ENVIRONMENTAL SUSTAINABILITY IN THE AVIATION SECTOR

ADDENDUM 2023

Colegio Oficial de Ingenieros Aeronáuticos de España's report

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1. PREFACE

Aviation and particularly air transport, like other sectors, maintain their commitment to mitigating climate change. Progress continues with the goal of achieving net-zero carbon emissions by 2050, seeking innovative and sustainable solutions and forging new agreements between organisations and companies both at the European and global levels.

Air transport emissions remain much lower than those of road transport; however, the expected growth in the number of operations is significant (the latest estimates suggest that global air transport demand will increase by an average of 4.3% annually over the next 20 years). This necessitates maintaining pressure to meet agreed commitments.

In Europe, the number of operations is expected to grow by 44%, from 11 million before the pandemic in 2019 to 16 million in 2050. According to Eurostat[1] (avia_tf_cm2) and the US Department of Transportation[3], the number of commercial flights in the EU and the US in 2023 was 6.3 million and 16.3 million, respectively. These figures underscore the importance of the sector and the imperative to combine efforts across all areas to ensure that research programmes in new technologies meet their targets, as well as to achieve better and more effective agreements to offset the increase in emissions resulting from the expected growth in operations.

The 2023 addendum outlines the progress made in environmental sustainability in aviation during 2023, covering new agreements and actions, innovations, and technological improvements:

- Progress or changes in agreements and regulations, such as a new Emissions Trading System (ETS2) or the new agreement aiming to reduce international aviation emissions by 5% by 2030 through the use of Sustainable Aviation Fuel (SAF) or other clean energies. This includes the ReFuelEU Aviation initiative, which aims to increase both the demand and supply of SAF and to create alliances to encourage the use and production of SAF and green hydrogen in Spain.
- Actions and commitments from an increasing number of airlines to become more sustainable by implementing emission offset measures, renewing their fleet with modern, less polluting aircraft, and reviewing the efficiency of their operations.
- Collaborations between companies and organisations related to the acquisition of SAF, the introduction of low-emission technologies in aircraft, or the acceleration of the development of disruptive technologies.
- Actions and measures implemented in many airports that have improved their Airport Carbon Accreditation (ACA).Proyectos relacionados con la eficiencia en la navegación aérea, tales como el proyecto ECHO, que establecerá las bases de las futuras operaciones en el espacio aéreo superior, o el proyecto HERON, cuyo objetivo es mostrar cómo la introducción de operaciones optimizadas de gestión del tráfico aéreo

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[1] *https://ec.europa.eu/eurostat/databrowser/view/AVIA_TF_CM__custom_9472123/bookmark/table?lang=en&bookmarkId=e66bdea7-1234-4044-804e-19cadfc4b5b0*

[2] *ttps://ec.europa.eu/eurostat/databrowser/view/AVIA_TF_CM__custom_9472123/bookmark/table?lang=en&bookmarkId=e66bdea7-1234-4044-804e-19cadfc4b5b0*

[3] *https://www.transportation.gov/briefing-room/2023-numbers-more-flights-fewer-cancellations-more-consumer-protections*

y nuevas tecnologías pueden mitigar la huella ambiental de la aviación y reducir el consumo de combustible y por tanto, de las emisiones.

- Projects related to efficiency in air navigation, such as the ECHO project, which will lay the foundations for future operations in the upper airspace, or the HERON project, which aims to demonstrate how the introduction of optimised air traffic management operations and new technologies can mitigate aviation's environmental footprint and reduce fuel consumption and, consequently, emissions.
- New research into revolutionary concepts with configurations such as Boeing's new Transonic Truss-Braced Wing (TTBW) demonstration aircraft or Airbus Helicopters' PioneerLab project, a twin-engine technology demonstrator in helicopters.
- Developments of new electric aircraft, such as the vertical AutoFlight eVTOL or the Pathfinder 1, which combines the airship concept with the best of modern technology.

This report, therefore, reflects the progress made since the previous edition concerning the fulfilment of the established roadmap for the decarbonisation of aviation. This progress has been materialised through new agreements and collaborations between companies and organisations, as well as advancements in research evolution, projects, and new developments in the field of sustainable aviation.

Contenido

3. INTRODUCTION

The evolution of aviation towards greater environmental sustainability continues to progress through multiple approaches, agreements, collaborations, and strategies. The aim of this 2023 addendum by COIAE is to build on what has been published in previous years, describing and contextualising the ongoing initiatives, new developments, advancements, and achievements made towards achieving sustainable aviation since the creation of the 2022 addendum. Therefore, this edition is confined to the events in this field that took place during 2023. To gain a broader and more comprehensive understanding of this topic, it is necessary to read the [1] reports as well as the 2022 Addendum [2].

As mentioned in previous reports, the sustainability of aviation encompasses a broader socioeconomic concept than what is addressed in this report, and it aligns with the Sustainable Development Goals established and approved by the UN in 2015. This report focuses on reducing the environmental impact of aviation by decreasing emissions, considering the entire lifecycle of an aircraft: from design, manufacturing, and production to its operations and final recycling.

Lastly, it is important to note that the intention of this report, like the 2022 addendum, is not to exhaustively compile each and every advancement, agreement, collaboration, and achievement related to emission reduction that has occurred during 2023. Instead, it aims to highlight the relevant events to provide an updated overview, which undoubtedly underscores the ongoing concern and involvement of aviation in the pursuit of greater environmental sustainability.

4. ENVIRONMENTAL IMPACT OF AVIATION IN CONTEXT

Various studies and comparisons have continued to assess CO2 emissions for 2022 and their estimates for 2023, as well as their impact on climate change. According to the Global Carbon Budget 2023[4], CO2 emissions increased by 0.9% in 2022 compared to 2021, raising fossil CO2 emissions to 9.9±0.5 GtC/year in 2022.[3]

Preliminary estimates based on available data suggest that fossil CO2 emissions will rise further in 2023: by 1.1% compared to 2022, bringing emissions to 10.0 GtC/year[5] (36.8 GtCO2/year[6]), which represents an increase of up to 1.4% above the pre-pandemic level of 2019. Specifically, the estimates for fossil CO2 emissions by fuel type are projected to grow as follows:

- +1.1% (range: −0.1%, +2.4%) for coal.
- +1.5% (range: −0.6%, +2.3%) for oil.
- +0.5% (range: −0.9%, +1.8%) for natural gas.
- +0.8% (range: −0.7%, +2.4%) for cement.

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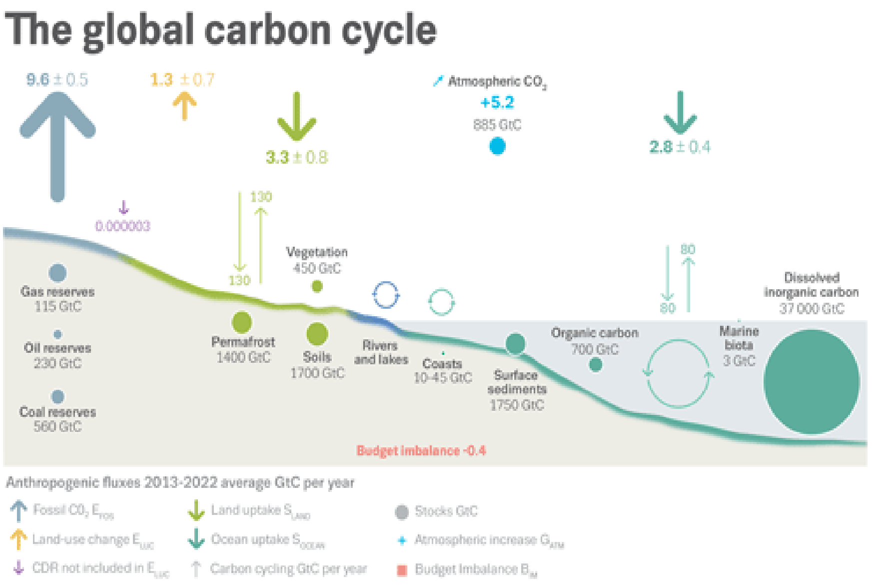
[4] *Global Carbon Badget, informe elaborado por una comunidad de investigadores para anunciar un presupuesto global de carbono que cuantifica las emisiones de dióxido de carbono del año previo, https://essd.copernicus.org/articles/15/5301/2023/*

[5] *GTC/año= 1 Gigatonelada de carbono por año.*

[6] *Gt CO2 /año=1 Gigatonelada de CO2 por año*



Schematic Representation of the General Disruption of the Global Carbon Cycle Caused by Anthropogenic Activities, Averaged Globally for the Decade 2013-2022[7]

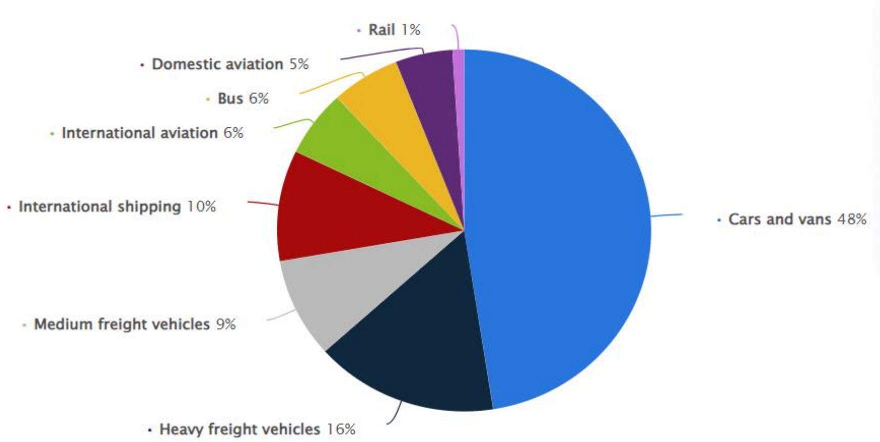
In 2022, the largest absolute contributions to global CO2 emissions came from China (31%), the United States (14%), India (8%), and the EU27 (7%). These four regions account for 59% of global CO2 emissions, while the rest of the world contributed 41%, including international aviation and shipping fuels [3].

On the other hand, according to IATA, global traffic, measured in revenue passenger kilometres (RPK), grew by 31.2% year-on-year in October 2023. The sector is operating at 98.2% of pre-COVID levels.

During 2023[8], data on global CO2 emissions from the transport sector were published. Specifically, Statista reported in September 2023 that global CO2 emissions from cars and vans peaked at 3.6 GtCO2 in 2019 before decreasing sharply by 11% the following year due to the COVID-19 outbreak and subsequent mobility restrictions. Although emissions have increased since then, they remain below pre-pandemic levels. Meanwhile, medium and heavy trucks accounted for approximately one-quarter of transportation emissions in 2022, despite constituting a small proportion of vehicles.

[7] *https://www.icos-cp.eu/science-and-impact/global-carbon-budget/202*

[8] *IATA, InternationalAir Transport, Asociación internacional del transporte aéreo*
https://www.iata.org/contentassets/a7b12fb866e44c87965ab70d27122f27/2023-12-05-02-sp.pdf
https://www.iata.org/en/pressroom/2023-releases/2023-12-05-02/



Distribution of Carbon Dioxide Emissions Produced by the Transport Sector Worldwide in 2022, by Subsector[9]

According to environmental consultancy Global Factor, based on the end of the health crisis and the return to normalcy, verified CO2 emissions in Spain increased by 9.07% in 2022. Three major sectors were responsible for this increase: combustion facilities saw a 21.3% rise in emissions compared to 2021, slightly above the refinery sector, which experienced a 6.3% increase. Aviation, with the return of tourism, doubled its total greenhouse gas emissions to reach 6.96 million tonnes of CO2. The sum of these three sectors accounted for 68% of the total carbon market emissions in Spain for the last year.[10]

Regarding the non-CO2 impact of contrails and cloudiness, EGUsphere, in its October 2023 [11]preprint[12], estimates that the global net radiative forcing (RF) of contrails for 2019-2021 is approximately half of the previous study's best estimate [4]. Furthermore, the climate impacts of contrails have not increased proportionally with the growth in air traffic due to greater growth in regions where contrail formation is less likely. The study also points out significant opportunities to mitigate the impacts of contrails, as only 2% of all global flights account for 80% of the annual radiative forcing of contrails.

The scientific debate on how to address aircraft contrails continues. Environmental activists and climate-focused non-profits are intensifying research on contrails. In October 2023, a flight with the ecoDemonstrator Explorer Boeing 737-10 using 100% SAF was conducted to examine its contrail and determine how the use of SAF may affect contrail characteristics, with results expected in 2024.

The controversy surrounding pollution from short flights, which led to France banning regular domestic flights that can be completed in less than two and a half hours by train, effective from May, has provoked numerous and varied opinions. According to Clement Beaune, French Minister of Transport, "This is an essential step and a strong symbol in the policy of reducing greenhouse gas emissions." In contrast, Iberia's director[13] argues that "it would leave passengers not living in Madrid without connectivity to long-haul destinations," and Santander Bank[14] analysts highlight the measure's minimal impact due to a "significant portion" of domestic traffic involving the islands and the current lack of infrastructure to connect high-speed rail at airports. They also point out that rail transport cannot meet all demand and that

[9] *https://www.statista.com/statistics/1185535/transport-carbon-dioxide-emissions-breakdown*

[10] *https://cincodias.elpais.com/companias/2023-04-17/las-aerolineas-duplican-sus-emisiones-locales-mientras-se-eleva-la-presion-de-la-ue.html -*

[11] *EGUsphere , el repositorio científico abierto sin fines de lucro de la Unión Europea de Geociencias (EGU)*

[12] *https://egusphere.copernicus.org/preprints/2023/egusphere-2023-1859/egusphere-2023-1859.pdf*

[13] *https://efeverde.com/fernando-candela-presidente-de-iberia-vuelos-cortos/*

[14] https://www.agenttravel.es/noticia-051867_La-reduccion-de-vuelos-cortos-es-una-medida--puramente-estetica--*sin-impacto-operativo--relevante--segun-analistas.html*

the measure would exclude Málaga, Sevilla, and northern Spain. Additionally, the COIAE[15] has published a report analysing the minimal impact of these actions, noting that they would have an imperceptible effect on emissions, less than 0.05% of the total emissions in Spain in 2022. The report also states that aviation has access to truly useful tools for significantly reducing emissions, such as sustainable aviation fuels (SAF), electric propulsion (with batteries or hydrogen fuel cells), the emissions trading system (EU ETS), as well as efficiency measures in operations and air traffic management.

5. TOWARDS SUSTAINABLE AVIATION

Throughout 2023, agreements, collaborations, and commitments have strengthened the path towards more sustainable aviation.

In March 2023, the IPCC[16] finalised the Synthesis Report (SYR) AR6: Climate Change 2023[17], which is the final product of the Sixth Assessment Report 2023 for the United Nations Framework Convention on Climate Change[18] (UNFCCC)/COP 28. In June 2023, the second general assembly of the European Alliance for Zero-Emission Aviation[19] took place to discuss progress made during the first six months of activities, summarised in a Progress Report. This context saw various documents prepared by each of the six working groups, notably highlighting the review of the current regulatory landscape for zero-emission aircraft and an assessment of the current standardisation landscape.

Also in June 2023, IATA presented a series of roadmaps at the 79th IATA Annual General Meeting[20] in Istanbul, aimed at establishing key actions and dependencies for the aviation sector to achieve net-zero carbon emissions by 2050. According to IATA, these strategies focus on areas such as aircraft technology, energy infrastructure, operations, financing, and policies.[21]

The strategies proposed by IATA[22] were:

1. Aircraft Technology: Focusing on the development of more efficient aircraft and engines, powered by sustainable aviation fuel (SAF), hydrogen, or batteries, with milestones supported by investment programmes and announced prototypes.

2. Energy and New Fuel Infrastructure: Concentrating on fuels and infrastructure needed for aircraft powered by SAF or hydrogen.

3. Operations: Identifying opportunities to reduce emissions and improve energy efficiency through enhancements in the operation of existing aircraft.

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15 *https://coiae.es/informe-de-vuelos-cortos-2022-del-coiae/*

16 *IPCC, the Intergovernmental Panel on Climate Change*

17 *https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_FullVolume.pdf*

18 *United Nations Framework Convention on Climate Change : UNFCCC/COP 28*

19 *Alianza que fue creada por la Unión europea en Junio del 2022, alineado con la Declaración de Toulouse*

20 *https://www.iata.org/en/events/agm/agm-2023/*

21 *https://defence-industry-space.ec.europa.eu/system/files/2023-06/Progress%20report%20v.1.0.pdf.*

22 *https://www.aviacionline.com/2023/06/el-paso-a-paso-de-la-sostenibilidad-en-la-aviacion-iata-presenta-sus-hojas-de-rutas-para-lograr-la-neutralidad-de-carbono/*

4. Policies: Emphasising the need for globally aligned strategic policies to provide incentives and support to the aviation industry in its transition towards a net-zero future.

5. Financing: Providing a framework to finance the $500 billion required for the aviation sector to reach net-zero emissions by 2050.

These strategies stress that time is of the essence and that immediate action is required to commercialise large-scale clean energy storage solutions, along with the necessary infrastructure, and to build a business case for rapid gigawatt-scale delivery.

From November 20 to 24, 2023, Dubai hosted the Third ICAO Conference on Aviation and Alternative Fuels (CAAF/3), where the ICAO Global Framework Agreement for SAF, LCAF, and other clean aviation energies was signed. At this meeting of 193 countries, excluding North Korea, a provisional target for 2030 was agreed upon to reduce international aviation emissions by 5% by using sustainable fuel (SAF) or other cleaner energy sources[23]. However, China, Russia, and others expressed some doubts about the impact on their economies. This target is lower compared to the previous 5-8% goal, aiming to encourage or incentivise critical investments needed to increase SAF production, while acknowledging each country's capacity limitations to contribute within their national timelines and maintaining the principle of non-obligation. This agreement was welcomed by the European Commission.

In December 2023, ICAO published the first edition of the "Special Environment Report on International Aviation Cleaner Energy Transition[24]," aimed at providing information on SAF, LCAF, and cleaner energies, and presenting the results of CAAF/3 and the Global Framework Agreement [5].

Additionally, from November 30 to December 12, 2023, the United Nations Climate Change Conference 2023, also known as COP28[25][26], was held in Dubai, highlighting the following directly impacting aviation:

- Mitigation Agreements: Now include a gradual transition towards phasing out fossil fuels, not just a progressive reduction, with the goal of achieving net-zero emissions by 2050.

- Private Sector Support: Through the launch of a $30 billion climate capital fund, which will mobilise private sector investments in low-carbon and climate-resilient projects, particularly in emerging and developing economies.

In October 2023, the inaugural IATA World Sustainability Symposium (WSS) took place in Madrid, focusing on the necessary actions to meet the aviation industry's commitment to achieving net-zero CO2 emissions by 2050. This includes climate impact mitigation strategies, where SAF is expected to contribute 62% towards achieving net-zero by 2050, analysis of a

[23] *https://www.icao.int/environmental-protection/Documents/ICAO%20Special%20Environment%20Report%20on%20International%20Aviation%20Cleaner%20Energy%20Transition%20.pdf*
[24] *https://www.icao.int/Meetings/CAAF3/Documents/ICAO%20Global%20Framework%20on%20Aviation%20Cleaner%20Energies_24Nov2023_SP.pdf*
[25] *https://unfccc.int/cop28*
[26] *https://www.icao.int/environmental-protection/Documents/ICAO%20Special%20Environment%20Report%20on%20International%20Aviation%20Cleaner%20Energy%20Transition%20.pdf*

coherent methodology and reporting mechanism for reliable and accurate progress tracking, and globally aligned strategic policies to provide incentives and support to aviation.

In Spain, the All4Zero[27] project was launched in September with the goal of decarbonising industrial operations. This project involves four major Spanish industry companies: Iberia, Repsol, ArcelorMittal, and Holcim, which share technological resources and infrastructure to research and develop disruptive decarbonisation and circular economy technologies aiming for net-zero emissions by 2050. Companies with similar goals, such as Enagás, Navantia, Tecnalia, and IMDEA Energía, will also be associated with this project, bringing expertise in relevant sectors like renewable energies, gas, and naval.

In the UK, BAE Systems has become one of the first aerospace industry members to sign a strategy that will help the UK meet its Net Zero goals by signing the Defence Aviation Net Zero Strategy Charter.

Additionally, new demonstration projects have been launched in both Europe and the US to achieve more sustainable aircraft: NASA, Boeing, and RTX are working on a single-aisle, medium-to-short-haul aircraft with a projected flight date of 2028. Collaborations such as Airbus Commercial and Altair SimSolid, a global leader in computational science and artificial intelligence (AI), are also forming. Among these is Airbus's global initiative to develop sustainable aircraft, ZEROe, aiming to create the world's first commercial zero-emissions aircraft powered by hydrogen to reduce delivery times for both parts and assemblies.[28]

Overall, these commitments and agreements aim to promote actions in the short term (improvements in conventional aircraft operations, reduction of plastics, circular economy), medium term (introduction of sustainable aviation fuels and fleet renewal), and long term (disruptive propulsion aircraft, including electric and hydrogen-powered ones) with implications for countries, authorities, and both public and private enterprises.

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Additionally, various emission compensation systems continue to be supported, including atmospheric carbon capture and incorporating other alternatives such as air traffic volume management, actions at airports for operations and energy supplies, etc., which will be detailed in the following sections.

6. ACTIONS, INNOVATIONS AND TECHNOLOGY

Progress towards sustainable aviation continues at an accelerated pace with actions yielding short, medium, and long-term results. Notably, in the medium term, there is a significant effort from airlines and airports to reduce their CO2 emissions, as well as numerous alliances, agreements, and collaborations between companies and public organisations to achieve the net-zero emissions target by 2050.

One notable development is the Cascade[29] tool, which Boeing publicly launched in May 2023. [30]This dynamic modelling tool allows for the analysis of potential strategies and scenarios to

[27] *https://aviaciondigital.com/all4zero-un-hub-de-innovacion-para-la-descarbonizacion-industrial-en-espana/*
[28] *https://actualidadaeroespacial.com/bae-systems-se-suma-a-la-estrategia-net-zero-de-aviacion-de-defensa/*
[29] *https://cascade.boeing.com/*
[30] *https://actualidadaeroespacial.com/boeing-lanza-publicamente-cascade-para-apoyar-el-objetivo-net-zero-de-la-aviacion/*

quantify the solutions adopted for reducing aviation emissions up to 2050. This tool will undoubtedly support companies in making their estimates according to the adopted strategy to achieve the aviation Net Zero goal.

Another initiative to highlight is the 'Skyteam' alliance, which in May launched for the second consecutive year the "Sustainable Flight Challenge"[31] (SFC), promoted by the KLM Group. The aim is to achieve a significant short-term change, with all participants committing to share their innovations and industry knowledge to reduce the environmental impact of aviation. The seven winners this year were:

TSFC award winners[32]

Consultancies such as Standard & Poor's (S&P Global[33]) conduct an annual ranking based on global sustainability performance according to Corporate Sustainability Assessment (CSA[34]). This assessment compares companies across 62 industries through industry-specific questionnaires that evaluate, on average, 23 sustainability topics with 110 questions. Based on their performance, companies receive scores ranging from 0 to 100 and percentile rankings for financially relevant sustainability criteria. In 2023, over 3,500 companies participated in the CSA, compared to 3,000 in 2022.

6.1. EMISSION OFFSETTING AND ECONOMIC MEASURES

6.1.1. Awareness and Compensation

In addition to the existing IATA CO2 CONNECT[35] Emission Calculator methodology, introduced in 2022 for calculating CO2 emissions, the general methodology version 12 was published in September 2023. This methodology is designed to estimate the amount of carbon emissions generated by a generic passenger on a flight following ICAO guidelines for use in the carbon

[31] *https://www.skyteam.com/en/sustainability/thesustainableflightchallenge/ https://sustainableflightch allenge.com/default/content/tsfc2023*
[32] *https://boletinturistico.com.mx/skyteam-anuncia-ganadores-del-sustainable-flight-challenge/*
[33] *https://www.spglobal.com/en/who-we-are/about-sp-global*
[34] *https://www.spglobal.com/esg/csa/*
[35] *https://www.iata.org/en/services/statistics/intelligence/co2-connect/*

offset program[36]. Additionally, version 1 of the methodology developed specifically to estimate CO2 emissions generated solely by cargo flights was also released.[37]

Increasingly, airlines, aviation industry associations, and online flight search engines offer CO2 emissions calculations for their flights. This is done in partnership with other companies or associations, such as the Brazilian airline Azul, which has joined IATA's CO2 Connect program to calculate CO2 emissions.

Similarly, IATA and ATPCO have announced a collaboration agreement to integrate IATA's CO2 CONNECT data through ATPCO's Routehappy interface by the end of this year. This integration will allow passengers or users to consistently, transparently, and reliably understand the environmental impact of their flights, including the carbon cost of different itinerary options (information that will be integrated with other data displayed by Routehappy).

At the beginning of the year, American Express Global Business Travel (Amex GBT) reached a new agreement with the climate technology company Chooose, through which it will integrate Chooose's carbon emissions calculation technology into Amex GBT's[38] travel booking tools. The goal is to enhance Amex GBT's sustainability solutions by improving the accuracy and consistency of greenhouse gas emissions data, as well as creating a structure for future carbon offsetting.

Lastly, in April 2023, the DHL Group held its first global summit on sustainable logistics in Valencia, where they presented their sustainability advancements, including the new GoGreen Dashboard[39] tool. This program allows the group's customers to see the carbon emissions of different business units.

In February 2023, the International Aerospace Environmental Group (IAEG)[40] announced its partnership with the corporate sustainability rating provider EcoVadis, aiming to help IAEG members accelerate improvements in environmental, social, and governance (ESG) performance.[41]

Starting in February 2023, the Lufthansa Group introduced a new product that expands its "sustainable travel offerings" with what they call "green fares" for flights with a lower environmental impact, making it the first commercial aviation consortium to launch such differentiated values.[42]

Reflecting the efforts to become more sustainable in the Spanish aviation industry, the III Sustainability Day took place in April, titled 'Social Concerns of Diversity, Equity, and Inclusion as Challenges and Opportunities,' organized by the Spanish Association of Technological Defense, Security, Aeronautics, and Space Companies (TEDAE) in collaboration with Navantia. The purpose of this session, focused on social sustainability, was to provide information on current corporate obligations in areas such as diversity and new approaches to managing professionals, as well as to examine the implications for companies of future human rights

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[36] *https://applications.icao.int/icec/Methodology%20ICAO%20Carbon%20Calculator_v12-2023.pdf*

[37] *https://applications.icao.int/icec/Freighter_Methodology_1.0.pdf*

[38] *https://www.agenttravel.es/noticia-048556_Amex-GBT-se-integra-con-Chooose-para-potenciar-la-sostenibilidad-en-viajes.htm*

[39] https://dhl-freight-connections.com/en/business/dhl-gogreen-dashboard-an-automated-and-efficient-solution-for-carbon-reporting/

[40] IAEG, el foro mundial sobre buenas prácticas medioambientales en el sector aeroespacial

[41] *https://fly-news.es/aviacion-sostenible/iaeg-se-asocia-con-ecovadis-para-gestionar-la-sostenibilidad-del-suministro-aeroespacial/*

[42] *https://www.aviacionline.com/2023/02/tarifas-verdes-grupo-lufthansa-ofrece-precios-diferenciales-para-la-compensacion-de-emisiones-en-determinadas-rutas/*

regulations in the European Union and Spain.[43]

6.1.2. CORSIA and EU ETS

In the first half of 2023, a new emissions trading system called ETS2 was created, independent of the existing EU ETS, which will be fully operational by 2027. This system will complement the "European Green Deal" policies by setting a carbon price that will provide a market incentive for investments in building renovations and low-emission mobility, aiming to help its members achieve emission reduction targets by 2050.[44]

In April 2023, the European Parliament approved, among other environmental preservation measures, the reform of the EU Emissions Trading System (EU ETS), including the aviation and maritime sectors.[45]

These decisions are part of the European "Fit for 55" package. The EU ETS reform involves a 62% reduction in greenhouse gas emissions in these sectors by 2030 compared to 2005 levels. As part of this, free emission allowances for the aviation sector will be gradually phased out by 2026, and the use of sustainable aviation fuels will be encouraged.

The agreement includes ending free emission allowances for the aviation sector by 2026, one year earlier than proposed by the Commission. To ensure this gradual phase-out, a 25% reduction in free allowances is planned for 2024 and a 50% reduction for 2025.

Negotiators agreed to reserve 20 million emission allowances from January 1, 2024, to December 31, 2030, for commercial aircraft operators that increase the use of sustainable aviation fuels, such as renewable hydrogen, non-biological renewable fuels, and advanced biofuels.

To address the impact of emissions from the aviation sector other than CO2, the Commission will establish and apply a framework for monitoring, reporting, and verifying these emissions starting in 2025. An assessment will be conducted in 2027, followed by a legal proposal in 2028 to extend the scope of the EU ETS to cover these emissions.[46]

However, an exception will be established for emissions generated until 2030 on flights between an airport located in an EU country's outermost region and another airport within the same country, as well as flights between airports in an outermost region of the same EU country.

In March 2023, the "Resolution A41-22: Consolidated Statement of Continuing ICAO Policies and Practices Related to Environmental Protection — Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)" was published, with 115 states participating.

Regarding the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA[47]), in May 2023, Directive (EU) 2023/958 of the European Parliament and the Council was published, amending Directive 2003/87/EC concerning the aviation sector's contribution to emissions across the economy and the proper implementation of a global market measure.[48]

In October, the European Commission approved the ReFuelEU Aviation initiative, the latest

[43] *https://www.defensa.com/espana/industrias-tedae-unidas-sostenibilidad*

[44] *https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/ets2-buildings-road-transport-and-additional-sectors_en*

[45] *https://www.europarl.europa.eu/RegData/etudes/ATAG/2023/745712/EPRS_ATA(2023)745712_ES.pdf*

[46] *https://www.icao.int/environmental-protection/Documents/Resolution_A41-22_CORSIA.pdf*

[47] *https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx*

[48] *https://eur-lex.europa.eu/legal-content/ES/TXT/HTML/?uri=CELEX:32023L0958*

agreement on the transport proposals of the "Fit for 55" package. The goal is to increase both the demand and supply of sustainable aviation fuels, which produce lower CO2 emissions compared to kerosene (fossil fuel), while ensuring fair competition conditions in the EU air transport market. With the adoption of the ReFuelEU Aviation Regulation and the revised Renewable Energy Directive, the EU now has legally binding climate targets covering all key sectors of the economy. According to the European Commission, this legislative package is expected to reduce the EU's net greenhouse gas emissions by 57% by 2030.

The ReFuelEU Aviation Regulation stipulates that aviation fuel suppliers must blend increasing amounts of sustainable aviation fuels (SAF) with kerosene[49]. This will start with a minimum blend of 2% in 2025, gradually increasing to 70% by 2050. This regulation is anticipated to reduce aviation CO2 emissions by approximately two-thirds by 2050 compared to a "business-as-usual" scenario, in addition to improving air quality.[50]

The European Union Aviation Safety Agency (EASA) hosted the ReFuelEU Member States Network meeting on November 16, committing to ensure that member states have what they need to implement ReFuelEU Aviation, a historic policy to decarbonize aviation.[51]

In May, the first independent certification standard for "carbon-neutral" products was presented. The standard, known as Carbon Offset Certification (COC[52]), is a Swiss-based initiative developed by carbon market professionals in strategic partnership with Bureau Veritas and contributions from recognized experts (SGS, KPMG, Oil & Gas Climate Initiative). This COC certification can be applied to various sectors (maritime, energy, etc.), and specifically to private aviation (e.g., certification for private jet flights from Come Play Fly). This is why it is of interest in this report.[53]

Meanwhile, EasyJet has become the world's first airline to sign a contract with Airbus for its carbon removal initiative using DACCS[54] technology, thereby obtaining carbon removal credits by extracting from the air an amount equivalent to the CO2 emissions released into the atmosphere during aircraft operations that cannot be directly eliminated at their source, and advancing its decarbonization goals. DACCS technology filters and removes CO2 emissions directly from the air using high-power extraction fans. Once removed, the CO2 is securely and permanently stored underground and complements other carbon reduction technologies, such as the use of sustainable aviation fuel (SAF).

6.1.3. Collaborations between companies

Numerous and varied collaborations have taken place in the aviation world to achieve the goal of net-zero emissions by 2050. Many of these efforts are focused on acquiring sustainable fuel, which will be addressed in the relevant section. Among them, the following stand out for their scale or originality:

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[49] https://aviaciondigital.com/europa-aprueba-la-iniciativa-refueleu-aviation-como-parte-del-paquete-fit-for-55/

[50] «Fit for 55», el plan de la UE para reducir las emisiones de gases de efecto invernadero en al menos un 55% para 2030 en comparación con los niveles de 1990. https://www.easa.europa.eu/es/light/topics/refueleu-aviation

[51] *https://aerolatinnews.com/gobiernos/easa-promueve-descarbonizacion-de-la-aviacion-en-europa/*

[52] *https://carbonoffsetcertification.com/certification*

[53] *https://www.hispaviacion.es/se-presenta-la-primera-norma-de-certificacion-independiente-para-productos-neutros-en-carbono/*

[54] *https://www.aerotendencias.com/aviacion-comercial/61719-easyjet-se-suma-a-la-solucion-pionera-de-eliminacion-de-carbono-de-airbus/*

- DHL Express and World Energy have signed a long-term strategic agreement[55] to accelerate the decarbonization of air logistics by purchasing approximately 668 million liters of sustainable aviation fuel (SAF). The contract, which spans seven years and will be valid until 2030, is one of the largest in terms of duration and scale in the aviation sector regarding SAF to date.

- Airbus and ZeroAvia have agreed to collaborate on certification approaches for hydrogen energy systems (including liquid hydrogen storage systems), in addition to Airbus's investment in the UK startup to accelerate the development of multi-megawatt hydrogen-electric propulsion systems, including high-temperature PEM (HTPEM) fuel cells, advanced electric motors, and power electronics.[56]

Other collaborations include partnerships between manufacturers and airlines. For instance, in February, ATR announced with New Zealand airline Air New Zealand[57] that they will accelerate the development and introduction of low-emission aircraft technology in New Zealand to explore disruptive innovations. Air New Zealand is partnering with several industry and academic stakeholders (Heart Aerospace, Embraer, and Universal Hydrogen[58]) to replace its domestic fleet of 23 Bombardier Q300 turboprops with a more sustainable option starting in 2030.

Also notable are alliances between companies to replace training aircraft with electric planes, such as Diamond and Lufthansa Aviation Training, aiming to replace the current fleet of DA40NGs with the new fully electric eDA40 aircraft. Additionally, AviaPro Consulting and Altair Advisory[59] will work together to assist the aviation sector on its path to sustainability. AviaPro will enhance its capabilities and position itself as a leader in Sustainability Consulting Services by developing a new Sustainability portfolio for Airports and Airlines in collaboration with Altair Advisory. Simultaneously, Altair Advisory will leverage AviaPro Consulting's infrastructure to expand its research on the topic and deploy new concepts and tools for the industry.[60]

On the other hand, Emirates has committed nearly 200 million euros[61] in research and development (R&D) over the next three years to fund projects focused on reducing the impact of fossil fuels on commercial aviation. Emirates is already implementing measures to reduce unnecessary fuel consumption, such as flexible routing to create more efficient flight paths, fuel savings while the aircraft is on the ground, using ground power units instead of the auxiliary power unit (APU), and renewable energy initiatives, such as installing solar panels to power some of its operational buildings in Dubai and using electric vehicles both on the ground and in the air.

6.1.4. Achievements

Quality Fly flight school has become the first school to fully offset all its CO2 emissions, thanks to its investments in renewables in India. It has also completely eliminated the use of paper in student training and started purchasing 100% renewable electricity from renewable energy producers.[62]

[55] *https://fly-news.es/aviacion-sostenible/dhl-express-y-world-energy-firman-un-acuerdo-para-acelerar-la-descarbonizacion-de-las-flotas-aereas/*
[56] *https://actualidadaeroespacial.com/airbus-invierte-en-zeroavia-permitiendo-avanzar-hacia-la-certificacion-de-su-primer-motor/*
[57] *https://www.airline92.com/industria-aeronautica/atr-air-new-zealand-acuerdan-acelerar-descarbonizacion-aeronaves*
[58] *https://www.greenairnews.com/?p=3910*
[59] *https://aero-naves.com/2023/03/15/diamond-y-lufthansa-aviation-training-apuestan-por-una-instruccion-mas-sostenible/*
[60] *https://a21.com.mx/index.php/aeronautica/2023/02/08/daran-consultoria-en-sostenibilidad-aeropuertos-y-aerolineas*
[61] *https://actualidadaeroespacial.com/emirates-crea-un-fondo-de-200-millones-de-dolares-para-la-sostenibilidad-de-la-aviacion*
[62] *https://fly-news.es/formacion-aeronautica/quality-fly-primera-escuela-espanola-cero-emisiones-netas/*

Another notable school is Flyschool Air Academy, a pioneer in offsetting 100% of its CO2 emissions. With the support of Climate Partners, it has calculated its Scope 1, 2, and 3 emissions from all its bases in Madrid and Mallorca and has purchased carbon offset credits through BP Energía España. This represents the first carbon offset credit agreement between BP Energía España and a flight school.[63]

As previously mentioned, during its first global summit on sustainable logistics in Valencia, DHL Group presented its advancements in sustainability, announcing its new GoGreen Dashboard tool. Among the major milestones achieved in recent years is the acquisition of 30,000 electric vehicles to reinforce its delivery fleets and the order of 12 electric cargo planes. Since a significant portion of the group's emissions comes from air cargo transport, the company is prioritizing the purchase and development of biofuels.

In India, Singapore Airlines is advancing its decarbonization plan for 2050[64], becoming in 2023 the youngest company in the market, with a fleet of 132 aircraft with an average age of 6 years and 8 months (industry average is usually 15 years).

In 2023, American Airlines was named by Air Transport World (ATW) as the Eco-Airline of the Year 2023 for its fleet renewal, considered one of the largest in the industry's history (half of American Airlines' main fleet is less than 10 years old).[65]

Nationally, Iberia has achieved significant environmental initiatives. According to Teresa Parejo (Iberia's Director of Sustainability[66]), sustainability has become part of its DNA, including:

- The retirement of its A340 aircraft: four-engine planes used for transatlantic routes, replaced by twin-engine aircraft (A330 and A350), which are 30-35% more efficient and environmentally friendly.

- Self-consumption plants[67] and the CO2labora Program[68], which allows passengers to offset their flight emissions through two certified climate projects.

- The recycling project of old uniforms and the elimination of plastic on board, along with other similar actions in the Premium Lounge[69].

- The first long-haul flights with SAF produced in Spain in collaboration with Repsol.[70]

6.2. AIRPORTS, NAVIGATION AND OPERATIONS

6.2.1. Airports

In the Airport Carbon Accreditation Annual Report 2021-2022[71], published in March, the progress of the 395 accredited airports is highlighted, including 204 European airports. These European airports exceed global carbon savings benchmarks with 57 at Level 3+ and 32 at Level

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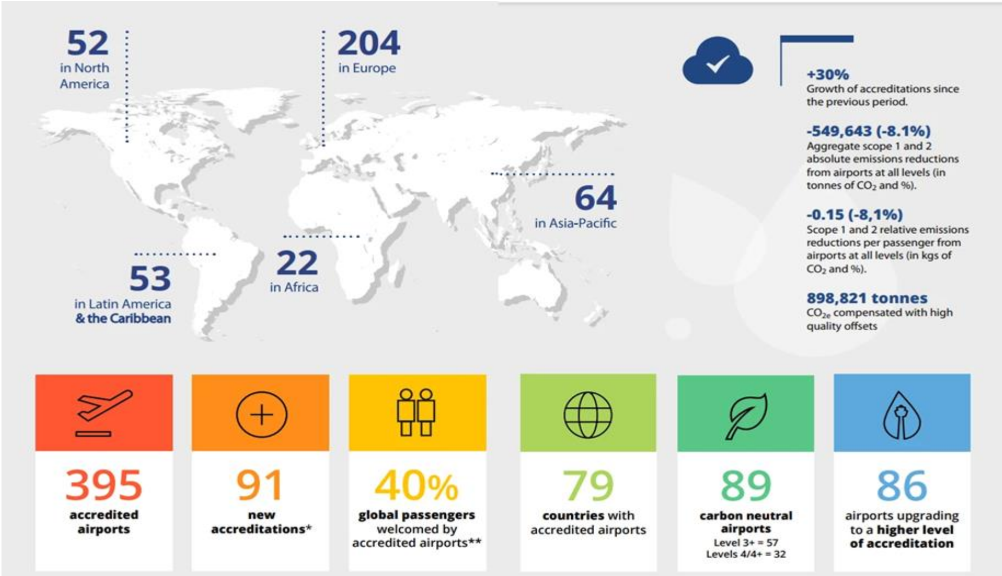
[63] *https://www.avionrevue.com/formacion-empleo/flyschool-pionera-en-la-compensacion-del-100-de-emisiones-de-co2/23*
[64] *https://www.hispaviacion.es/singapore-airlines-avanza-en-su-plan-de-descarbonizacion-para-el-2050/*
[65] *https://thejetset.com/espanol/air-transport-world-nombra-a-american-airlines-como-eco-aerolinea-del-ano-2023/*
[66] *https://www.larazon.es/medio-ambiente/20230124/wkjsmfbuxrhxlpzarslkvpxya4.html*
[67] *https://www.iberia.com/es/sostenibilidad/medioambiente/reduccion-emisiones/*
[68] *https://www.iberia.com/es/sostenibilidad/cliente/huella-carbono/*
[69] *https://actualidadaeroespacial.com/iberia-preve-reducir-hasta-200-toneladas-de-plastico-en-sus-vuelos-este-ano/*
[70] *https://www.repsol.com/es/sala-prensa/notas-prensa/2022/iberia-opera-en-colaboracion-con-repsol-sus-primeros-vuelos-de-largo-radio-con-biocombustible-producido-en-espana-a-partir-de-residuos/index.cshtml*
[71] https://www.airportcarbonaccreditation.org/media/annual-reports/

4/4+.



From the Airport Carbon Accreditation Annual Report 2021-2022

European airports also topped the ranking for the highest number of airports at the most advanced accreditation levels: Levels 3+ (Neutrality) and 4/4+ (Transformation/Transition), with 68 airports in the region accredited at these levels by the end of the year, out of 89 worldwide.

	LEVELS						
REGION	1	2	3	3+	4	4+	TOTAL
Europe	72	44	20	44	11	13	204
Asia-Pacific	10	18	25	5	4	2	64
North America	22	9	15	4	1	1	52
Latin America & the Caribbean	28	14	8	3	-	-	53
Africa	12	7	2	1	-	-	22
Global	144	92	70	57	16	16	395

From the Airport Carbon Accreditation Annual Report 2021-2022

European airports also surpassed the global average in carbon performance, recording an 11.9% reduction in Scope 1 and 2 CO2 emissions compared to the global reduction rate of 8.1%.

In Spain, Aena's network airports renewed their certification, with the Málaga-Costa del Sol Airport advancing to Level 3 "Optimization." In total, nine Aena airports are accredited under this program, representing 70% of passengers and over 90% of emissions in the airport network.

Many airports are becoming centers of innovation and collaboration, bringing together science, technology experts, product developers, and companies to test the latest ideas related to cybersecurity, passenger experience, and sustainability:[72]

Kansai Airports partnered with Kobe University to conduct an energy-saving and infection-control air conditioning system demonstration at Terminal 2 of Kansai International Airport (KIX).

At Hamad International Airport (DOH) in Doha, the second-best airport in the world (according to SKYTRAX), a revolutionary artificial intelligence system called EMMA (Environmental and Movement Monitoring for Airports) is transforming airport operations, optimizing efficiency and improving safety with the help of Qatar Science Technology Park.

Other airports are recognizing the urgent need to achieve net-zero emissions by taking action and accelerating their commitment to reaching this goal, such as Gatwick Airport in London, which is advancing its target for Scope 1 and 2 carbon emissions to 2030 (10 years earlier than its previous commitment). It will invest over £250 million[73] to reduce carbon emissions, including transitioning to an electric vehicle fleet and replacing gas boilers and refrigerants with low-carbon alternatives. Additionally, they will allocate funds to other renewable energies, including solar energy, and source renewable electricity through power purchase agreements (PPAs).

Other airports are focusing on intermodality. For example, Lufthansa Group signed a joint Memorandum of Understanding with the Italian state railway company Ferrovie dello Stato Italiane S.p.A. to cooperate on rail link traffic within Italy to better and more conveniently connect different modes of transport for the customer. The goal of this cooperation is, in particular, to connect passengers with FS rail connections to their respective air connections at various Italian airports.

In Australia, Newcastle Airport has signed a new power purchase agreement with Flow Power, a leading Australian renewable energy retailer, to achieve its goal of 100% renewable energy seven years ahead of schedule, significantly reducing its carbon footprint and supporting the airport's sustainability efforts.

Regarding renewable energy use, the Eco-ENAIRE[74] initiative has saved more than 110,000 tons of CO2 since 2015 by purchasing 100% of its electricity from certified renewable sources. Additionally, it is investing in photovoltaic installations at its control centers, resulting in an 18% reduction in electricity consumption and 13.7% of ENAIRE's total consumption.

Finally, ENAIRE[75] is exploring the use of hydrogen and biofuels for generators and self-consumption, as well as investing in a significant strategic line in self-consumption and biofuels. This Green Sky plan represents an ambitious initiative aimed at promoting a more sustainable and responsible aviation industry, focusing on efficiency in missions and flight miles, reducing noise impact, and utilizing renewable energies.

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[72] *https://www.icao.int/environmental-protection/Documents/Forms/AllItems.aspx#InplviewHashb581a199-f3f6-4b28-a7c9-46465f7695d7=SortField%3DCreated-SortDir%3DDesc*

[73] *https://a21.com.mx/aeropuertos/2023/03/17/adelanta-gatwick-10-anos-su-meta-de-cero-de-emisiones*

[74] *https://www.enaire.es/es_ES/2023_01_27/np_enaire_emisiones*

[75] *https://aviaciondigital.com/el-plan-green-sky-de-enaire-para-una-aviacion-mas-sostenible*

6.2.2. Navigation

The Performance Review Body (PRB), under the European Commission, published the 'Performance Review Body Monitoring Report 2022'[76] in October, presenting the results of monitoring the European Single Sky ATM System's air navigation services for 2022. It assesses whether member states met their objectives in key performance areas of safety, capacity, environment, and cost-efficiency. The findings reflect how the persistent lack of air traffic management capacity has had an adverse impact on the environment and climate. This Annual Monitoring Report notes that member states have reported poor results in capacity, as they "have not invested sufficiently in rebuilding route capacity post-pandemic."

Additionally, route expansions due to the closure of Ukrainian, Belarusian, and Russian airspace to European traffic, coupled with capacity limitations, have resulted in not meeting EU-wide environmental efficiency targets for flights, reaching their lowest point since 2016.

All member states achieved their profitability targets for 2022; however, the European Commission notes that this was not due to adequate investment by some states in their post-pandemic capacity.

In summary, the 2022 monitoring system report highlights poor results from most member states in terms of environmental objectives and a decrease in flight efficiency.

The HERON Project (Highly Efficient gReen OperatioNs)[77] is being developed as an expanded continuation of the SESAR program known as ALBATROSS, with a timeframe from late 2022 to 2025, and is part of the Single European Sky ATM Research Joint Undertaking (SESAR JU). The project aims to demonstrate how the introduction of optimized air traffic management operations and new technologies can mitigate the aviation environmental footprint and reduce fuel consumption and emissions. It is co-funded under the Connecting Europe Facility. The demonstrator is led by Airbus, a member of SESAR 3 JU, bringing together partners from 10 countries representing the entire aviation ecosystem, including airlines, airports, air traffic control agencies, and service providers.

This year concludes the findings of the third and final ECHO[78] workshop (European Concept of High Performing Airspace), a project led by Eurocontrol that will lay the groundwork for future upper airspace operations, defining future operational functions, responsibilities, procedures, and infrastructure needed to support increased airspace demand in the short, medium, and long term. The findings will be made public in 2024.[79]

In March, ITA Airways announced it would be the first European full-service airline to incorporate the innovative Iris data link technology from the European Space Agency (ESA) and Inmarsat across its entire fleet, a program that enables aircraft to fly more fuel-efficient routes.[80]

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[76] *https://transport.ec.europa.eu/system/files/2023-10/PRB_Annual_Monitoring_Report_2022.pdf*
[77] *https://www.sesarju.eu/projects/HERON*
[78] *Proyecto ECHO Se trata de un programa financiado a través de la Empresa Conjunta SESAR 3 en el marco del programa de investigación e innovación Horizonte 2020 de la Unión Europea, y dirigido por EUROCONTROL https://higherairspace.eu/echo-project/*
[79] *https://a21.com.mx/aerolineas/2023/03/10/ofrece-ita-airways-vuelos-mas-ecologicos-en-italia*
[80] *https://www.boe.es/diario_boe/txt.php?id=BOE-A-2023-17506*

The Resolution of July 17, 2023, from the General Directorate of Quality and Environmental Assessment, formulated an environmental impact report for the project "Redesign of departure, arrival, and instrumental approach procedures for Málaga-Costa del Sol Airport." In line with this report, the "Midas" project was launched. This project (Málaga Improved Design of Airspace) aims to modernize the current instrumental procedures at Málaga-Costa del Sol Airport, adapting them to RNAV (Area Navigation) specifications based on PBN (Performance-Based Navigation). This will enable the development of routes with higher operational safety, greater precision, efficiency, directness, and flexibility.[81]

In November 2023, the European CANSO General Directors Committee (EC3) and EUROCONTROL held the Sustainable Sky Conference, focusing on condensation trails with the main purpose of bringing together scientists, researchers, the aviation industry, policymakers, and other stakeholders to deepen the study of the formation and characteristics of vapor trails and cirrus clouds induced by them, as well as their impact on the climate, and explore possible mitigation measures to reduce their occurrence.[82]

Innovative technologies for engine-off and single-engine taxiing (TaxiBot and WheelTug) are being analyzed and experimented with under the European AEON program, funded by SESAR. This program aims to innovate airport ground operations with more environmentally friendly taxiing techniques for the aviation sector[83]. In addition to single-engine taxiing, new technologies such as replacing fuel generators with electric power units (e-CPUs) and other electric systems to supply air to cabins (PCAs) have been incorporated, as seen at Schiphol Airport (Amsterdam). [84]

6.3. Gradual Eficiency and Design Improvements

As mentioned in previous reports, in the near future, innovation based on current technologies may play a crucial role in reducing the impact of flights, serving as an intermediate step before implementing more disruptive strategies. The importance of innovation in the manufacturing of critical rotating components in aircraft engines is highlighted due to the challenges found in their geometry and materials used and the need for test benches with more demanding requirements than the elements themselves.

In February, AURA AERO and Thales announced a collaboration on a project to develop next-generation connected avionics solutions for regional aviation. The aim is to provide enhanced hardware, software, connectivity, and services to adapt new aircraft to new life cycles through hybrid management and real-time trajectory optimization.[85]

In September 2023, LTA Research received a special airworthiness certificate from the FAA for Pathfinder 1[86], a helium-based airship resulting from years of research and development. Measuring 124 meters in length, it is designed as an innovative solution for disaster response and heavy cargo transport.[87] It is equipped with two electric motors for vertical takeoff and

[81] *CANSO, Europe proveedores de servicios de navegación aérea de Europe*
[82] *https://canso.org/event/canso-eurocontrol-sustainable-skies-conference-contrails-in-focus/*
[83] *https://cordis.europa.eu/article/id/443621-innovative-engine-off-technologies-to-enhance-airport-operations/es*
[84] *https://news.schiphol.com/new-electric-equipment-for-parked-planes-at-schiphol/*
[85] *https://www.interempresas.net/Aeronautica/Articulos/494573-Fabricacion-de-alabes-aeronauticos-desafios-en-el-proceso-de-fabricacion.html*
[86] *https://aviaciondigital.com/pathfinder-1-el-dirigible-del-futuro-liderado-por-el-cofundador-de-google/*
[87] *https://www.hispaviacion.es/aura-aero-y-thales-se-unen-para-descarbonizar-la-aviacion-regional/*

landing (VTOL) that rotate from +180° to -180° for effective directional control and features a lightweight titanium and carbon fiber structure.

In December 2023, Delta, after years of research into creating environmentally compliant, durable paper cups[88], began final testing of these containers on various flights. Once the prototypes are approved, their deployment across Delta's network will help eliminate nearly 3,200 tons of single-use plastics onboard annually. The challenge with these cups is ensuring they maintain appropriate temperatures for both hot and cold beverages while resisting the solvent properties of alcohol. Additionally, the cups must stack efficiently in aircraft catering carts and separate easily for crew service. One of the key considerations in transitioning to paper cups is that many versions include a plastic coating that can complicate recycling.

AFKLMP Cargo,[89] within its sustainable flight operations, undertakes various actions:[90]

- Use of lighter cargo nets, containers, and pallets. For example, cargo nets are 50% lighter than standard pallet nets and save 795 liters of jet fuel per year.

- An innovative painting system that reduces aircraft paint weight by 15%.

- Flight optimization where Group pilots are trained to apply the most fuel-efficient procedures possible: flight plan accuracy, speed adjustments, optimized procedures, landing configurations, and single-engine taxiing on the ground, optimizing aircraft performance.

- Fleet renewal, with the Group's fleet having an average aircraft age of 12.1 years in 2020.

Nationally, according to data published by ENAIRE in early 2023, ENAIRE[91] has avoided emitting 285,000 tons of CO2 between 2017 and 2022, surpassing flight efficiency in 2022 at 96% (96.68%) through continuous improvement of the air route network, which is part of "Fly Clean," one of the three initiatives in its sustainability strategy (Green Sky plan). To achieve this, ENAIRE is prioritizing performance-based navigation and satellite navigation, facilitating the creation of more efficient procedures and the application of advanced airspace design techniques. For instance, continuous descent and ascent have been implemented. During the first eight months of the year, ENAIRE authorized an average of 35% of operations using this method, significantly more than the European average of 14%, resulting in considerable benefits for airlines in terms of efficiency.

Spain has the opportunity to position itself as a technological leader in hydrogen use for aerial mobility through the PERTE[92] H2 "value chain" program, managed by the Institute for Diversification and Energy Savings (IDAE), where Destinus has been selected to lead a national project developing a renewable liquid hydrogen propulsion system for aerial mobility. Additionally, Destinus is participating as a main partner in the CRIPICOM project, co-funded by the Aeronautical Technological Plan (PTA) managed by CDTI (Center for the Development of Technology and Innovation of Spain) to develop the first hydrogen-powered aircraft engine.[93]

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88 *https://fly-news.es/aviacion-comercial/aerolineas/delta-suprime-3200-toneladas-de-plastico-de-un-solo-uso-a-bordo/*
89 *AFKLMPCARGO: Airfrance, KLM, Martinair and Cargo*
90 *https://www.afklcargo.com/CA/en/common/products_and_solutions/sustainable_flight_operations.jsp*
91 *https://www.enaire.es/es_ES/2023_01_27/np_enaire_emisiones*
92 *PERTE (Proyectos Estratégicos para la Recuperación y Transformación Económica) Los PERTE son un nuevo instrumento de colaboración público-privada que permite la co-financiación de las actividades de I+D+i a través de los fondos Next Generation EU de la Unión Europea.*
93 *https://www.industriambiente.com/noticias/20230329/los-fondos-europeos-next-generation-impulsan-el-desarrollo-del-avion-de-*

6.3.1. Propulsion

Airbus Helicopters is developing PioneerLab[94], its new dual-engine technology demonstrator based on the H145 platform. This project complements Airbus's range of FlightLabs and focuses on testing technologies aimed at reducing helicopter emissions, increasing range, and integrating bio-based materials. The goal of PioneerLab is to demonstrate a fuel reduction of up to 30% compared to a conventional H145, thanks to a hybrid electric propulsion system and aerodynamic improvements. It is partially funded by the BMWK, the Federal Ministry for Economic Affairs and Climate Action of Germany, through its national research program LuFo. PioneerLab has already started at the manufacturer's largest facility in Donauwörth, with a rotor impact alert system being the first technology tested onboard the demonstrator. The next phase will involve testing an automated takeoff and landing system.

PioneerLab (Airbus Helicopters)[94]

The A321XLR is the next step in the evolution of the A320neo family of single-aisle aircraft, meeting market demand for greater range and payload on longer routes. The A321XLR will offer unprecedented range for single-aisle aircraft of up to 4,700 nm (8,700 km), with 30% less fuel consumption per seat compared to previous-generation aircraft, as well as lower NOx emissions and noise. On Thursday, October 5th, the A321XLR successfully completed its "early passenger flight" demonstration with 167 employees acting as passengers.[95][96]

It has been announced that Safran will lead the Open Fan demonstration program with European partners under the Clean Aviation OFELIA project. The goal of OFELIA[97] is to demonstrate the benefits of an open fan architecture in terms of efficiency to address the needs of the next generation of short- and medium-range (SMR) aircraft around 2035, on the path towards the industry's goal of achieving net-zero carbon emissions by 2050.

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destinus-propulsado-por-hidrogeno

[94] *https://actualidadaeroespacial.com/airbus-helicopters-lanza-pioneerlab-un-demostrador-de-tecnologia-de-doble-motor-para-reducir-emisiones-y-aumentar-la-autonomia/*

[95] *https://www.airbus.com/en/newsroom/stories/2023-03-a321xlr-programme-completes-second-cold-weather-testing-campaign*

[96] *https://www.airbus.com/en/newsroom/stories/2023-10-the-a321xlr-demonstrates-passenger-comfort-and-cabin-maturity*

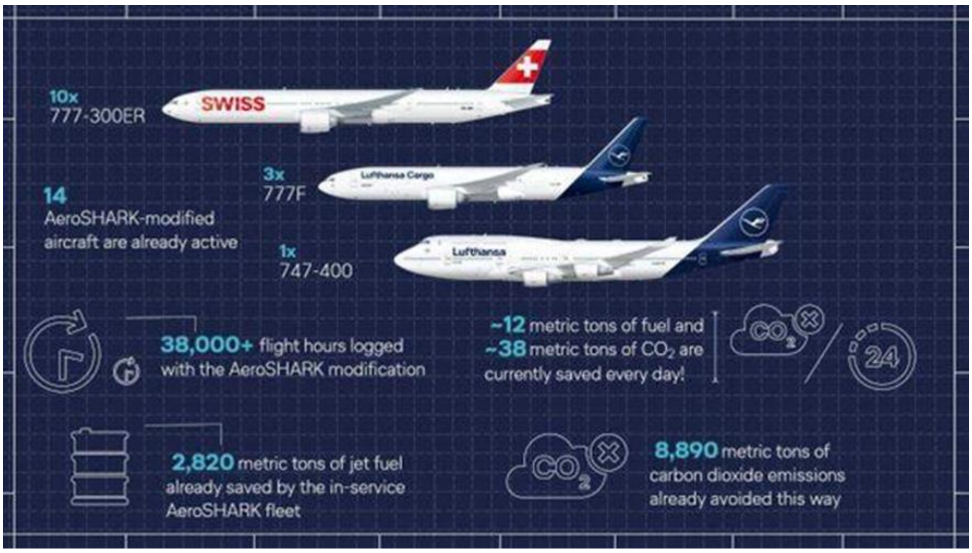
[97] *https://www.safran-group.com/pressroom/safran-lead-open-fan-demonstration-program-european-partners-under-clean-aviation-ofelia-project-2023-04-26*

6.3.2. Aerodynamics and Wing Control

In March 2023, the Canadian airline WestJet conducted its first flight with the drag reduction kit designed by Aero Design Lab (ADL)[98], where the redesign of the wing-fuselage fairing reduces drag, thereby lowering CO_2 emissions.

Aero Design Labs (ADL) drag reduction kit on a 737-700.[99]

As of October 2023, Lufthansa Group has installed "Aeroshark"[100] technology on 13 of its aircraft. This bionic adhesive film is applied to the fuselage and engine nacelles. The film features micrometer-scale grooves, known as 'riblets,' which mimic the hydrodynamic properties of shark skin and help reduce friction drag.



'Aeroshark'100 technology

[98] *https://aviationweek.com/aerospace/aircraft-propulsion/aero-design-labs-launches-boeing-737ng-drag-cut-kit*
[99] *https://www.prnewswire.com/news-releases/westjet-first-airline-in-canada-to-fly-aero-design-labs-drag-reduction*
[100] *https://business.lufthansagroup.com/at/es/news/lhg-aeroshark-technology*

NASA[101] continues to promote research on revolutionary aircraft configurations in the U.S. through public-private collaboration programs, with industry R&D activities. Boeing has been selected to lead the development and flight testing of a new Transonic Truss-Braced Wing (TTBW) demonstrator aircraft, which could reduce fuel consumption and pollutant emissions by up to 30% compared to single-aisle aircraft. This aircraft is part of the Sustainable Flight Demonstrator (SFD) program.

Boeing's X-66 [102]

Delta Air Lines has implemented improved winglet installations to reduce drag, weight reduction initiatives, and flight route optimization. The company is exploring alternative propulsion methods beyond traditional jet fuel through partnerships with Joby Aviation, a developer of eVTOLs, and is also working with Airbus on its Airbus ZEROe program to conduct hydrogen-powered flights.[103]

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[101] *https://aviaciondigital.com/boeing-colabora-con-rtx-en-el-proyecto-demostrador-de-vuelo-sostenible-x-66a-de-la-nasa/*
[102] *https://www.nasa.gov/image-article/new-look-at-nasa-boeing-sustainable-experimental-airliner/*
[103] *https://a21.com.mx/aerolineas/2023/03/10/presenta-delta-proyecto-de-sostenibilidad*

6.4. SUSTAINABLE FUELS

As mentioned in previous reports, while sustainable propulsion alternatives such as electrification or hydrogen are not yet technologically competitive, SAFs (Sustainable Aviation Fuels) are the primary candidate for short-term compliance with increasing environmental restrictions over the coming years.

Currently, several types of SAF are available on the market. These include Hydroprocessed Esters and Fatty Acids (HEFA), produced from vegetable oils and animal fats; Alcohol-to-Jet (ATJ), derived from the fermentation of agricultural residues; and Fischer-Tropsch (FT), which is generated from natural gas, biomass, or solid waste. Lastly, the Power-to-Liquid concept, based on combining CO2 and hydrogen, is still in the development phase. Each type of SAF has its own advantages in terms of sustainability and efficiency, offering viable and scalable alternatives for the aviation industry.

	HEFA	Alcohol-to-jet[i]	Gasification/FT	Power-to-liquid
Opportunity description	Safe, proven, and scalable technology	—	Potential in the mid-term, however significant techno-economical uncertainty	Proof of concept 2025+, primarily where cheap high-volume electricity is available
Technology maturity	Mature	—	Commercial pilot	In development
Feedstock	Waste and residue lipids, purposely grown oil energy plants[ii] Transportable and with existing supply chains Potential to cover 5%-10% of total jet fuel demand	—	Agricultural and forestry residues, municipal solid waste[iv], purposely grown cellulosic energy crops[v] High availability of cheap feedstock, but fragmented collection	CO_2 and green electricity Unlimited potential via direct air capture Point source capture as bridging technology
% LCA GHG reduction vs. fossil jet	73%–84%[iii]	—	85%-94%[vi]	99%[vii]

i. Ethanol route; ii. Oilseed bearing trees on low-ILUC degraded land or as rotational oil cover crops; iii. Excluding all edible oil crops; iv. Mainly used for gas./FT; v. As rotational cover crops; vi. Excluding all edible sugars; vii. Up to 100% with a fully decarbonized supply chain

Source: CORSIA; RED II; De Jong et al. 2017; GLOBIUM 2015; ICCT 2017; ICCT 2019; E4tech 2020; Hayward et al. 2014; ENERGINET renewables catalogue; Van Dyk et al., 2019; NRL 2010; Umweltbundesamt 2016

Main SAF production's methods [Clean Skies for Tomorrow][104]

The following outlines the main advancements in SAF (Sustainable Aviation Fuel) that took place in 2023. Undoubtedly, this has been a year of significant relevance, as numerous projects have moved from being future prospects to immediate realities. It is estimated that with the replacement of traditional fuel by SAF, aviation could reduce greenhouse gas emissions by up to 80%, leading to broad international consensus on the comprehensive implementation of SAF.[104]

6.4.1. Agreements and Policies

Regarding sustainable aviation fuels, one of the main concerns lies in achieving the necessary production levels, both in quantities that meet market needs and in regulations that standardize production processes as well as the products obtained. On this topic, in March 2023, ICAO published version 2 of the document 'GUIDANCE ON POTENTIAL POLICIES AND COORDINATED APPROACHES FOR THE DEPLOYMENT OF SUSTAINABLE AVIATION FUELS.' This will serve as a support reference for ICAO member states to promote the production of SAF in a harmonious and competitive manner.[104]

On the other hand, in September 2023, the European Parliament approved the ReFuelEU Aviation initiative, which establishes the progressive implementation of SAF starting in 2025.

[104] *Los combustibles de aviación sostenibles podrían ser la clave para cumplir con el Acuerdo de Paris - Diario Responsable*

This regulation improves the initial requirements proposed by the EU and is part of the 'Fit for 55' package, which paves the way for a greener society with fewer greenhouse gas emissions.[105] The ReFuelEU Aviation regulation will require aviation fuel suppliers to blend increasing amounts of sustainable aviation fuels with kerosene, starting with a minimum of 2% in 2025 and reaching 70% by 2050. This is expected to reduce aviation CO_2 emissions by approximately two-thirds by 2050 compared to a no-action scenario.[106]

As a final agreement of the year, the Third ICAO Conference on Aviation and Alternative Fuels (CAAF/3), held in Dubai in November 2023, resulted in the new 'ICAO Global Framework for Sustainable Aviation Fuels (SAF), Low Carbon Aviation Fuels (LCAF), and Other Cleaner Energies for Aviation.' ICAO Member States have agreed to take measures to achieve a 5% reduction in international aviation CO_2 emissions by 2030 through the use of SAF and LCAF ('Low Carbon Aviation Fuel'). Furthermore, the importance of promoting positive reinforcement and rewards by states, rather than merely imposing sanctions on those who do not comply with restrictions, has been emphasized. This is a significant incentive in light of the potential initial loss of competitiveness that the transition might entail for the states and companies that implement it first.[107]

6.4.2. Private Initiatives

Large companies play a crucial role in the transition to SAF-based aviation. Beyond the collective awareness that society demands regarding environmental respect, businesses must adapt to more sustainable technologies in order to comply with the restrictions and recommendations set by public organizations on behalf of the international community. In this context of balance and negotiations, the 'Air Transport Sustainability Alliance in Spain' (AST) was formed in April 2023, comprising agents from the private, business, and academic sectors. The goal is to create a coalition of various participants in the decarbonization process of the sector, encompassing all possible solutions and technologies to achieve this and enhancing Spain's industrial capacity to offer disruptive technologies, as well as other low-carbon alternatives and circular economy projects. Additionally, the alliance aims to promote public-private collaboration to support R&D and innovation[108]. ALA, AESA, the Polytechnic University of Madrid, and Exolum are some of the members of this new consortium.

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[105] *Europa aprueba el uso del SAF en aviones - Aviación Digital (aviaciondigital.com)*

[106] *Final adoption of ReFuelEU Aviation completes 'Fit for 55' legislation, putting EU on track to exceed 2030 targets - European Commission (europa.eu)*

[107] *IATA - Strengthened Global Framework for Accelerating Aviation's Decarbonization*

[108] *Alianza para la Sostenibilidad del Transporte Aéreo en España (AST) | Estrategia de Movilidad Segura, Sostenible y Conectada 2030 (transportes.gob.es)*

AST creation

The year 2023 is notable for the emergence of significant new investments made by various private companies, particularly producers and airlines[109]. A prominent example is Iberia, which has agreed to procure sustainable fuels from Repsol (which already has refineries prepared to produce SAF) to power its corporate flights. Additionally, the Spanish airline is leading negotiations with various stakeholders to promote the establishment of a SAF plant in the Canary Islands, with the aim of boosting the emerging SAF market in Spain[110]. However, this is just one of several cases of fuel supplier-airline operator alliances; throughout 2023, numerous similar initiatives have started to emerge to address the RefuelEU Aviation initiative's restrictions more competitively, such as the agreements between Wizz Air and Cepsa[111], or between Lufthansa Group and VARO Energy.[112]

Regarding major aircraft manufacturers, Airbus made a significant advance in 2023 by using over 11 million liters of SAF[113] in commercial flights, in collaboration with key airlines such as Air France and Volotea, among others—double the amount used in 2022. This contribution helped the company reduce CO2 emissions by 23,587 tons. Meanwhile, Boeing made its largest SAF purchase to date: 35.6 million liters of SBC fuel (composed of 30% SAF produced from waste in the mix). The American company is expected to increase its activity in negotiations next year to promote the production and use of SAF by creating new synergies and consortia.[114]

[109] *Iberia y Repsol comerciarán con SAF para alimentar viajes corporativos - Aviación Digital (aviaciondigital.com)*
[110] *La aerolínea Iberia trabaja en un proyecto para producir SAF en las Islas Canarias - Hispaviación (hispaviacion.es)*
[111] *Acuerdo entre Cepsa y Wizz Air para promover el combustible sostenible de aviación (fly-news.es)*
[112] *Lufthansa Group y VARO Energy se unen para cooperar en materia de SAF - Hispaviación (hispaviacion.es)*
[113] *Airbus is raising the bar for sustainable aviation fuel | Airbus*
[114] *Boeing Makes its Largest Purchase of Blended Sustainable Aviation Fuel - Apr 16, 2024 (mediaroom.com)*

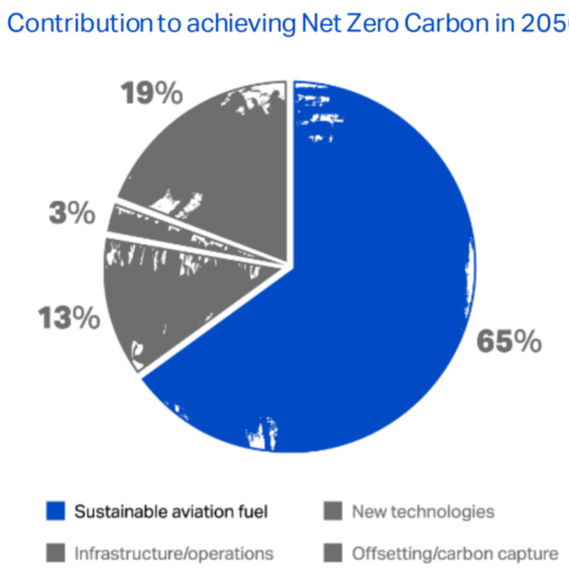
Iberia's A321[115]

6.4.3. Production

Based on a study published by IATA, the following data highlights the progress in SAF production at an international level:

- In 2023, the volume of SAF produced exceeded 600 million liters, doubling the 300 million liters produced in 2022.
- SAF represented 3% of all renewable fuels produced.
- In 2024, SAF production is expected to triple, reaching 1.875 billion liters (1.5 million tons), which will account for 0.53% of aviation fuel needs and 6% of renewable fuel capacity.
- It is estimated that sustainable aviation fuels will contribute 65% to the sector's decarbonization process, compared to other CO2 emission factors.

[115] Iberia Airbus A321



SAF contribution in de-carbonizing

6.4.4. Testing and Operations

Like any new technology, sustainable fuels in the aviation sector require a gradual implementation period to evolve into a commercially viable option. The compatibility of SAF with current aviation engines significantly facilitates this process, as the high quality and safety standards in this sector often pose challenges for the introduction of new concepts.

In 2023, numerous tests began to be conducted, both on test benches and in flights (experimental and commercial), using SAF to power aviation engines. The two most notable testing cases were conducted by Emirates and Airbus, respectively. Emirates carried out a ground test in January involving the two GE-90 engines of a Boeing 777-300ER, running one engine on traditional fuel and the other on SAF, operating them at different flight regimes to compare their performance. In Airbus's case, they conducted a test flight in March with an A321neo, where both engines were powered exclusively by SAF, without any blending.

Boeing 777 testeado por Emirates

Finally, here are some notable flights conducted with SAF-based blends:

- Safran Helicopters flew a single-engine Bell 505 helicopter using 100% SAF.[116]
- Latam Airlines completed its first transatlantic flight using SAF (5% in the blend).[117]

[116] *Un helicóptero Bell 505 se ha convertido en el primer helicóptero monomotor que vuela con un 100% de SAF - Hispaviación (hispaviacion.es)*
[117] *Latam Airlines realiza su primer vuelo internacional con Combustible Sostenible de Aviación (SAF) - Forbes España*

- Emirates conducted the first flight of an Airbus A380 with SAF. The previously tested configuration was employed, where one of the engines used 100% SAF. This demonstration coincided with the Third ICAO Conference on Aviation and Alternative Fuels held in Dubai.[118]

6.5. Electric Aviation

Electric propulsion continues to advance toward technological maturity, which in the medium to long term will enable the competitive operation of electric aircraft. This scenario would imply the standardization of aircraft with no direct emissions to the atmosphere. However, the evident technological limitations, with the most significant being the (still) limited specific energy of electric batteries, make the effective transition to electric aviation a future project. Additionally, the aviation sector is particularly difficult to electrify compared to other sectors like automotive or industrial, as carrying batteries onboard results in a severe penalty regarding flight range due to the increased weight of the vehicle.

It is important to highlight that despite these challenges, the advantages of electrifying aviation are worth the effort. Some of the benefits include:

- Greater energy efficiency of electric motors.
- Reduced mechanical complexity and lower maintenance costs.
- Significant noise reduction.
- The possibility of using sustainable primary energy sources (since electricity itself is an energy vector).
- The potential for thrust redistribution (distributing thrust to a greater number of propellers offers certain advantages, such as the use of smaller propellers and reduced compressibility effects).

Even when the aircraft is not 100% electric but uses electric motors, the mentioned advantages can be fully or partially exploited. This idea has given rise to some developing concepts and projects that do not rely on batteries, such as the H2FLY[119] demonstrator aircraft. The smaller size of these aircraft allows for testing technologies that are still distant from commercial and military aviation at a lower cost and with reduced risk.

6.5.1. Hybrid and Electric Aircraft

Hybrid propulsion, combining fossil fuels with electric propulsion, is an evident intermediate step between traditional aircraft and complete electrification. Similar to SAF, hybrid aircraft designs for short and medium-haul flights are a good option for testing various concepts that progressively reduce the reliance on non-renewable energies for flying. While 2022 saw the implementation of various hybrid aircraft projects that were able to conduct test flights, 2023 has been marked by increased investments in this field, notably with the start of construction of the Aura Aero hybrid aircraft factory. Following an investment of 150 million euros, the French company claims to be prepared to lead the new paradigm of electric aviation when this factory becomes operational in 2026.

[118] *Primer vuelo de Emirates de un Airbus A380 con SAF - Fly News (fly-news.es)*
[119] *https://eshidrogeno.com/avion-pila-hidrogeno/*

Current Infrastructure of Aura Aero

However, significant progress has been made in the field of 100% electric aircraft. Some milestones that have marked a difference in this still-emerging sector are as follows:

- AutoFlight[120] announced that it has achieved the longest eVTOL (Electric Vertical Take-Off and Landing) flight in history, covering a distance of 250 kilometers on a single charge of the aircraft's lithium-ion batteries. The tested model, 'Prosperity I,' is in the development phase to obtain EASA certification by 2025. This prototype can reach a cruising speed of 200 km/h.

eVTOL 'Prosperity I'

- Diamond[121] announced that its electric aircraft eDA-40 successfully completed its first flight. This aircraft is powered by an ENGINeUS™ electric power system, manufactured by Safran Electrical & Power. The company plans to certify this aircraft under Part 23, in accordance with EASA/FAA standards. The performance achieved by this single-seat aircraft includes:
  - A flight range of up to 90 minutes.
  - An operational cost reduction of up to 40% compared to traditional piston single-seaters.
  - A DC fast-charging system capable of completing a charge in under 20 minutes.

[120] *Un eVTOL 100% eléctrico realiza el vuelo más largo de la historia – GENTE Online (revistagente.com)*
[121] *Aviación General: Diamond completó el primer vuelo del avión eléctrico eDA-40 - Aviacionline.com*

Single-Seat Electric eDA-40 Completing Its First Flight

- The 100% electric ALIA eVTOL aircraft, developed by Beta Technologies in collaboration with the U.S. Air Force, completed a journey of over 3,000 km with four intermediate stops.[122]

ALIA eVTOL

- Flight of the 100% electric single-propeller aerobatic aircraft Aero 1 by Dufour, demonstrating a range of 35-45 minutes while cruising at speeds between 160 and 200 km/h.

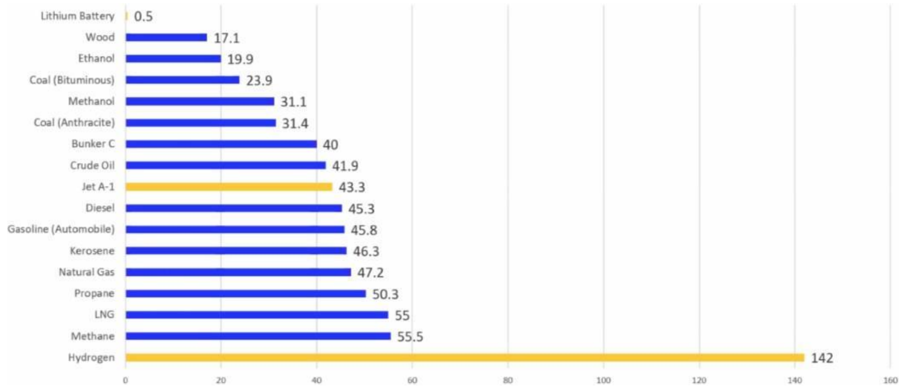
Flight of the Aero1 aerobatic aircraft, characterized by its elliptical wing.

[122] *El avión eléctrico que aterrizó en Florida y promete revolucionar la industria del transporte aéreo - Infobae*

6.6. HYDROGEN

The future of aviation is undoubtedly tied to hydrogen as an energy source. Its high energy density and efficient storage capacity make it an attractive alternative to conventional fossil fuels. Although there are technical and infrastructure challenges to overcome, such as safety in storage and distribution, as well as adapting engines and airport infrastructure, technological advancements and increasing awareness about climate change are driving research and development in this field.

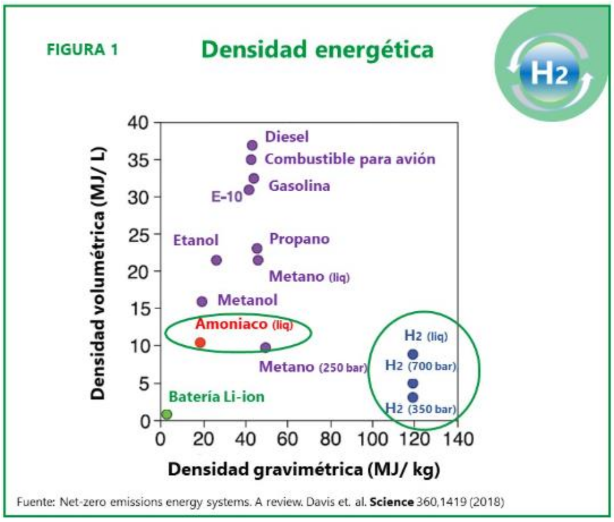
Beyond the evident use of hydrogen as a fuel, which has an energy density almost three times higher than that of kerosene, there are other applications of hydrogen within sustainable aviation. These include the production of SAF through the 'Power-to-Liquid' process (which requires hydrogen combined with CO2 captured from the atmosphere) and powering fuel cells to provide energy to electric motors (offering an alternative to batteries, which limit electric aviation due to their lower energy density).



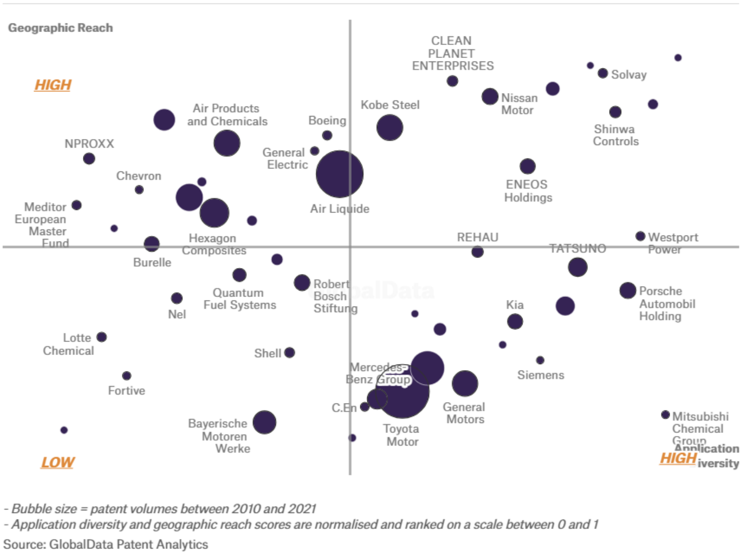
Specific Energy (MJ/kg) of Different Fuels and Batteries [IATA]

However, hydrogen has a number of disadvantages, with its low energy density compared to traditional fuels being the primary one. This leads to challenges in onboard and ground storage, as hydrogen requires tanks with much larger volumes to provide the same amount of energy in flight, significantly limiting the aircraft's ability to carry payload. This can be seen in the figure above, where fossil fuels, although they do not reach the specific energy values of hydrogen, offer a very favorable trade-off between the two variables. Also notable is the improvement in energy density that liquid hydrogen (H2 liq) presents compared to gaseous hydrogen (at both 350 and 700 bars); however, transporting and storing liquid hydrogen poses another technological challenge that affects logistics and maintenance throughout its lifecycle: cryogenics. This problem is already being addressed by numerous companies, both in the aerospace sector and other industries, who are aware of hydrogen's potential as a green energy source.[123] A hydrogen-based aircraft would, in principle, be emission-free (except for condensation trails produced when using H2 as fuel; this would not be the case for hydrogen fuel cells, which would not produce such trails).

[123] *https://www.offshore-technology.com/data-insights/innovators-liquified-hydrogen-storage-oil-and-gas/?cf-view*



Specific Energy (Gravimetric Density) vs. Energy Density (Volumetric Density) of Different Aviation Fuels



Companies that Have Published Patents Related to Liquid Hydrogen Storage from 2020 to 2023

6.6.1. Initiatives and Agreements

Similar to the lobbies created to promote the development, production, and use of SAF, leading companies and institutions in the aerospace sector are now compelled to establish agreements focused on green hydrogen. The geopolitical and market landscape surrounding hydrogen as a fuel is, understandably, at a much earlier stage of development compared to the SAF sector due to technological development gaps. Consequently, there is still a long way to go in testing new concepts, gaining knowledge about hydrogen propulsion systems, and achieving proper certification.

In Spain, the aviation sector made a significant step forward in January 2023 with the creation of the 'Alliance for the Use of Green Hydrogen in Aviation.[124]' Its main objectives are to identify the needs related to the development, production, storage, and distribution of green hydrogen for the aviation industry in the country. Additionally, it aims to promote coordination among various stakeholders in the hydrogen aviation value chain and facilitate information exchange. Planned actions include developing roadmaps and timelines, creating working groups to address production and supply needs and goals, organizing forums and conferences to share knowledge and develop projects, as well as drafting position papers.

[124] *El sector de la aviación se une para descabonizarse con hidrógeno verde (energias-renovables.com)*

The participants involved in this Alliance are as follows:

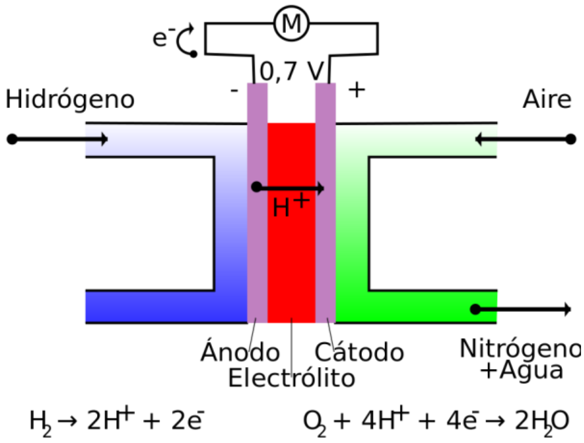
- The Ministry of Transport, Mobility, and Urban Agenda
- The airport operator Aena
- The Spanish Aviation Safety Agency (AESA)
- The Airline Association (ALA)
- The Spanish Association of Defense, Security, Aerospace, and Space Technology Companies (TEDAE)
- The Spanish Association of Petroleum Product Operators (AOP)
- The National Hydrogen Center (CNH2)
- Gasnam-Neutral Transport
- The National Institute for Aerospace Technology (INTA)
- The Spanish Aerospace Technology Platform (PAE)
- The Spanish Hydrogen Technology Platform (PTEH)

Creation of the Alliance for the Use of Green Hydrogen in Aviation

Outside of Spain, the British 'Hydrogen in Aviation' Alliance, driven by several private companies and led by Airbus, is also noteworthy. Its goal is to form a pressure group to accelerate the arrival of zero-emission aviation through hydrogen. Airbus states: "*The aim of the HIA is to assist the Government and policymakers in setting the necessary milestones to ensure that changes in infrastructure, regulations, and policies keep pace with pioneering technological advances in carbon-free flights. This will include establishing the path to expand infrastructure and the necessary political, regulatory, and safety frameworks to make large-scale zero-emission commercial aviation a reality*."

6.6.2. Hydrogen Cells

Hydrogen fuel cells (also known as fuel cells or simply cells) are leading the charge in the initial adoption of hydrogen in aviation by leveraging hydrogen's weight advantages and the total absence of emissions in electric aviation. Several projects, including flight tests, are underway to apply this emerging technology in practice. This well-known technology is based on generating electrical current from the dissociation of hydrogen, which is then used to power an electric motor.



Basic Operation of a Hydrogen Fuel Cell[125]

In January 2023, an important milestone in hydrogen-powered aviation was achieved: the flight of the largest aircraft to date using this concept, powered by hydrogen fuel cells. The aircraft in question was ZeroAvia's[126] Dornier Do228 demonstrator, which completed a ten-minute flight. The plane was equipped with an electric motor powered by a fuel cell in the left wing, while the right wing had a conventional turboprop engine. This 19-seat aircraft is the successor to a smaller prototype that the company had been testing for two years and is considered a precursor to the next milestone: an integrated propulsion system in a 90-seat aircraft. This startup is making significant efforts to reach the development levels necessary to certify its innovative systems in the coming years.

ZeroAvia's Dornier Do228 Powered by Fuel Cells

However, this advancement was overshadowed two months later when Universal Hydrogen conducted a demonstration flight with a converted ATR-72, equipped to operate with fuel cells and capable of carrying 40 passengers. Again, this system was implemented in one of the two propulsion systems, with a conventional turboprop engine retained in the other for safety. The aircraft completed a 15-minute flight, and according to the pilots, they felt very comfortable with the hydrogen-based engine's performance, which responded well to control inputs and exhibited notably lower noise and vibration levels compared to the traditional engine.

[125] *Pila de combustible - Wikipedia, la enciclopedia libre*
[126] *Logra ZeroAvia completar vuelo con tren eléctrico de hidrógeno | Aviación 21 (a21.com.mx)*

Universal Hydrogen's ATR-72 Modified to Fly with Fuel Cells[127]

Universal Hydrogen's direction is attracting investors from North America and Europe interested in introducing aviation hydrogen into their commercial activities. The business model is based on converting traditional aircraft to hydrogen propulsion, which is extremely advantageous for companies operating aircraft already converted and verified by the American firm (currently, ATR-72 and Dash 8 aircraft), as a post-sale modification avoids the need for new fleets and maintains air traffic volume at the same level during the process. By 2025, Universal Hydrogen plans to carry out more than 200 conversions for clients worldwide.

Lastly, to address the aforementioned issue of storing hydrogen in liquid state at very low temperatures, which occupies a much larger volume than fossil fuels, the German company H2FLY has conducted a rigorous ground testing program for its cryogenic tanks throughout 2023. The company already has experience implementing hydrogen-based fuel cells in prototypes that have flown successfully, which is their primary field of application. However, these advancements will also be significant in the race to use hydrogen as a direct fuel in aircraft engines.

H2FLY's HY4 Prototype Powered by Fuel Cells[128][129]

[127] *Primer vuelo de Universal Hydrogen – Avion Revue Internacional*
[128] *H2FLY And Partners Mark A Significant Step Toward Zero-Emission Commercial Flight Following Developments Of Liquid Tank Integration (fuelcellsworks.com)*
[129] *https://www.h2fly.de/*

6.6.3. Direct Hydrogen Combustion

The addition of oxygen gas to hydrogen at high temperatures is the exothermic chemical reaction upon which hydrogen propulsion systems rely[130]. This concept is still pending widespread implementation in other sectors, such as automotive, but has proven effective in very specific fields, such as space shuttle propulsion. In the aerospace sector, advances in hydrogen combustion propulsion are still far from offering a realistic and competitive alternative to society, but each passing year brings a new step towards the inevitable replacement of fossil fuels with sustainable energy sources.

In 2023, for example, the flight of the Blue Condor[131] aircraft stands out: the first Airbus aircraft entirely powered by hydrogen. This marks the beginning of a new phase of flight testing for Airbus's ZEROe project[132], aimed at verifying that all flight systems are functioning correctly and according to estimates. The next step will involve studying the condensation trails generated by this propulsion method, which do not contain soot or sulfur oxides but do produce nitrous oxides and much more water vapor—up to 2.5 times more than kerosene trails. Both are considered climate-impacting emissions, and as such, the aviation industry has a responsibility to address them.

Airbus's Blue Condor Powered by Hydrogen Combustion

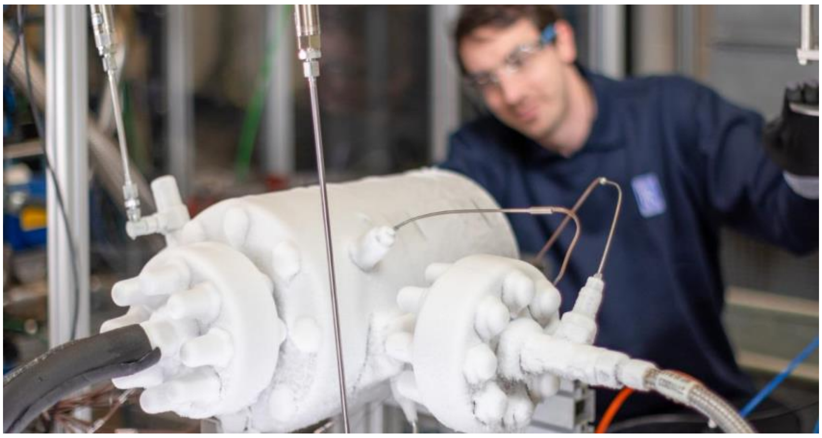
Finally, as the most ambitious project for the medium-to-long term, the milestone achieved by Rolls-Royce in collaboration with easyJet stands out: both companies succeeded in the first operation of a modern aerospace engine using hydrogen, on which they have been conducting tests throughout the year[133]. The first ground test was conducted on an initial concept demonstrator using green hydrogen produced from wind and tidal energy. This represents a significant step toward demonstrating that hydrogen could be a future carbon-free aviation fuel and is a key testing point in the decarbonization strategies of both Rolls-Royce and easyJet, which are firmly committed to meeting the goals of the 2015 Paris Agreement.

[130] *https://www.cummins.com/engines/hydrogen*

[131] *El Blue Condor realiza el primer vuelo de Airbus propulsado íntegramente por hidrógeno - Actualidad Aeroespacial*

[132] *ZEROe - Low carbon aviation - Airbus*

[133] *Rolls-Royce and easyJet set new world first | Rolls-Royce*



Rolls-Royce Hydrogen Engine Assembly Line[134]

6.7. NOISE

In March 2023, the European Commission's report to the European Parliament and Council on the implementation of the Environmental Noise Directive, as per Article 11 of Directive 2002/49/EC[135], indicated that even with the current measures in place, the total number of people chronically disturbed by transport noise is likely to increase by 3% by 2030, compared to 2017, falling short of the original goal of a 30% reduction. However, the report also suggests that a substantial set of measures adopted at local, regional, and national levels, combined with EU-wide actions, could reduce the number of people chronically disturbed by transport noise by 19% by 2030. It also highlighted the need for significant additional efforts to reduce road traffic noise, which remains the largest source of acoustic pollution.

In the EU, the fourth phase of implementing Directive 2002/49/EC involves developing various Strategic Noise Maps (MER).[136]

In the US, the FAA is revising its noise policy[137] and, in March 2023, issued a notice for comments until September 2023[138]. The more than 4,800 comments received are currently under review.

Significantly, the FAA has awarded $19 million to 14 universities nationwide through the Aviation Sustainability Center (ASCENT) to investigate ways to reduce noise and achieve net-zero emissions flights by 2050.[139] Noise-related projects include:

- Reducing noise from new aircraft,
- Examining potential benefits,
- Simulating sonic booms,
- Predicting noise from supersonic aircraft,
- Developing noise models for various types of advanced air mobility vehicles,

[134] *https://www.ainonline.com/news-article/2023-12-21/rolls-royce-and-easyjet-start-hydrogen-fuel-delivery-testing*
[135] *https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52023DC0139*
[136] *https://sicaweb.cedex.es/los-mapas-de-ruido/*
[137] *https://www.faa.gov/sites/faa.gov/files/FAA-2023-0855-0002_attachment_1_0.pdf*
[138] *https://www.faa.gov/noisepolicyreview*
[139] *https://www.faa.gov/newsroom/quiet-skies-universities-research-way-reduce-aviation-noise*

- Evaluating and quantifying correlations between aircraft noise, sleep, cardiovascular health, and mental health.

In Spain, Royal Decree 630/2023 of July 11[140], which modifies the acoustic servitudes, noise map, and action plan for Sevilla Airport, has been approved.

Nationally, within ENAIRE's sustainability strategy mentioned earlier, there is another initiative called Fly Quiet, aimed at improving the acoustic impact on communities near airports. ENAIRE systematically studies the impact of all flight maneuver designs and, in collaboration with Aena, monitors the acoustic levels produced by approach and departure paths, promoting active communication with affected citizens and municipalities.

6.8. DRONES

6.8.1. Agreements and Regulations

The Federal Aviation Administration (FAA) authorized Zipline International to deliver commercial packages around Salt Lake City and Bentonville, Arkansas, using drones that fly beyond the visual line of sight of the operator (BVLOS) with the long-term goal of safely integrating drones into the National Airspace System[141], rather than reserving separate airspace for drones.

Moya Aero and N2 Infrastructures are partnering for more sustainable drone logistics[142]. The agreement includes N2 acquiring four units of the Moya eVTOL drone. Moya Aero, a spin-off of ACS Aviation, the Brazilian aerospace engineering and aircraft development entity, has announced its strategic partnership with N2 Infrastructure Technologies, a Canadian startup working in the air cargo industry as a logistics and transport operator. The agreement consists of supplying four Moya eVTOL drones and also allows the development of logistics operations with high-capacity unmanned aircraft. The Moya eVTOL is a fully electric vertical takeoff and landing drone, designed to carry bulky and heavy cargo up to 200 kg or 160 liters of phytosanitary products at a maximum speed of 150 km/h and a range of 110 km. N2 Infrastructure Technologies' mission is to revolutionize the transportation and logistics system using eVTOL drones to provide emergency medical services (EMS); both groups want to use their synergies to make logistics simpler and more sustainable.

In Scotland, a project is underway to measure CO2 emissions from agricultural operations using drones equipped with Lidar (Light Detection and Ranging) sensors.[143] This project, combined with soil analysis in the laboratory, will estimate carbon reserves in agricultural operations, advancing towards the goal of net-zero production.

The Abu Dhabi National Oil Company (ADNOC), in collaboration with the state-owned defense and advanced technology conglomerate Edge Group, has announced a partnership to employ unmanned aerial vehicles (UAVs) manufactured in the United Arab Emirates (UAE) in its land and marine operations. Edge's autonomous systems branch, known as Adasi, will use its existing UAS to allow the oil company to use them for monitoring and as support in emergency

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[140] *https://www.boe.es/diario_boe/txt.php?id=BOE-A-2023-17767*

[141] *https://a21.com.mx/normatividad/2023/09/20/autoriza-faa-uso-de-drones-para-entrega-de-paquetes*

[142] *https://www.infodron.es/texto-diario/mostrar/4485189/moya-aero-n2-infrastructures-alian-logistica-drones-sostenible*

[143] *https://www.infodron.es/texto-diario/mostrar/4110739/drones-calcular-catidad-carbono-explotaciones-agricokl*

situations. This collaboration will also include a commercial agreement to deploy specialized drones for detecting greenhouse gas leaks.

6.8.2. Technology

In 2023, the inaugural flight of the Kea Atmos MK1[144] took place, a short-duration technological demonstrator with a wingspan of 12.5 meters and weighing less than 40 kilograms. It will fly at approximately 15 kilometers (50,000 feet) for up to 16 hours. The Kea Atmos, designed by Kea Aerospace, is a solar-powered drone intended to operate in the stratosphere carrying payloads for acquiring high-resolution images. The goal is to develop subsequent versions of the Kea Atmos to fly at higher altitudes continuously for months at a time.

A project presented at the Aero India 2023 fair was the SURAJ[145] drone, directed by the National Aerospace Laboratories of India (NAL) and the Defence Research and Development Organisation (DRDO), featuring a propulsion system with two-blade propellers in a tractor configuration, a wingspan of six meters, and two tails with control surfaces. It is capable of reaching an altitude of 3,000 meters and has a flight endurance of 12 hours provided by solar panels located on the upper surface of the wings.

Skydweller Aero[146], a company based in Spain that develops an unmanned aerial vehicle (UAV) using a new fly-by-wire (FBW) control system powered by solar energy for commercial and defense sectors, announced that in February it successfully completed the initial autonomous flight tests of its aircraft using its new fly-by-wire control system, designed to fly autonomously for indefinite periods. This marks the completion of the initial validation of converting a piloted aircraft to a redundant FBW system with no pilot intervention, from takeoff to landing autonomously. This test demonstrates the robustness of these systems to reduce risk in the air and will facilitate the acceleration of Skydweller's commercialization.

Skydweller AeroDrones

7. CONCLUSIONS

The path towards sustainable aviation continues to progress as evidenced by the commitments made in 2023 both within the industry and at governmental and international levels.

[144] https://www.keaaerospace.com/kea-atmos/
[145] https://aviaciondigital.com/suraj-el-dron-capaz-de-volar-con-la-energia-solar/
[146] https://www.infodron.es/texto-diario/mostrar/4167549/skydweller-finaliza-albacete-primeras-pruebas-vuelo-autonomo

Many obstacles and barriers must still be overcome to achieve the goal of net-zero emissions by 2050, compounded unfavorably by projected air traffic growth averaging 4.3% annually over the next 20 years. However, as seen throughout this addendum, numerous and varied actions are being taken across the industry with short, medium, and long-term results.

In the short term, notable programs include the sustainability initiatives of an increasing number of airlines, awareness measures regarding CO2 emissions for travelers, and the existence of sustainability competitions and rankings among airlines.

For medium-term results, significant collaborations between companies are underway to achieve technological advances more rapidly, as well as the continued establishment of agreements and incentives at both national and international government levels to promote and support the achievement of zero-emissions goals. Examples include the publication by ICAO of a guide to encourage SAF production and the new independent emissions trading system apart from the existing EU ETS. Additionally, progress in hybridization, such as the initiation of construction for the Aura Aero hybrid aircraft factory, will influence medium-term outcomes.

Finally, in terms of long-term results, 2023 has seen significant advancements in aircraft electrification, such as AutoFlight's flight covering 250 km on a single battery charge. Moreover, considering hydrogen technology, which is in an earlier development phase than SAF, working groups and collaborations are being established, such as the 'Alliance for the Use of Green Hydrogen in Aviation' in Spain.

In conclusion, many obstacles remain and numerous commitments and efforts are still pending, but undoubtedly, these actions by companies and organizations across various aviation sectors contribute to making the goal of total zero emissions increasingly achievable and feasible.

8. REFERENCES

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