly, there is the CORSIA emissions offset programme which is based on the idea that airlines can offset their greenhouse gas emissions by purchasing carbon offset credits. These credits are generated by emission reduction projects in other sectors, such as renewable energy projects or reforestation. In a similar way to the above, airlines must report their emissions annually and purchase offset credits to cover their emissions above the baseline level set by CORSIA.

It is important to note that these mechanisms are a key mechanism to reduce carbon emissions, especially in the short term as in the long term it is not a real solution to climate change and emissions reduction. However, they can be an effective way to engage customers in the fight against climate change, foster environmental awareness and drive acceleration towards the energy transition by serving as a bridge until other technologies are fully developed. Over time, other measures will achieve greater impact and importance and reduce the role of these cost-effective measures.

3. METHODOLOGY

This work is underpinned by a multi-case comparative case study, it thus relies on comparing the configurations of different case studies to identify the components that appear to be primarily responsible for producing specific outcomes. This study design produces more generalisable knowledge and emphasises comparison within and across contexts. It is appropriate when there is a need to understand and explain the influence of contextual characteristics on the success or failure of programme initiatives or actions. These studies involve analysing and synthesising the similarities, differences and patterns of cases that share a common approach (Goodrick, D. 2016).

This study design option is appropriate when questions are asked about the how and why of the processes or outcomes of an intervention.

3.1 Airlines to be analysed

The case study is carried out with low-cost airlines mainly for two reasons: their cost leadership strategies and their rise in the industry.

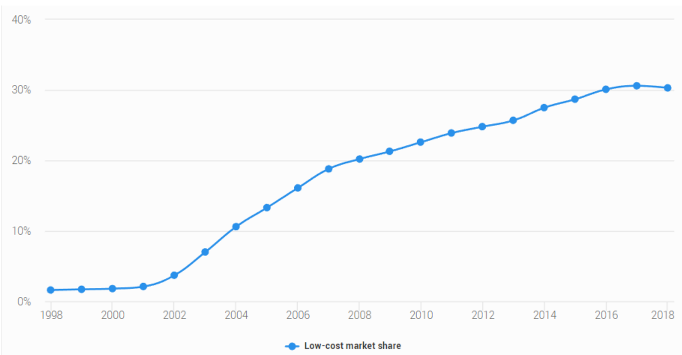
Firstly, this strategy of cost leadership may at first appear incompatible with environmental sustainability actions. The need to optimise resources is therefore curious in this area where efforts must be made for the common good.

A low-cost airline is defined as an airline that offers a very low fare in exchange for eliminating many services that passengers receive or charging for these services in addition. As a rule, these airlines focus on connecting secondary cities and tourist destinations in Europe, so most routes are short to medium duration (approximately 2-3 hours).

Among the characteristics of these companies are the following:

-Direct connections (non-stop flights).
-Short-distance routes.
-A fleet of one or two types of aircraft.
-Private companies.
-High aircraft utilisation rates (virtually no turnover).
-Limited passenger service (additional service charges).

Figure 9: Low-cost carriers' share of total IFR flights



Source: Eurocontrol data on the rise of low-cost airlines in Europe.

As Figure 9 shows, the share of flights operated by low-cost airlines has grown significantly since the turn of the century, and is now very important and popular with customers.

Secondly, the choice of the airlines selected is mainly due to the market share they represent in the sector together with the accessibility of the data needed to investigate. While it is true that more and more companies are moving towards a more transparent future in terms of publication of results and data, there are still some that are reluctant to do so, which makes it difficult to compare them.

As Table 3 shows, three of the five selected airlines have the highest average number of daily flights as well as the highest percentage of flights in Europe. The other two, on the other hand, do not have such high figures but have accessible and adequate information that allows them to be compared with the others.

Table 3: Low-cost carriers' share of total flights in Europe in 2022

Airline	***Average daily flights***	***Percentage of flights operated in Europe (%)***
Ryanair	*2.854*	*10,10*
EasyJet	*1.367*	*5,30*
WizzAir	*660*	*2,60*
Vueling	*547*	*2,10*
Eurowings	*430*	*1,70*

Source: Own elaboration based on Eurocontrol data on the rise of low-cost airlines in Europe.

A ranking of the low-cost airlines with the highest number of flights operated in Europe can be seen, which is led by the Irish airline Ryanair followed by the British airline EasyJet.

When it comes to the choice of companies to carry out the analysis, it is observed that both Vueling and Eurowings belong to airline groups (IAG and Lufthansa respectively) and are not independent companies, so it is not possible to obtain the required data because they are not available individually.

The analysis therefore focuses on: Ryanair, Wizz Air, EasyJet, Norwegian and Jet2. From the outset, they can be divided into 3 groups according to their figures recorded years ago. In first place is Ryanair, Europe's low cost carrier par excellence, followed by WizzAir and EasyJet, while Norwegian and Jet2 are ranked one step below.

Ryanair is an Irish airline founded in 1985 and is Europe's largest low-cost carrier with a wide network of routes and destinations, flying to over 200 destinations in 40 different countries. The airline has more than 80 bases across Europe, including Dublin, London, Milan, Madrid and Berlin. It has become one of the most profitable airlines in the world by cutting costs.

WizzAir is an airline based in Budapest, Hungary, founded in 2003 and its flights are operated mainly within Europe. It serves just over 160 destinations in 45 different countries and has bases at more than 25 airports across Europe, including Budapest, Bucharest, Milan, London and Barcelona.

EasyJet, founded in 1995, operates flights to over 150 destinations in more than 35 different European countries. The airline has more than 30 bases across Europe, including Geneva, London, Paris and Milan.

On the other hand, Norwegian (Norway), founded in 1993, has close to 100 European routes and has several operational bases throughout Europe, including Copenhagen, Stockholm, Helsinki and London. In contrast, Jet2 (UK), founded in 2002, is the smallest of the airlines analysed, with just over 60 destinations. It has operational bases at several UK airports, including Manchester, Leeds, Newcastle and Glasgow.

3.2 Variables analysed and sources of information

The previous sections have developed how the future of European aviation is believed, mentioning a series of measures that the sector is expected to improve or develop in order to achieve the objectives set. Therefore, the aim is to analyse the performance of these companies and their strategy in relation to the different measures mentioned in point 3 of this project. How they approach and the importance they give to these measures in each of the airlines chosen.

With regard to the fleet and technological advances, the number and models currently owned by each of the companies are analysed, as well as their technological advances and the impact these have on fuel consumption and noise pollution. About the advances in traffic improvements and aircraft operations, the digitalisation and modernisation of cockpit programmes are analysed, as well as the piloting actions that currently have the greatest influence on fuel savings.

In addition, the relationship between the chosen companies and sustainable aviation fuel will also be analysed, looking at whether they already use SAF in their operations and what targets they have set for the future for this type of greener fuel. Economic measures are also the subject of analysis as the aim is to observe the differences between the low-cost airlines in relation to their emissions offsetting schemes.

All measures undertaken by airlines are aimed at reducing their corporate footprint. Calculating it is necessary to know where the business stands in relation to global standards to reduce its carbon dioxide emissions and global warming. Growing awareness of carbon footprint and climate change in conjunction with regulatory requirements are driving sustainable decision making.

In the world of aviation, the most important metric when analysing a company's corporate footprint is CO2 emissions per passenger-kilometre gCO2/pax-km, a measure used to assess the environmental impact of air travel and which refers to the amount of carbon dioxide (CO2) released into the atmosphere for each unit of distance travelled by a passenger.

The calculation of CO2 emissions per passenger-kilometre takes into account both the amount of CO2 emitted and the distance travelled by each passenger. The longer a flight lasts or the greater the distance travelled, the higher the CO2 emissions generated. In addition, the passenger load factor percentage also influences this measure as it refers to the percentage of occupied seats on an aircraft in relation to the total passenger capacity it can carry.

If the load factor is high, it means that there are more passengers on board compared to the total capacity of the aircraft. On the other hand, if the load factor is low, it means that there are fewer passengers in relation to the total capacity. Therefore, when the load factor is high and the majority of seats are occupied, the airline maximises the capacity of the aircraft and spreads fuel consumption over a larger number of passengers. This can lead to greater efficiency in terms of CO2 emissions per passenger-kilometre, as more passengers are being carried with a similar amount of emissions. Conversely, if the load factor is low and there are many empty seats, the airline is using the capacity of the aircraft less efficiently, which can result in higher fuel consumption and therefore higher CO2 emissions per passenger-kilometre.

In this sector, the calculation of the corporate footprint focuses mainly on the grams of CO2 emitted in relation to the number of passengers transported and kilometres travelled (gCO2/pax-km). This metric allows for objective comparison, as it provides a unit of emissions performance that is comparable between companies of different sizes and business models.

Changes in emissions intensity highlights an alteration in company efficiency, while the analysis of total emissions focuses on changes in economic performance. Reductions in total emissions could simply be the result of reduced economic activity, without positive changes in efficiency and related processes. Therefore, the gCO2/pax-km figures of each of the companies in the previous years and especially the figures they want to achieve in the coming years are analysed.

The sources of information used for the preparation of this comparison are mainly obtained from the airlines themselves. Through the reports and updates published both on their corporate website and on social networks, these airlines provide the company's real annual data. The vast majority of them have a specific section for each of the points to be addressed in this analysis, which facilitates the collection of information and, thanks to this, the comparison between different airlines.

Airlines have a variety of ways of communicating their environmental strategies and related information. Among the most common ways are the following:

Firstly, through sustainability reports in which airlines publish reports detailing their commitments, targets and progress mainly on environmental issues. These reports can be found on the airlines' corporate websites and usually include information on carbon emissions and other related aspects. In the past, this information was contained in annual reports, but since the COVID-19 pandemic, several European airlines have ventured into sustainability reporting with a greater focus on environmental issues.

Despite the previous mentioned reports, the websites also provide additional information in a clearer and simpler way through infographics highlighting the most important information: objectives, emissions and news. In addition, a common aspect of all the corporate websites analysed is the publication of graphics and videos with the aim of raising awareness of their efforts in this area.

Press releases are another way for airlines to announce new initiatives or achievements in their environmental approach. These are distributed to the media and published on social media as well as on the airlines' websites, thus reaching a wider audience. On the other hand, there are the marketing and advertising campaigns carried out by airlines where, through slogans and images, they launch messages highlighting their commitment to sustainability and promoting the choice of more environmentally responsible flights. Finally, there are the sustainability-related trade fairs and conferences where airlines can present their strategies and share best practices in a way that is useful to other organisations engaged in the field of environmental sustainability.

4. RESULTS

The results obtained will be analysed below, divided into several sections according to the following structure. Firstly, the measures explained in the previous section and how each of them has been managed by the airlines studied are analysed. Subsequently, the evolution of emissions per passenger-kilometre in recent years is analysed. Finally, we will try to link both sections to see the relationship between them, if any.

4.1 Measures implemented by airlines

The information collected for each of the three measures for each of the airlines studied is presented below. The first of these is fleet technology innovations and aircraft development, the second is operational improvements and finally there is sustainable aviation fuel.

a) *Fleet and technological development:*

If we focus on the technological advances in aircraft and engines, we can see that there are significant changes from one case to another. Below are two tables showing the aircraft models owned by the fleets of each company, the number of these and the percentage of the total.

Table 4: Boeing aircraft by model and company in 2022

Airline		**Ryanair**		**Norwegian**		**Jet2**	
Aircraft type		*Number*	*Percentage of fleet*	*Number*	*Percentage of fleet*	*Number*	*Percentage of fleet*
Boeing	*737-300*					*7*	*6%**
	737-800	*225*	*81%*	*68*	*85%*	*87*	*81%**
	737-Max 8200	*53*	*19%*	*12*	*15%*		
	757-200					*8*	*7%**
Total		*278*		*80*		*102*	

Source: Own elaboration

Table 4 shows that the vast majority of these airlines' fleets are B737-800s due to fleet renewal since the 2000s. Despite this, it can be seen that more and more companies are acquiring the new generation B737-Max 8200 models and it is expected that in the coming years the percentage will equal or even surpass the more traditional model. It should be noted that while Ryanair and Norwegian do have the latest generation aircraft, Jet2 has lagged behind in this respect.

Table 5: Airbus aircraft by model and carrier in 2022

Airline		**WizzAir**		**EasyJet**		**Jet2**	
Aircraft type		*Number*	*Percentage of fleet*	*Number*	*Percentage of fleet*	*Number*	*Percentage of fleet*
Airbus	*A319*			*94*	*29%*		
	A320	*59*	*40%*	*167*	*52%*		
	A320neo			*44*	*14%*		
	A321	*41*	*28%*	*15*	*5%*	*5*	*5%**
	A321neo	*47*	*32%*				
	A330-200					*1*	*1%**
Total		*147*		*320*		*6*	

Source: Own elaboration

With regard to Table 5, we can initially rule out Jet2 airline because, despite having Airbus models in its fleet, it only represents a tiny percentage (6%) of the total. In contrast, Wizz Air stands out for its high percentage of latest generation aircraft (32%) while EasyJet has already modernised approximately one sixth of its fleet (14%).

To make a comparison we can look at the following two tables:

Table 6: Boeing aircraft models by company in 2022

Boeing	***Ryanair***	***Norwegian***	***Jet2***
737-300			✅
737-800	✅	✅	✅
737-Max 8200	✅	✅	
757-200			✅

Source: Own elaboration

Ryanair acquires between 2000 and 2020 more than 500 aircraft but it is not from 2021 that it renews the fleet again and invests in the latest generation aircraft such as the Boeing B737-Max 8200 and retires older and less fuel-efficient aircraft from the airfield. On the other hand, the Norwegian airline has started to procure these newer models one year later in 2022.

This model is equipped with CFM international LEAP-1B engines and technologically advanced winglets, which reduces fuel consumption by approximately 16% per seat. It can also carry 197 passengers, 8 more than the traditional model, which significantly reduces the CO_2 emitted per passenger.

Table 7: Airbus aircraft models by carrier in 2022

Airbus	WizzAir	EasyJet	Jet2
A319		✅	
A320	✅	✅	
A320neo		✅	
A321	✅		✅
A321neo	✅	✅	
A330-200			✅

Source: Own elaboration

In 2019, Wizz Air introduced the Airbus A321neo, a more efficient and fuel efficient aircraft per seat, to its fleet. This model offers exceptional fuel savings by reducing fuel consumption by 10% compared to the A321ceo and about 20% compared to the A320ceo mainly due to its Pratt and Whitney engines and a higher seat configuration (43 more seats).

EasyJet plans to modernise its fleet with the acquisition of around 160 new-generation Airbus NEO (New Engine Option) aircraft, which will be added to those already in the fleet. In addition, following the acquisition of these first aircraft, the company's strategy is to preferentially use the NEO aircraft as they are more efficient than the aircraft they replace.

As explained above, Jet2 has hardly any Airbus in its fleet because it has traditionally always been a Boeing airline. At the end of 2022, the airline starts acquiring A321neo aircraft in order to renew its fleet and to try to match the competition in these terms.

To understand a little more about the difference between fleets, the following figure shows the approximate average age of each fleet. According to Eurocontrol data, the average age of all European fleets is estimated to be close to 10 years.

Table 8: Average age of aircraft fleet by company in 2022

Airline	***Ryanair***	***WizzAir***	***EasyJet***	***Norwegian***	***Jet2***
Average age (years)	*11.3*	*5.04*	*10.3*	*8.5*	*15.6*

Source: Own elaboration

The two extremes stand out. On one side is Jet2, with a rather old fleet compared to the other airlines, while on the other side Wizz Air has one of the youngest fleets in the world with an average of about 5 years old. Ryanair, EasyJet and Norwegian are close to the European average.

b) *Improvements in traffic management and aircraft operations:*

One aspect that all five case studies have in common is that no airline makes stopovers on their flights because point-to-point direct flights consume less fuel and therefore reduce their pollutant emissions.

With regard to the aids received by pilots and the aircraft cockpit, different actions have been observed:

Both Norwegian and EasyJet have Sky Breathe, a BigData and AI-powered fuel management software that helps pilots fly more efficiently. It is currently used by 55 airlines worldwide. Among its functions, it automatically collects and analyses fleet data and combines it with weather conditions and air traffic control to identify fuel-saving opportunities.

Despite being a top software in the market, all other airlines have similar digitisation services and applications. Ryanair also has a new, more dynamic and accurate flight planning system in the vast majority of its fleet, while WizzAir has also optimised and modernised its system through the introduction of a new continuous learning algorithm logic that allows estimating fuel consumption based on real factors such as weather.

Jet2, on the other hand, is lagging behind in technological advances, mainly due to the aforementioned non-renewal of its fleet of aircraft.

Other improvements to be considered in aircraft operations include Descent Profile Optimisation (DPO) and the single-engine taxi policy.

Table 9: Fuel saving operations per company in 2022

Airline	***Continued decline***	***Single-engine taxi***
Ryanair	✅	✅
WizzAir	✅	
Norwegian		
EasyJet	✅	✅
Jet2	✅	✅

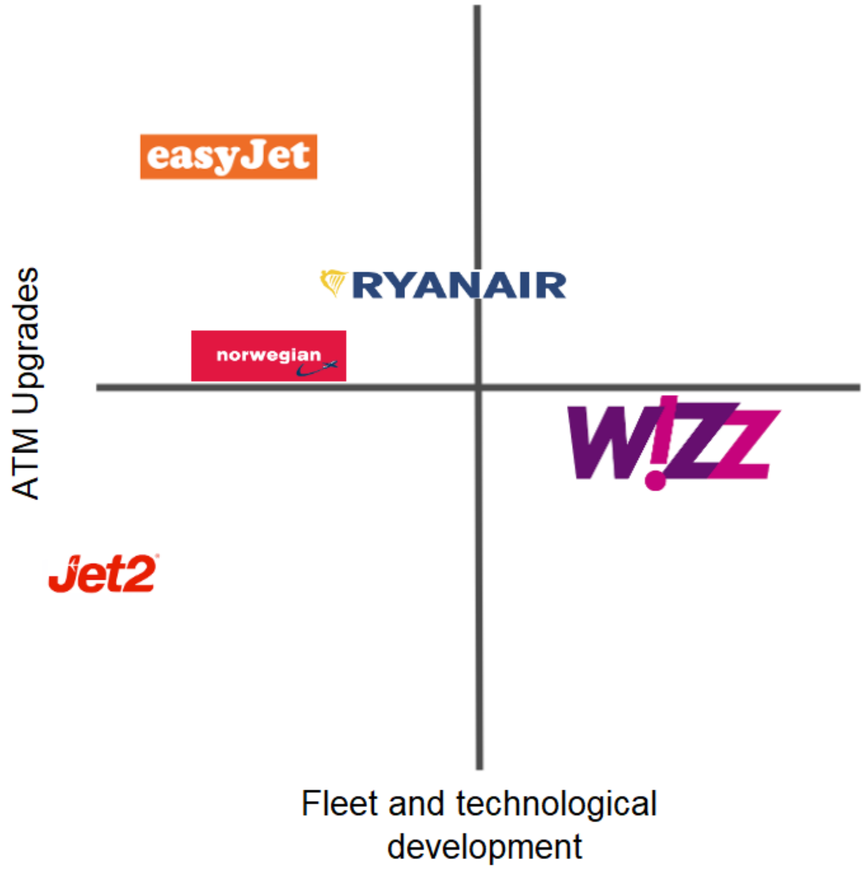
Source: own elaboration

Continuous descent operations are the modernisation of the traditional staggered descent, and allow the aircraft to stay at a higher altitude for longer and therefore use less fuel. This type of operation is of considerable magnitude as the DPO saved Ryanair around 80,000 tonnes of fuel in 2022.

The single-engine taxi policy is a common and growing practice. Ryanair, EasyJet and Jet2 use this practice in virtually all of their operations, enabling them to reduce emissions considerably compared to previous years.

If we combine the two criteria analysed so far (technological development and operational improvements), we obtain a positioning map that reflects the importance of improvements in aircraft and operations management in the strategies of each of the companies. It is concluded that Wizz Air would be the best positioned while Jet2 would be the opposite. The other three airlines would be very similar.

Figure 10: Map of positioning of operations improvements vs. fleet and technology development



Source: own elaboration

c) *Sustainable aviation fuel:*

As explained above, sustainable aviation fuel is a measure that Europe is trying to encourage and emphasise the importance of in order to try to achieve a sustainable future in aviation, which is why an agreement has been reached for the mandatory use of SAF from 2025. However, as we will see below, several companies already use it today or wish to incorporate it in their refuelling before that date. As in the other sections of the study, there are also variations in the use of SAF from one company to another.

First of all, Norwegian is one of the most proactive companies in relation to this type of fuel. The latest aircraft purchased by the company can store up to 50% SAF, and it has agreements with the company Neste to blend 0.5% sustainable aviation fuel in all consumption in Norway and 1% in Sweden and France. In 2021, the total percentage of SAF used was 0.3%.

Ryanair also has a relationship with the aviation fuel company Neste, but unlike Norwegian, their contacts are in 2022. As a result, they have only conducted test flights with SAF of which the results obtained are very positive. By 2023 they have committed to use 32% SAF on all flights at Amsterdam airport.

In contrast, Wizz AIr does not attach much importance to sustainable aviation fuel, not until 2025 when the Hungarian company considers that it must use it. Jet2 is another company that does not attach much importance to SAF and according to its management will also wait and follow the European standards set for 2025.

EasyJet considers that the current price of this type of fuel is very high and therefore not viable. However, as it becomes affordable and available, it will be part of their decarbonisation process. Nevertheless, they are already working with some suppliers to operate flights with a 30% SAF blend.

- *Other measures:*

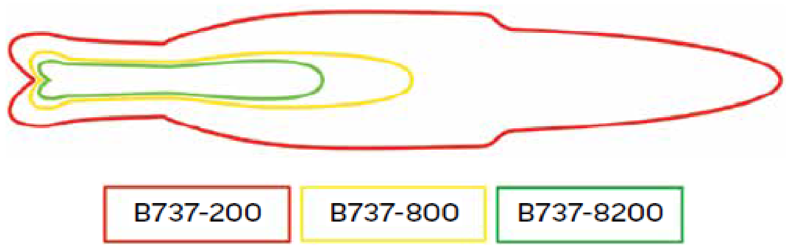
Apart from the above-mentioned measures where airlines can take actions that have an impact on their carbon dioxide emissions, there are other aspects where decisions taken have a positive impact on the environment.

<u>Noise reduction:</u>

Noise pollution is understood as the excess of sound that alters the normal conditions of the environment in a certain area. Technological advances in aircraft, more specifically in engines, winglets and aircraft configuration itself, as well as affecting fuel consumption, also directly affect the noise pollution produced by aircraft.

If we take the Boeing family as an example, the differences in terms of acoustics are abysmal. The B737-8200 reduces noise pollution by around 40% compared to its predecessor, the B737-800.

Figure 11: The new Boeing 737-8200's noise compared to previous fleets



Source: Ryanair Sustainability Report 2021

Furthermore, if we focus on take-off operations, it can be seen that the change from the Boeing 737-200 to the B737-800 aircraft reduced take-off noise by 86%, while with the latest B737-8200 model this reduction reaches 93%.

If we look at the Airbus, the result is almost identical. Those NEO (New Engine Option) aircraft will be approximately 50% quieter than their predecessors.

Therefore, airlines with a younger fleet will have a lower noise impact compared to airlines with a higher average age. Despite the differences and the time it takes to renew fleets, all airlines seek to be constantly growing and modernising their aircraft in order to have a positive impact on pollutant emissions.

After analysing the importance of the fleet and its technological development, we can conclude that despite the airlines' future intentions, there are currently big differences between them. So, WizzAir would be the airline with the best strategy regarding technological innovations in the fleet, followed by Ryanair. Norwegian and EasyJet have followed a similar strategy with the only difference being the number of aircraft they own. Finally, there is Jet2 which, having been founded after 2000, its aircraft acquisition has not been the most appropriate compared to its competitors.

<u>Handling equipment:</u>

One of the main issues in the world of aviation is the handling equipment used during aircraft ground operations. Nowadays, many airlines have their own handling services at most airports, so more and more of them are also modernising their vehicles and replacing them with more sustainable ones.

The pioneer in this aspect in Spain was Ryanair with its partner Azul Handling, which in 2021 began acquiring the first electric equipment in the entire peninsula. Another company with modernised handling is Jet2, which has a large number of sustainable vehicles (41%), whether electric, hybrid or biodiesel.

EasyJet has started to implement these measures this year, while Norwegian and Wizz Air do not intend to do so in the short term, mainly due to the fact that they have very few airports with their own handling.

Waste management:

Another very important aspect in commercial aviation is the management of waste generated on board the aircraft, especially the use of plastics. Virtually all airlines choose to eliminate single-use plastics and try to reduce waste.

Norwegian aims to stop consuming non-recyclable plastics by 2023 and to reduce single-use plastics by 30%.

At Jet2, however, these measures to reduce plastics began in 2019, when single-use plastics were replaced with more biodegradable and recyclable alternatives. Since then, 25% of these plastics have been replaced and up to 50% of the waste generated on board has been recycled.

At EasyJet, around 51% of the waste produced on board can be recycled and around 25% of single-use plastics are removed.

4.2 Linking measures implemented by airlines and their CO2 emissions

In order to evaluate emissions, the metric grams of CO2 per passenger-kilometre must be analysed, since in the aviation world it is the benchmark par excellence in terms of the environmental impact of airlines. It should be noted that these data are obtained from estimates made by the airlines themselves and that these figures are achievable in the short term thanks to the previous measures. On the other hand, in the long term, these targets do not seem so achievable due to the uncertainty of the measures once the CO2 emissions per passenger-kilometre figures have been achieved in the first years.

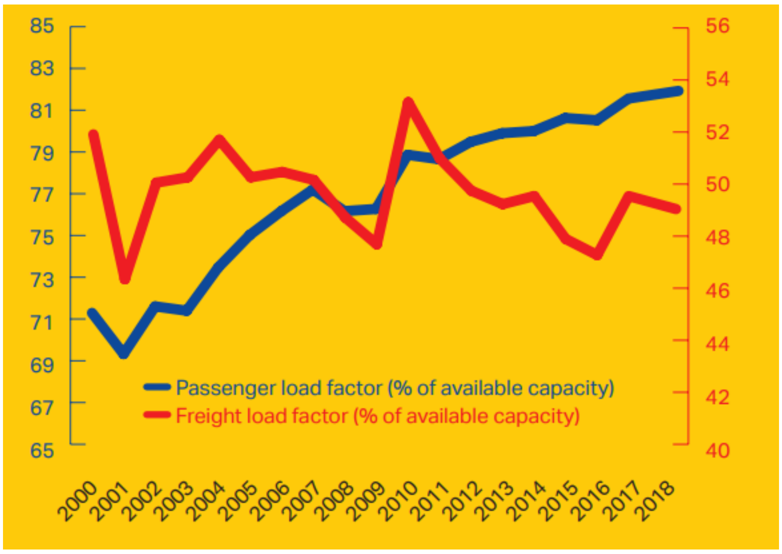
First of all, it should be noted that the measures imposed by Europe start from 2020, so all the technological innovations described above do not have a significant impact on the figures in the following tables. In addition, the environmental impact of airlines has traditionally focused on reducing their carbon dioxide emissions per passenger-kilometre based solely on obtaining a higher load factor.

The load factor, also called occupancy factor, refers to the number of seats sold divided by the capacity of the aircraft. In other words, the percentage of seats occupied during a flight in relation to the total number of seats available. It is a key element as it measures the efficiency of your transport capacity.

A high percentage of this metric is what all airlines seek to achieve as it translates into maximising their revenues due to high seat occupancy. If we focus on the relationship between CO2 emissions and load factor we can see that there is a direct relationship, in other words, the closer to the maximum seating capacity of a flight, the lower the amount of CO2 emissions generated per passenger-kilometre as the total amount of CO2 emitted is divided by more passengers carried. Similarly, a lower side factor results in a higher environmental impact per passenger-kilometre as the total emissions emitted are distributed over fewer passengers.

Therefore, airlines are looking for a high load factor to reduce CO2 emissions and minimise their environmental impact, as by optimising flight occupancy, they can carry more passengers with lower CO2 emissions per passenger-kilometre.

Figure 12: Industry passenger and freight load factors



Source: IATA Annual Report 2019

As can be seen in Figure 12, there is a big difference between the values at the beginning of the century and those actually achieved today. As we can see, the average international passenger load factors have risen by more than 10 percentage points and thus the carbon dioxide emissions of airlines have reached lower values than in the first decade of the century.

As can be seen in Table 10, in 2017, 2018 and 2019 the load factors of the five companies were quite high, with an average of 91.46%, 91.64% and 92.2% respectively. In addition, it is worth mentioning that there was growth in all of them compared to the previous year. In 2020, on the other hand, it started to decline due to the bad omens of the COVID health situation. While it is true that it did not affect all airlines equally, it had bad consequences for all of them. Ryanair and Jet2 were the only ones to maintain a similar load factor to previous years while the other three airlines suffered a significant decrease. In 2021, it is clear that the results were very poor, resulting in an average load factor of 70.72% for the five airlines analysed.

Finally, in 2022, the latest data collected show a rapid improvement compared to the pandemic, with values rising again to around 85%. Despite the strong consequences of the health situation, the recovery shown in 2022 has been very positive and rapid. It should be noted that the load factor is one of the main elements when talking about CO_2 emissions per passenger-kilometre.

Table 10: Evolution of load factor by year and airline

Airline	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***
Ryanair	94%	95%	96%	95%	71%	82%
WizzAir	91.2%	92.1%	93.4%	70.8%	71.1%	86.6%
EasyJet	92.6%	92.9%	91.5%	87.2%	72.5%	85.5%
Norwegian	88%	86%	87%	75%	73%	83%
Jet2	91.5%	92.2%	93.1%	92.2%	66%	90.7%

Source: Own elaboration based on companies' annual reports.

If we focus on the case study, we can see how the COVID-19 pandemic had a strong impact on the world of aviation, which is why all the load factors were significantly lower than in other years, mainly due to a lower number of passengers on their flights. The figures collected in 2021 are also the lowest in recent years for all airlines.

On the other hand, if we focus only on the years prior to 2020, we can see that there is hardly any deviation between their data, so we can affirm that the values obtained from year to year are quite similar between them. Moreover, the values recorded by the five airlines are quite acceptable, oscillating around 90%.

By 2022 we can see airlines returning to higher load factor values with figures close to 85% and expected to reach pre-pandemic figures.

As can be seen in Table 11, in recent years the emission values emitted by the companies have also remained very similar for each of them. This is due to the fact that by focusing on load factors alone there is a limit which cannot be exceeded without additional measures or strategies. This is why both airlines and European institutions have decided to take action to reduce pollutant emissions in European commercial aviation.

Table 11: Evolution of CO2 per passenger-kilometre by year and airline

Airline	2017	2018	2019	2020	2021	2022
Ryanair	67	67	66	66	83.33	67.2
WizzAir	61.5	59.2	57.36	71.82	68.73	55.4
EasyJet	72.46	71.56	70.41	70.77	81.08	70.4
Norwegian	72.9	72	70	83	88	77
Jet2	72	69	68	67	89.8	82

Source: Own elaboration based on companies' annual reports.

If we take the year 2021 as an example, we can see that COVID also has some influence, leading to the highest emission figures in recent years.

With respect to previous years, we can see that there is hardly any dispersion between the data and in fact three of the five airlines have a negative trend, as from 2019 the CO2 figures per passenger-kilometre achieved are decreasing slightly over the years. In the case of Norwegian and Wizzair, according to sources from the airlines themselves, the decrease in passenger numbers obtained at the end of 2020 means that this does not follow the same pattern as their competitors. In 2020, they had a passenger decrease compared to the previous year of around 81% and 42% respectively. The decrease in load factor was 12% and 22% respectively.

If we focus on 2022, the last year recorded, we can see how airlines reach more normal figures and closer to the previous CO2 emissions due to the stabilisation after the pandemic. This can be understood thanks to the comparison in Table 12, which allows us to draw some conclusions. This table is obtained by linking Table 10 and Table 11 and allows us to compare the results obtained in this last year with those before the pandemic, which are the so-called logical values since 2020 and 2021 can be considered biassed.

Table 12: Variation of current and pre-pandemic Load Factor values and CO2 emissions

Airline	Load Factor (%)			CO2 emissions (grams)			
	2019	2022	Change (%)	2019	2022	Variation	Change (%)
Ryanair	96.00	82.00	-14.00	66.00	67.20	1.20	1.82
WizzAir	93.40	86.60	-6.80	57.36	55.40	-1.96	-3.42
EasyJet	91.50	85.50	-6.00	70.41	70.40	-0.01	-0.01
Norwegian	87.00	93.00	6.00	70.00	77.00	7.00	10.00
Jet2	93.10	90.70	-2.40	68.00	82.00	14.00	20.59

Source: Own elaboration

Ryanair and EasyJet have managed with a lower load factor in 2019, 14% and 6% respectively, to keep their CO2 emissions per passenger-kilometre fairly constant. In the case of the Irish airline they have risen by just 1.82% while the British airline has registered its pre-pandemic figures. This is mainly due to the fact that both airlines have an acceptable aircraft fleet age which, together with improvements in traffic management and commercial operations, means that despite a decrease in the load factor percentage, lower emissions per passenger-kilometre are achieved.

WizzAir, on the other hand, with a decrease in its load factor of almost 7%, has also managed to reduce its CO2 emissions per passenger by almost 3.5%. The Hungarian airline is the one with the lowest emissions per passenger-kilometre of the five airlines analysed, which is why the youthfulness of its fleet and improvements in commercial operations have been key to its success.

The last two airlines analysed, unlike the others, have achieved significantly higher emissions per passenger-kilometre than those achieved in 2019. Norwegian has increased them by around 10%, while Jet2 has increased them by around 20%. These facts are due, according to the airlines themselves, to a change in the destinations of their operations resulting in longer routes than previously. This results in significantly higher emissions figures and therefore higher CO2 emissions per passenger-kilometre.

Therefore, we can conclude that in the coming years, by achieving the pre-pandemic load factor values, a reduction in CO2 emissions per passenger is possible through the measures explained throughout this work.

Firstly, fleet renewal is a very important factor as newer aircraft models reduce in-flight pollution considerably. However, it would reach a certain limit on its own and needs to be accompanied by other measures. On the other hand, while it is true that most airlines want to implement and start using sustainable aviation fuel, in the 2022 figures recorded the use of SAF does not have significant improvements in reducing CO2 emissions per passenger-kilometre.

It should also be noted that these conclusions can be supported by the so-called "céteris páribus", defining that if all factors remain constant (same load factor and destinations), measures such as fleet renewal, technological improvements or use of sustainable aviation fuel lead to a reduction of CO2 emissions per passenger-kilometre.

4.3 Emissions roadmap to decarbonisation

This section analyses the expected impact of the measures airlines take with their roadmap to decarbonise their operations by 2050.

To analyse this section, the year 2022 is considered as the base scenario as it is the most recent and the years 2020 and 2021 reflect unusual figures highly influenced by the pandemic situation. Table 13 therefore reflects the roadmap that airlines have set for themselves to achieve decarbonisation by 2050.

Table 13: Roadmap CO2 emissions per passenger-kilometre (gCO2/pax-km)

Year	*Ryanair*	*WizzAir*	*EasyJet*	*Norwegian*	*Jet2*
2022 (actual)	*67.2*	*55.4*	*70.4*	*77*	*82*
2025 (estimated)	*63*	*47.9*	*64.69*	*59.8*	*65*
2030 (estimated)	*60*	*43*	*55.24*	*53*	*60*

Source: own elaboration based on the companies' 2022 annual report.

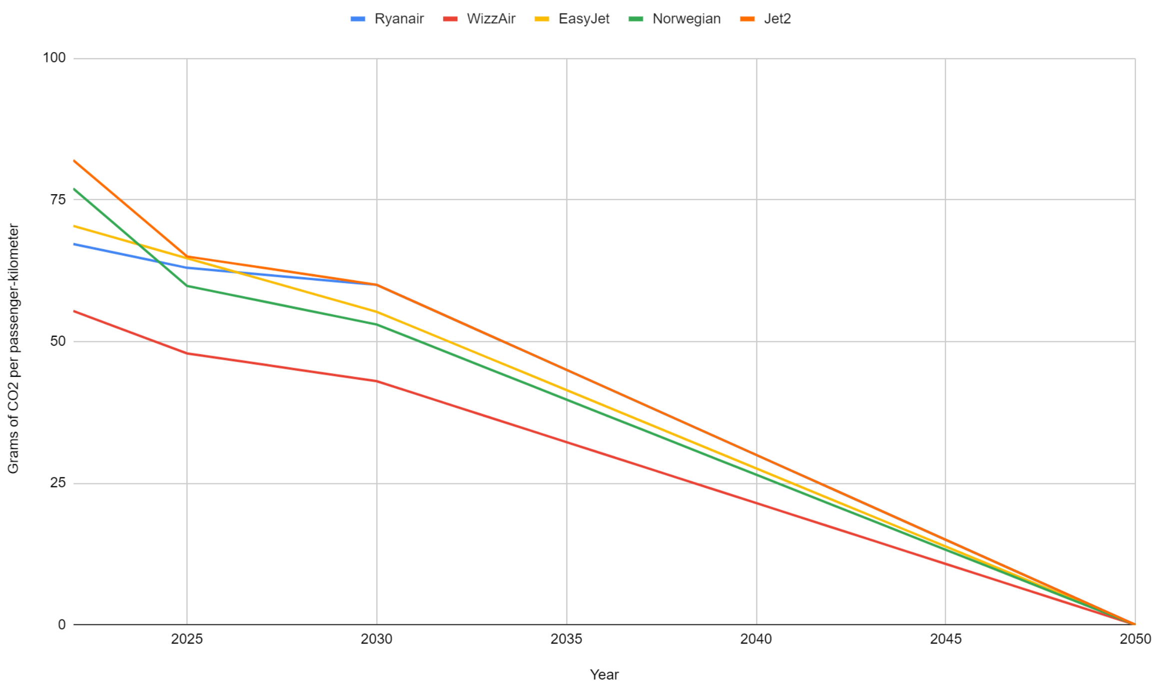
The figure of grams of CO2 emissions per passenger-kilometre that airlines wish to achieve in 2025 and 2030 in order to reach the desired target in 2050 is shown. While it is predicted to be feasible to achieve a significant reduction within several years, some estimates seem somewhat more difficult to achieve without good action.

As Table 13 shows, Ryanair is following a softer strategy as in the eight years to 2030, it only aims to reduce its emissions by approximately 7 grams of CO2 per passenger-kilometre. In contrast, Wizzair and EasyJet want to reduce their emissions more quickly and in the same period of time they aim to reduce their emissions by approximately 12 and 15 grams of CO2 per passenger-kilometre respectively. Finally, there is Norwegian and Jet2 where differences with respect to the rest of the airlines can be seen, mainly due to the poor figures obtained in 2022, where the emissions results were significantly higher than in 2019. Therefore, taking the figures for the last year, the reduction marked up to 2030 would be approximately 24 and 22 grams of CO2 per passenger-kilometre, making it the largest reduction of the five airlines.

Similarly, if we take the values for 2019 before the pandemic, this reduction would be 17 and 8 grams of emissions respectively, thus equating with the other cases analysed.

Figure 13 shows an elaborate graphic showing the roadmap of each of the airlines in different colours. It can be seen that there is a big change from 2022 to 2025 in terms of the reduction of CO2 emissions per passenger-kilometre due to the implementation of more sustainable measures in conjunction with an acceptable load factor level. From 2025 to 2030, both variables remain fairly constant so the emission reduction is smoother. Finally, from 2030 onwards, a more hypothetical situation is estimated where the decrease is more radical, mainly due to new measures introduced from this period onwards such as high levels of SAF in operations and even aircraft with electric, hybrid or hydrogen engines.

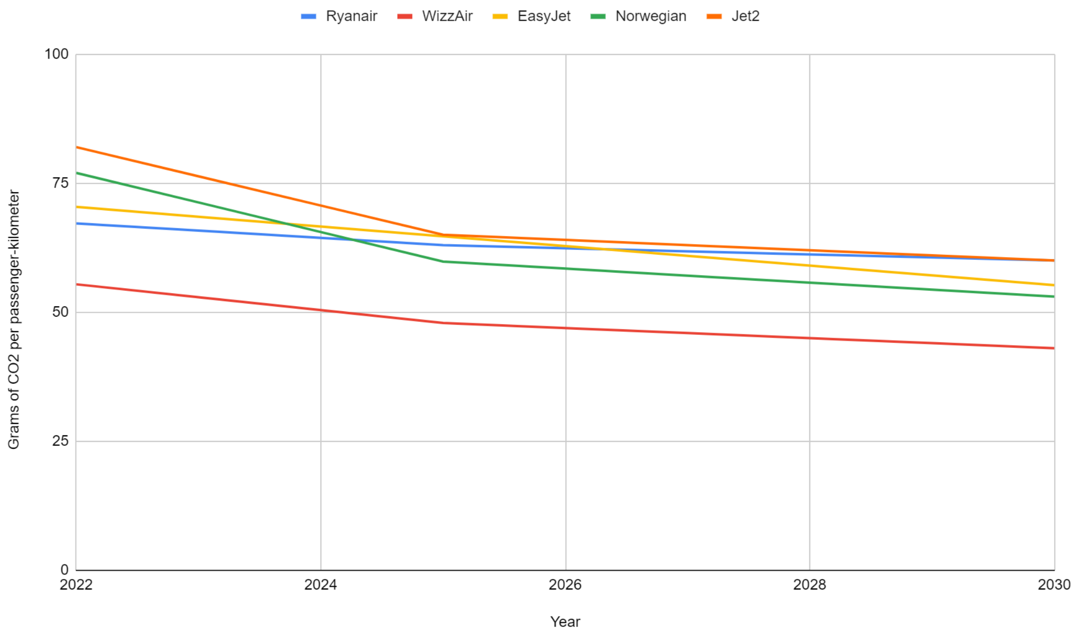
Figure 13: Roadmap to net zero CO2 emissions per passenger-kilometre (gCO2/pax-km)



Source: Own elaboration

As can be seen in Figure 14, the most important change occurs in the first years of the roadmap where new improvements and measures are introduced, mainly fleet renewal due to the recent health situation where a large number of aircraft were taken out of operation. In contrast, from 2025 to 2030, the reduction is very smooth as airlines focus their efforts on maximising the load factor while maintaining the measures put in place since 2022.

Figure 14: Roadmap to net zero CO2 emissions per passenger-kilometre (gCO2/pax-km) in 2022-2030 period



Source: Own elaboration

It should be noted that the key element of this roadmap set out by the airlines is to maintain or increase the load factor to pre-pandemic figures (above 90%-95%), as this is the only way to come closer to the targets set for the future. With regard to the other measures, fleet renewal and operational improvements will have a notable improvement until 2030, while after that date the airlines cannot be sure that CO2 emissions per passenger-kilometre will decrease at the estimated rate until decarbonisation is achieved.

As has been discussed throughout the work, in order to achieve decarbonisation or simply to significantly reduce the amount of CO2 per passenger-kilometre emitted by airlines, a combination of all the above measures is necessary. Therefore, airlines present a rough estimate of what influence each of these measures will have on the final comparative result as a metric of grams of CO2 per passenger-kilometre. While it is true that not all of them have made this publicly available, Jet2 and Ryanair do publish it in their respective reports.

Jet2 estimates that improvements in aircraft technology will reduce emissions by around 10%, SAF by 4% and improvements in traffic management and aircraft operations by approximately 9%. In contrast, the remaining emission reductions are expected to come from economic measures such as offsetting and taxation, around 77%.

For Ryanair, the expectations are very different. They estimate that around 32% of carbon emission reductions will come from technological and operational improvements, around 34% will be achieved through the SAF, improvements in traffic management and aircraft operations will reduce by around 10% while economic and offsetting measures will reduce by 24%.

Therefore, all airlines will have to make decisions on the basis of all measures taken together but giving greater weight to those that they consider to be more economically viable or have a quicker impact on their bottom line.

5. CONCLUSIONS

Thanks to the preparation of this project, it is possible to learn more about sustainability in the airline industry and, above all, to analyse whether it is possible to fly without polluting. As we have seen in the various previous sections, the roadmap set by both Europe and the airlines themselves does consider this option. In order to achieve this, it is necessary for all the groups involved to work together to reach a common goal, which is the decarbonisation of operations in the aviation sector.

The literature review carried out allows us to observe how historically, the commercial aviation sector has followed a traditional model focused on maximising profits without being committed to sustainability. Despite this, sustainability is gradually becoming more important, mainly due to environmental social awareness. In the case studies in particular, it can be seen that sustainability is becoming more and more important, but without neglecting the profitability of low-cost airlines.

The results show that the sector is following the EU's three main guidelines for achieving carbon emission reduction targets. Firstly, advances in technology and innovation are a key element in reducing airlines' carbon emissions, mainly through investment in more modern and sustainable aircraft and engines. Secondly, regulations and standards set from Europe are forcing airlines to act accordingly. Finally, it is the airlines themselves that require Europe to work together to achieve the goals set by both sides.

If we focus on the comparison of the low-cost airlines analysed, we can see that there are really no major differences in terms of the future actions they want to carry out. All the airlines must continue to work on the different measures explained in this study to a greater or lesser extent. However, it is true that there are differences in favour of those that in recent years have opted for better practices such as fleet renewal by incorporating more modern aircraft with a lower environmental impact.

According to the results obtained in the case study, it is concluded that WizzAir has the lowest CO2 emissions per passenger-kilometre in the years evaluated. This is mainly due to the significant difference between the aircraft fleets of the analysed cases. Moreover, thanks to this, it is the airline that in the key years (2025 and 2030) has the lowest target figure compared to the other airlines. On the other hand, Ryanair is an airline with a strategy based on its high occupancy factor levels. Despite this, the Irish airline is targeting a gentle decline in its CO2 emissions per passenger-kilometre but easily achievable by renewing its fleet and returning to its estimated occupancy levels.

The British airline Jet2 follows a similar strategy to Ryanair, focusing on fleet renewal and keeping the load factor very high. The difference with respect to the Irish airline is that it starts from higher CO2 emission values and an older fleet, so if it wants to reach its targets for 2025 and 2030, it must follow a strategy of more aggressive measures. With regard to EasyJet and Norwegian, we can say that they are generally the worst performers, they have the lowest load factors in the analysis and the highest CO2 emissions per passenger-kilometre.

On the other hand, with regard to the decarbonisation roadmap, it can be seen that in the short term, the targets for CO2 emissions per passenger-kilometre are achievable for the years 2025 and 2030, as the implementation of these measures and strategies seems likely to work, but there is no such certainty for the years after 2030, as there is no certainty as to whether the economic measures can reduce these emissions by so many grams. Nevertheless, it would be a major step forward for both society and the industry if the figures for the coming years can be achieved.

We can conclude that efficiency in aviation is mainly due to the improvements that have been outlined throughout this paper, because while the number of passengers increases exponentially over the years, CO2 emissions show a much lower increase. This is due, among other things, to technological renewal and increased load factors. Historically, the reduction of aircraft emissions focused on an increase in the number of seats sold per flight, with the load factor being of paramount importance. Today it continues to be of great importance, but airlines also seek to take action on various aspects such as optimising operations to reduce fuel consumption or renewing technology in their fleet to increase aircraft capacity.

Maintaining a modern fleet through the use of the latest aircraft contributes significantly to CO_2 reduction in the aviation industry, and helps to achieve greater fuel efficiency. Although some companies are already testing and working together with sustainable aviation fuel suppliers, they do not procure large quantities of SAF due to its high cost and lack of consensus on sustainability criteria. With good promotion of its production, together with support mechanisms for these initiatives by both European and national policies, airlines would be more confident to invest in and use this type of fuel. Nevertheless, the use of this sustainable biofuel is in the future operations of all airlines analysed as they have a lower impact on carbon emissions compared to fossil fuels.

Despite the work carried out, it is true that there are major limitations when it comes to finding information about the companies' own environmental strategies and actions. Furthermore, although all five airlines name and describe in their annual reports the measures for decarbonisation, there is no concretion of these measures or of the targets to be achieved in the following years. They all agree on an overall description of their sustainability strategies without going into detail. However, in the last two years, sustainability reports have appeared in some of the companies analysed with a focus on environmental issues in which they do begin to publish and detail all aspects related to this area, so it is possible that as companies become more environmentally aware, they will publish better and more information on their corporate websites.

In terms of recommendations, I believe that airlines should continue to pursue their low-cost strategies with a focus also on environmental sustainability, where through investment in fleet renewal and maintaining high load factors the CO_2 emissions per passenger-kilometre can be much lower than those achieved years ago. I believe that the targets set by the airlines for the years 2025 and 2030 are easily achievable but that for the roadmap set from 2030 onwards it is necessary to wait to draw conclusions. Moreover, as this is a highly polluting sector, focusing on improving and caring for the environment could be well received by customers and represent a turning point to change the dynamics of the sector towards a more sustainable one.

To conclude the paper, decarbonisation of operations must be a joint action and measures leading to zero net CO2 emissions from European aviation must be achieved through collective policies and actions by governments and industry. Both must work towards a global commitment to avoid differentiated policies. These regulations seek to incentivise the adoption of cleaner and more sustainable technologies in aviation through research, innovation and investment in the safest possible way. Possible actions welcomed by industry include support for research and development of clean technologies and emission reduction targets for the aviation sector.

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