Norway
2025

ICAO State Action Plan

On CO2 emissions reduction activities

Table of contents

List of abbreviations

AAT - Aircraft Assignment Tool

ACARE – Advisory Council for Research and Innovation in Europe

ACA – Airport Carbon Accreditation

ACI – Airports Council International

ADS – Automatic Dependent Surveillance

AIRE – The Atlantic Interoperability Initiative to Reduce Emissions

AOC – Air Operator Certificates

APER TG - Action Plans for Emissions Reduction Task Group of the ECAC/EU Aviation and Environment Working Group (EAEG)

ATCO – Air Traffic Control Officer

ATM – Air Traffic Management

CAA Norway – Civil Aviation Authority Norway

CAEP – Committee on Aviation Environmental Protection

CNG – Carbon neutral growth

CoCiP – Contrail Cirrus Prediction Model

CORSIA - Carbon Offsetting and Reduction Scheme for International Aviation

EAER – European Aviation Environmental Report

EASA – European Aviation Safety Agency

EC – European Commission

ECAC – European Civil Aviation Conference

EEA – European Economic Area

EFTA – European Free Trade Association

EU – European Union

EU ETS – the EU Emissions Trading System

GHG – Greenhouse Gas

HEFA SAF – Sustainable Aviation Fuels made from Hydroprocessed Esters and Fatty Acids

ICAO – International Civil Aviation Organisation

IFR – Instrumental Flight Rules

IPCC – Intergovernmental Panel on Climate Change

IPR – Intellectual Property Right

JU – Joint Undertaking

KPIs – Key Performance Indicators

LTAG - Long-Term Aspirational goal for international aviation

MBM – Market-based Measure

MSW – Municipal Solid Waste

MT – Million tonnes

PRISME - Pan European Repository of Information Supporting the Management of EATM

PSO – Public Service Obligation routes

RED – Renewable Energy Directive

RPK – Revenue Passenger Kilometre

RTK – Revenue Tonne Kilometre

RTD – Research and Technological Development

SAF – Sustainable Aviation Fuels

SBTi – Science Based Targets initiative

SES – Single European Sky

SESAR – Single European Sky ATM Research

SESAR JU – Single European Sky ATM Research Joint Undertaking

SESAR R&D – SESAR Research and Development

SMEs - Small and Medium Enterprises

RNP – Required Navigation Performance

RPK – Revenue Passenger Kilometre

1. Common introductory section for European states action plans

a) The ICAO Contracting State Norway is not a member of the European Union (EU). However, through the Agreement on the European Economic Area (EEA Agreement), Norway is a fully integrated member of the single European aviation market. The EEA Agreement comprises the EU States and the three EFTA States Norway, Iceland and Liechtenstein. Norway is a member of the European Civil Aviation Conference (ECAC). ECAC is an intergovernmental organisation covering the widest grouping of Member States[1] of any European organisation dealing with civil aviation. It is currently composed of 44 Member States and was created in 1955.

b) ECAC States share the view that the environmental impacts of the aviation sector must be mitigated, if aviation is to continue to be successful as an important facilitator of economic growth and prosperity, being an urgent need to achieve the ICAO long-term aspirational goal (LTAG) for international aviation of net-zero carbon emissions by 2050, and to strive for further emissions reductions. Together, they fully support ICAO's on-going efforts to address the full range of those impacts, including the key strategic challenge posed by climate change, for the sustainable development of international air transport.

c) All ECAC States, in application of their commitment in the 2016 Bratislava Declaration, support CORSIA implementation and have notified ICAO of their decision to voluntarily participate in CORSIA from the start of its pilot phase and have effectively engaged in its implementation.

d) Norway, like all of ECAC's 44 States, is fully committed to and involved in the fight against climate change and works towards a resource-efficient, competitive and sustainable multimodal transport system.

e) Norway recognises the value of each State preparing and submitting to ICAO an updated State Action Plan for CO2 emissions reductions as an important step towards the achievement of the global collective goals agreed since the 38th Session of the ICAO Assembly in 2013 and the monitoring of the long-term aspirational goal agreed at Assembly 41.

f) In that context, it is the intention that all ECAC States submit to ICAO an action plan. This is the action plan of Norway.

g) Norway strongly supports the ICAO basket of measures as the key means to achieve ICAO's LTAG target and shares the view of all ECAC States that a comprehensive approach to reducing aviation CO2 emissions is necessary, and that this should include:

   i. emission reductions at source, including European support to CAEP work in this matter (standard setting process);

[1] Albania, Armenia, Austria, Azerbaijan, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Monaco, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, and the United Kingdom.

ii. research and development on emission reductions technologies, including public-private partnerships;

iii. development and deployment of sustainable aviation fuels, including research and operational initiatives undertaken jointly with stakeholders to meet the ICAO aspirational vision of reducing CO_2 emissions by 5% by 2030 through increased use of SAF worldwide;

iv. improvement and optimisation of Air Traffic Management and infrastructure use within Europe, in particular through the Single European Sky ATM Research (SESAR), and also beyond European borders through participation in international cooperation initiatives; and

v. Market Based Measures, which allow the sector to continue to grow in a sustainable and efficient manner, recognizing that the measures at (i) to (iv) above cannot, even in aggregate, deliver in time the emissions reductions necessary to meet the ICAO long term aspirational goal of net-zero carbon emissions by 2050.

h) In Europe, many of the actions which are undertaken within the framework of this comprehensive approach are in practice taken collectively, including many led by the European Union. They are reported in Section 1 of this Action Plan, where the involvement of Norway is described, as well as that of other stakeholders.

i) In Norway a number of actions are undertaken at the national level, including those by stakeholders. These national actions are reported in Section 2 of this Plan.

j) In relation to European actions, it is important to note that:

- The extent of participation will vary from one State to another, reflecting the priorities and circumstances of each State (economic situation, size of its aviation market, historical and institutional context, such as EU/non-EU). The ECAC States are thus involved in different degrees and on different timelines in the delivery of these common actions. When an additional State joins a collective action, including at a later stage, this broadens the effect of the measure, thus increasing the European contribution to meeting the global goals.

- Acting together, the ECAC States have undertaken measures to reduce the region's emissions through a comprehensive approach. Some of the measures, although implemented by some, but not all of ECAC's 44 States, nonetheless yield emission reduction benefits across the whole of the region (for example research, SAF promotion or ETS).

2. Current state of aviation in Norway

2.1 General characteristics of Norway and its aviation sector

Norway is situated in the north of Europe. It has a mainland area of 323 804 sq. km. Approximately 44% of the area consists of mountains and mountain plateaus, 38% of forest, 7% of freshwater/glaciers, and approximately 3,5% is cultivated land. Harsh climatic conditions, poor soil quality and difficult terrain means that a large part of the country is unsuitable for settlement or agriculture. The longest distance from north to south is 1752 km. Norway has 5,55 million inhabitants. The country has a population density of 18 inhabitants pr. sq. km. and has one of the lowest populations densities in Europe. However, almost 83% of the population live in urban areas.

Norway has a network of public roads totalling 95.052 km. The railway consists of a total of 4247 km railroads. Norway has one of the world's longest coastlines with its 104 600 km (including mainland and all islands), with over 3000 ports and wharf facilities.

A comprehensive outline of the Government's transport policy is presented in the current National Transport Plan for the period 2025 – 2036. In the plan the Government has adopted the following overarching goal and five main objectives for the transport policy:

Overarching goal: An efficient, environmentally friendly and safe transport system nationwide in 2050

Five main objectives:

- Easier daily travel and increased competitiveness for businesses
- Contribute to the fulfilment of Norway's climate and environmental goals
- Vision zero – no one killed or seriously injured
- Efficient use of new technologies
- More value for money

This overarching goal and objectives are also applicable to the aviation sector. The Government's National Aviation Strategy's intention, a separate white paper published in 2023, is to ensure that the aviation industry aligns with the nation's broader goals for sustainability, efficiency, and accessibility. The strategy emphasizes environmental sustainability by promoting the use of sustainable aviation fuels (SAF) and low- and zero-emissions technologies.

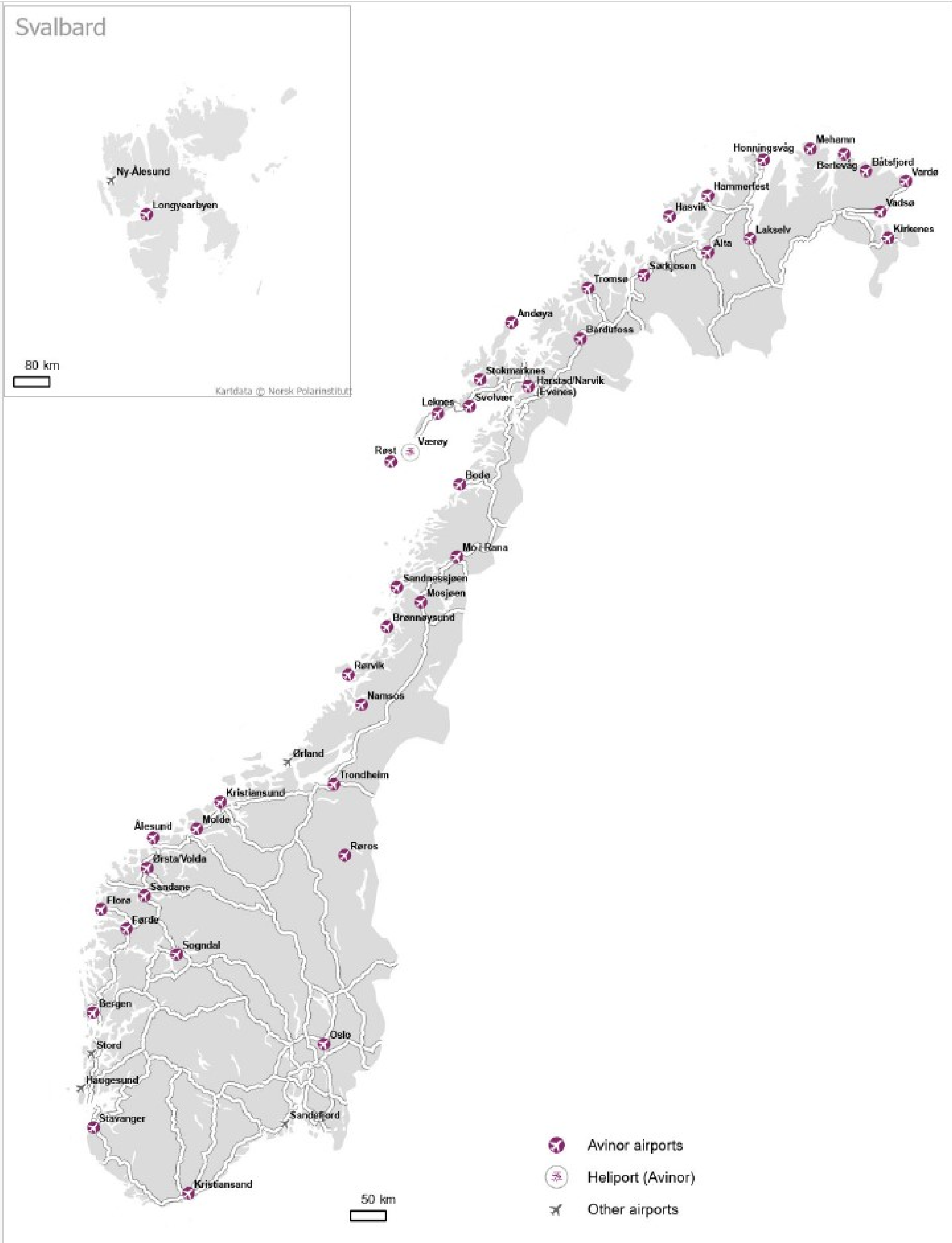
2.2 Airport structure and airlines operating in Norway

There are in total 47 airports with civil scheduled air traffic in Norway. Avinor operates 43 of the airports. Of all Avinor's airports, 42 are organized in the same legal unit. Svalbard Airport is organized as a wholly owned subsidiary. Avinor is responsible for operations and development at 41 airports that it owns, including Værøy heliport. In addition, Avinor has operational responsibility for Andøya airport, which is owned by the Norwegian Armed Forces, and is responsible for the operation and development of the civilian part at Bardufoss Airport, which is also owned by the Norwegian Armed Forces.

Avinor also owns Haugesund Airport, which is leased to external operators, and Fagernes Airport, where operations have been shut down and parts of the areas are now planned to be used for solar parks.

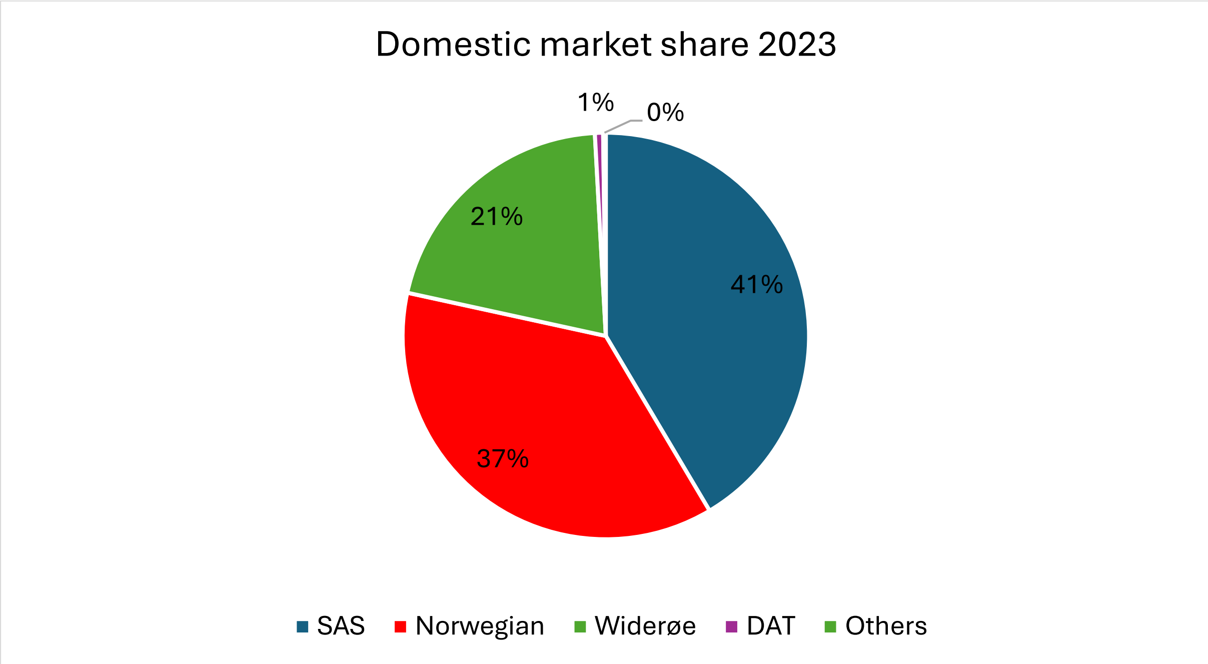
There are furthermore two airports with commercial traffic operated by local municipalities: Sandefjord Torp and Stord. Ørland airport is owned and operated by the armed forces. Route traffic to and from Ørland is financed by the armed forces.

All Avinor's airports had scheduled domestic flights in 2023. 14 of Avinor's airports also had international flights (charter and/or scheduled routes). The airports in Stavanger, Bergen, Florø, Kristiansund, Brønnøysund and Hammerfest are permanent bases for the transport of passengers and goods between the mainland and installations for offshore petroleum activities.



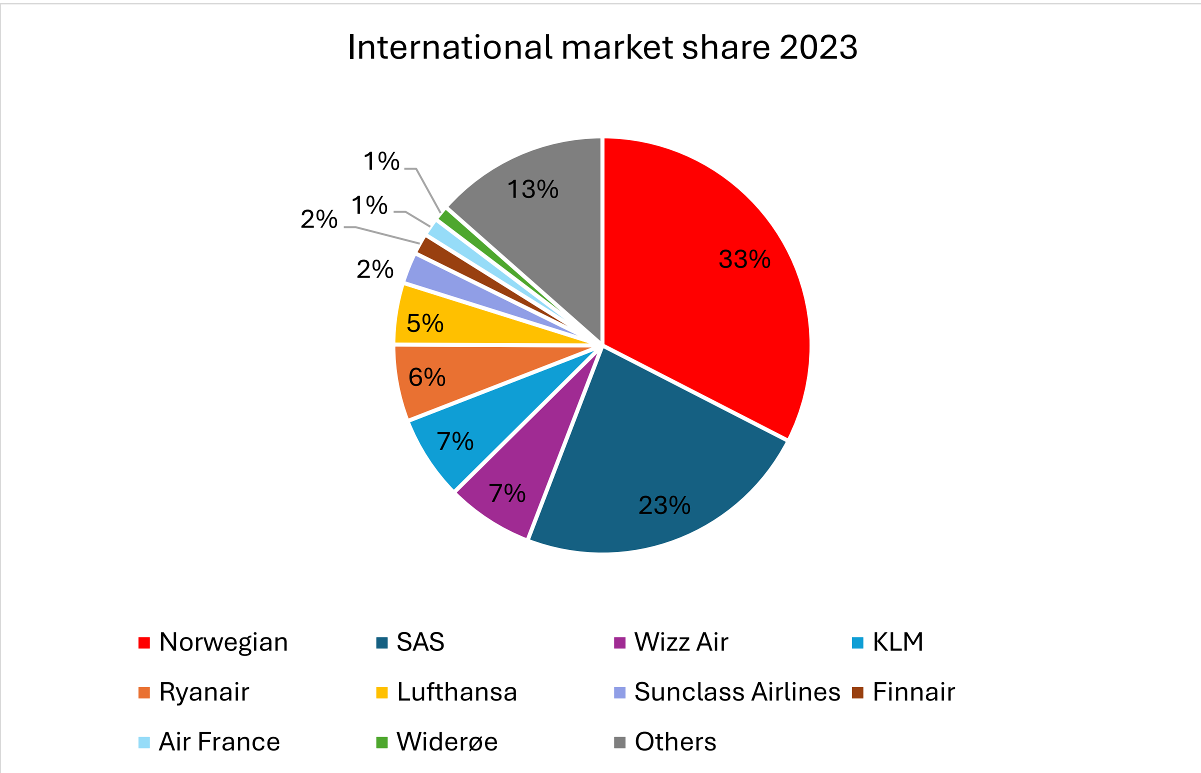
Airports with scheduled passenger traffic. Source: Avinor

The figures below illustrate the airline market shares in 2023 for domestic and international traffic. There are three dominating airlines operating on the domestic network. SAS, Norwegian and Widerøe had a market share of more than 99% in 2023. In addition, DAT and Lufttransport operated some domestic flights.



Airlines operating in Norway and market share 2023 – domestic. Source: Avinor

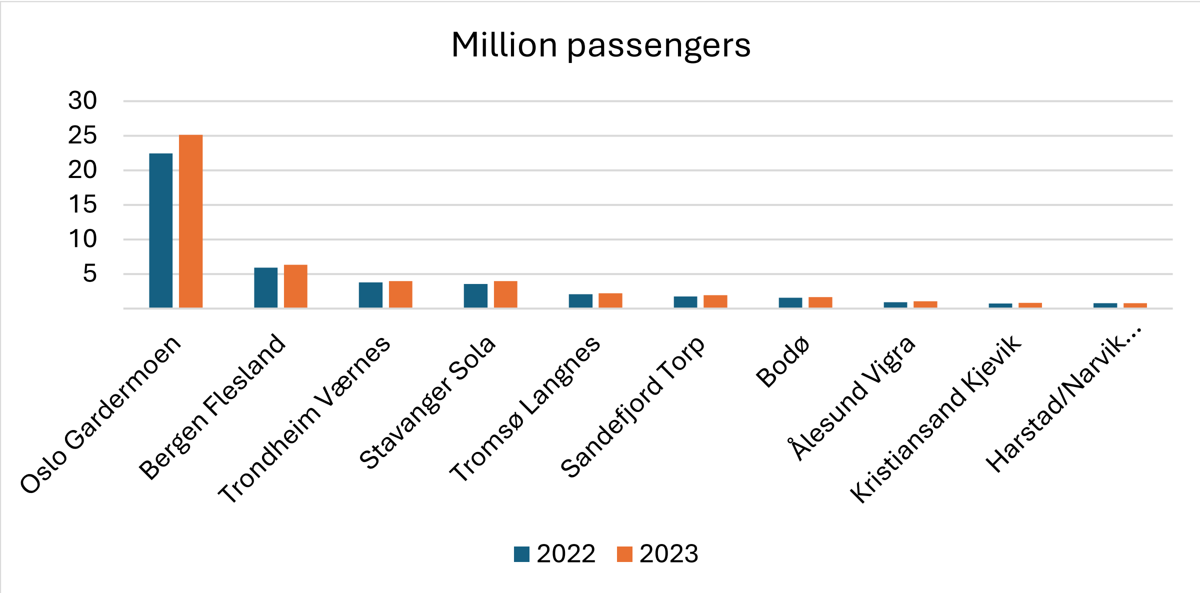
Norwegian and SAS had a combined market share of 56% of the international traffic to/from Norway. With KLM and Wizz Air as the third largest airlines with a market share of 7 % each.



Airlines operating in Norway and market share 2023 – international. Source: Avinor

2.3 Top 10 airport passengers

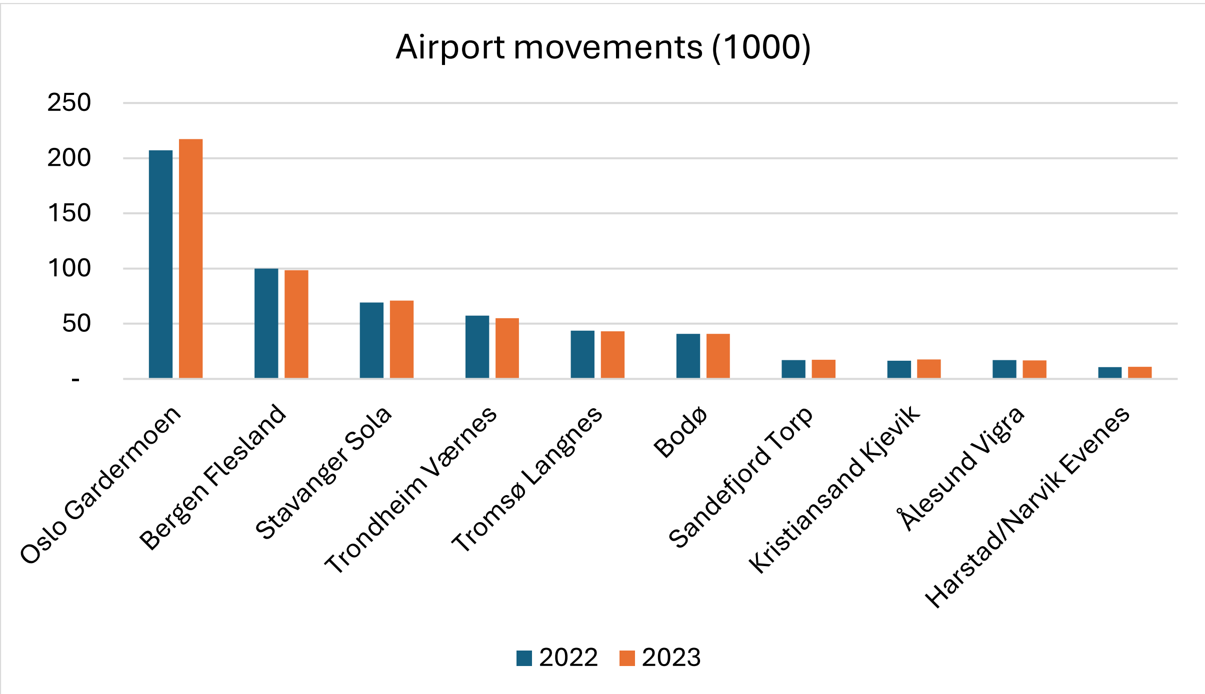
In 2023 51.6 million passengers travelled to and from Norwegian airports. Oslo is by far the biggest airport, and in 2023 25.1 million passengers travelled via this national hub. Bergen, Trondheim and Stavanger are the biggest amongst the other airports with commercial traffic.



Million passengers at top 10 Norwegian airports 2022 and 2023. Source: Avinor

2.4 Top 10 airport movements

In 2023 there were 750 000 aircraft movements at Norwegian airports, and 217 400 of these were at Oslo Airport. Three other airports, Bergen, Stavanger and Trondheim, had more than 50 000 movements each.



Aircraft movements (1000) at the 10 biggest airports in Norway 2022 and 2023. Source: Avinor

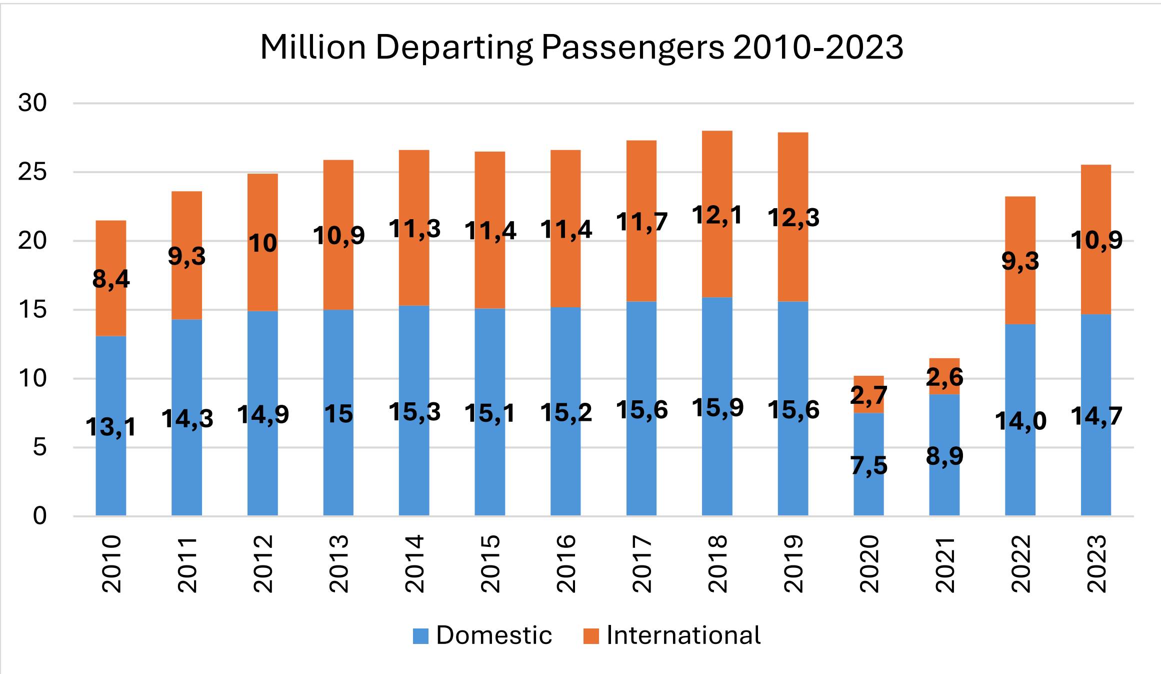
2.5 Air Navigation Services

Avinor Air Navigation Services is organized as a wholly owned subsidiary of Avinor and is the main operator of air navigations services for civil and military customers in Norway. As a result of exposure for limited competition, Avinor has chosen a foreign provider to operate tower services at two airports in Norway – at Kjevik in Kristiansand and Vigra in Ålesund. The Spanish company Saerco has operated the two units since March 2020.

2.6 Passengers total from all Norwegian airports

The number of departing passengers from Norwegian airports increased from 21.5 million in 2010 to 27.9 million in 2019 but dropped by 63% to 10.2 million passengers in 2020 due to COVID-19. International traffic was down 78% from 12,3 million to 2,7 million.

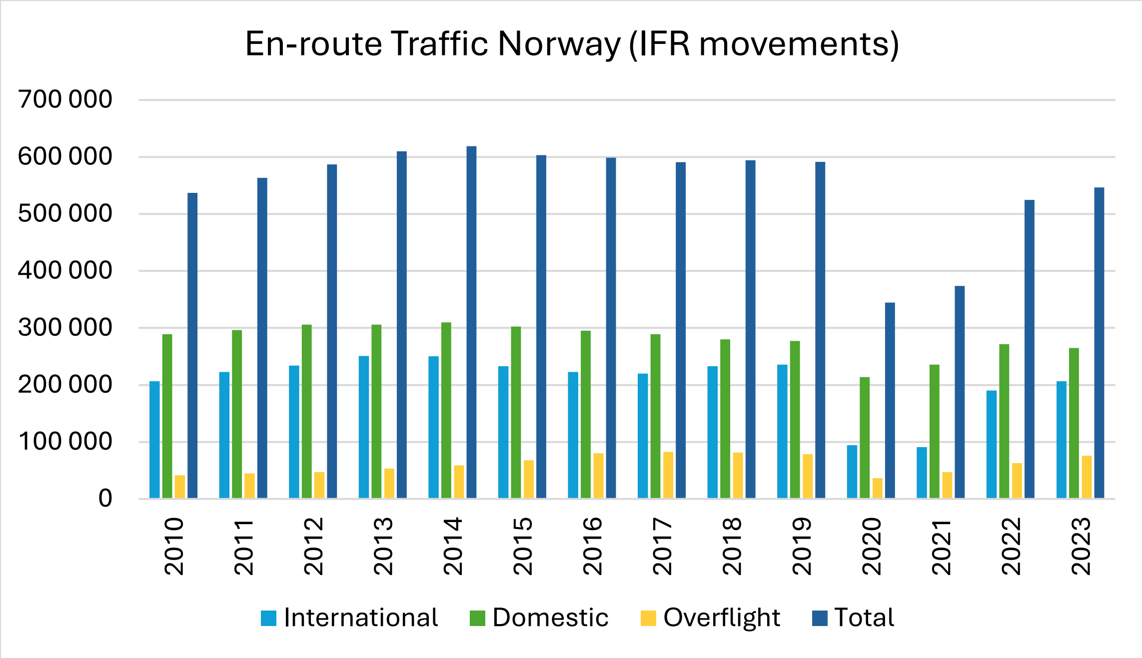
Domestic passenger traffic had recovered to 94% of pre-pandemic traffic in 2023, while the international traffic recovery was 88% of 2019 traffic.



Million departing passengers domestic and international from Norwegian airports 2010-2023. Source: Avinor

2.7 Movements total in Norwegian airspace

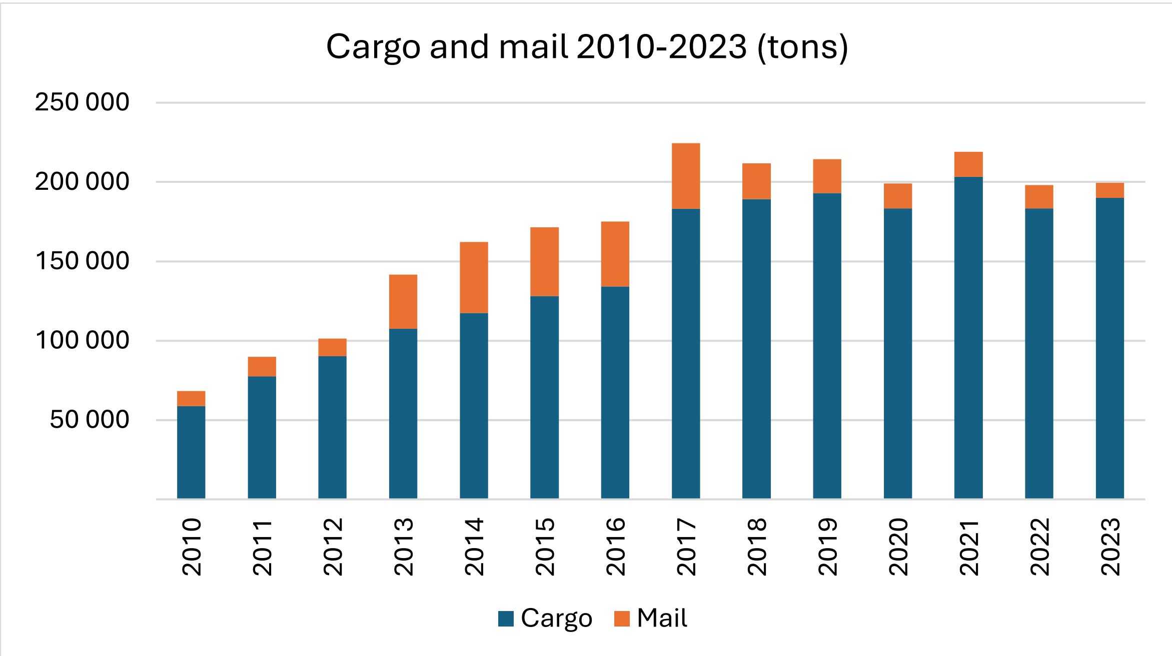
In 2023 about 547 000 instrument flight rule (IFR) movements (206,000 international, 265 000 domestic, and 76 000 overflights) were recorded in Norwegian airspace. The number of IFR movements was 8 % below 2019 traffic.



Development in number of movements in Norwegian airspace 2010-2023. Source: EurocontrolL/STATFOR

2.8 Cargo and mail

Cargo has grown significantly during the last decade, mainly driven by seafood exports. The growth from 2010 to 2019 was 233 %. In 2023 a total of 199,000 tons of cargo and mail was flown to/from Norwegian airports, 85% of which was to/from Oslo. Cargo and mail held up well during the pandemic, contrary to the passenger numbers, but has levelled out in 2022 and 2023 due to slower economic growth and international tensions.



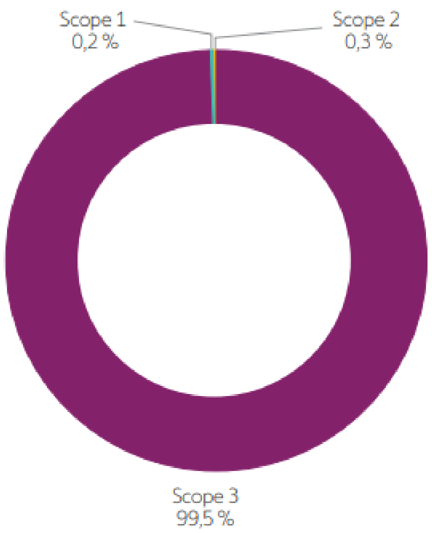
Cargo and mail flown to and from Norwegian airports 2010-2023 (tons). Source: Avinor

2.9 Air operators and aircraft

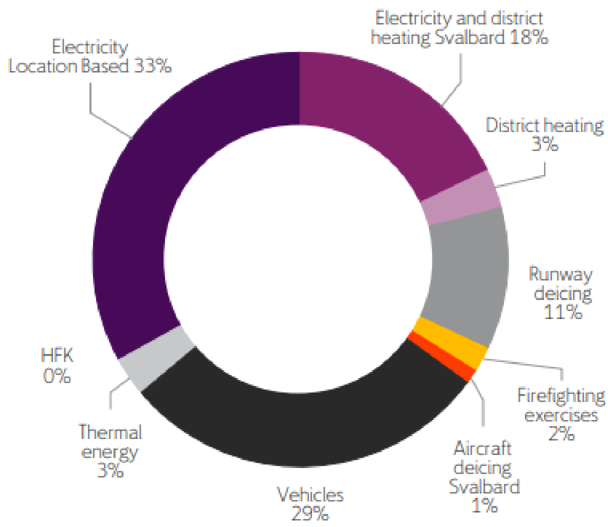
There are 21 Air Operator Certificates (AOCs) granted by the Norwegian Civil Aviation Authority (CAA Norway) as of May 2024. There are 736 motor-powered airplanes and 249 helicopters on Norwegian civil aircraft register as of May 2024.

2.10 Greenhouse gas emissions from airport operations

Avinor has disclosed Greenhouse gas emissions from airport operations in the company's annual report since 2007. In-line with the expectations of Avinor's owner and stakeholders, Avinor is working to set science-based climate targets, i.e. goals that are in-line with what climate science says are necessary to achieve the goals of the Paris Agreement. Based on the Norwegian State Ownership Report, which expects state-owned companies to set science-based targets, Avinor sent a commitment letter to the Science Based Targets initiative (SBTi) in June 2023. The Greenhouse Gas Accounting for 2022 was established as the base year, and based on previous and ongoing climate measures, a plan was made to reduce greenhouse gas emissions towards 2030. Subsequently, climate targets were set, both short-term (2030) and long-term (2050). In May 2024, Avinor submitted an application to SBTi for validation of the short-term and long-term climate targets. The climate targets were validated by SBTi in August and September 2024, and in October it was confirmed that they are in line with the requirements set by SBTi. The targets are set according to SBTi's 'The Corporate Net-Zero Standard'



Avinor's greenhouse gas emissions, scope 1, 2, and 3



Avinor's greenhouse gas emissions, scope 1 and 2. Emission sources in scope 2 are indicated with various shades of purple.

Avinor greenhouse gas emissions 2023. Source: Avinor

Scope 1 is Avinor's direct emissions. Over the years, data quality on various scope 1 sources has improved, as airports report via Avinor's environmental database. Furthermore, a central audit of reported figures is carried out twice a year. In 2023, Avinor's scope 1 emissions were around 5700 tonnes of CO2 equivalents. This is a reduction from approximately 6200 tonnes CO2 equivalents in 2022. The main reason for the reduction is increased use of advanced biodiesel (53 % blend in

2023 versus 43 % blend in 2022), as well as blending biodiesel in fossil diesel via the Norwegian blending mandate for non-road machinery.

Scope 2 specifies indirect emissions resulting from the company's energy supply and includes purchased electricity and district heating. Emissions from purchased electricity consumption are specified using location-based and market-based methods, and the emission factors are obtained from The Norwegian Water Resources and Energy Directorate (NVE) annually. However, there is a delay in the factors, and for the 2023 accounts, we had to use the same emissions factor as for 2022. The energy monitoring system established in Avinor provides a good overview of how much energy is used at each airport. Scope 2 emissions in 2023 were approximately 6890 tonnes of CO2 equivalents. This is about the same level as in 2022 (6830 tonnes). Total energy consumption has increased somewhat in 2023, while the emission factor for district heating and electricity in Svalbard has decreased somewhat due to the transition from coal power to diesel generators from 19 October 2023 in Longyearbyen. Avinor has not purchased electricity with a Guarantee of Origin in recent years.

Scope 3 specifies other indirect emissions that occur upstream and downstream in the company's value chain. Emissions have been identified and quantified in 9 of the 15 categories in scope 3 that are relevant to Avinor. For 2022, 99,5% of Avinor's emissions were in scope 3, and only 0,5 % of emissions in scope 1 and 2 combined. The numbers are distributed similarly in 2023. Greenhouse gas emissions from aviation fuel uplifted at Avinor's airports by our partners is the reason why scope 3 emissions are so high. Scope 3 emissions are approximately 2.5 million tonnes CO2 equivalents.

Airport Carbon Accreditation (ACA) is an industry scheme administered by Airport Council International (ACI) Europe in which airport operators can accredit. Airports participating in the scheme must set binding targets for reducing greenhouse gas emissions, prepare detailed climate accounts and adopt action plans. In Avinor, Oslo, Trondheim and Kristiansand Airports have been accredited under the scheme since its inception in 2009. Bergen and Stavanger airports have participated since 2014.

2.11 Greenhouse gas emissions from Norwegian civil aviation

According to the latest official figures from Statistic Norway, greenhouse gas emissions from all domestic civil aviation in Norway in 2022 corresponded to 2,4% of total national emissions (1,2 of a total of 48,9 million tonnes of CO2 equivalents).

The emission data below in 1000 metric tons of CO2 are reported annually by the Norwegian Environment Agency to the United Nations Framework Convention on Climate Change (UNFCCC):

Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021
Domestic									
CO2	1099	1202	1155	1089	1114	1152	1117	781	808
International									
CO2	1596	1678	1623	1587	1669	1748	1743	555	513

CO2 emissions of flights from Norwegian airports. Because of changes of reporting systems to UNFCC the most recent data is for 2021. Source: Norwegian Environment Agency

There are also non-CO2 emissions from aviation, such as nitrogen oxides (NOx), soot particles and water vapor. These emissions also have significant climate effects. It is important to include non-CO2 effects in the assessment of aviation's total climate impact to get a more comprehensive picture.

2.12 Benefits of aviation in Norway

Text and numbers in this subchapter are provided by Avinor.

Norway is a country with long distances between communities and a challenging topography. It is crucial that the population and businesses throughout the country have good accessibility to airports, with an adequate route service at an affordable price. In Norway, an extensive network of large, medium-sized, and local airports has been established, operated, and developed by the state-owned company Avinor AS. In addition, the state contributes with the procurement of air services on routes that cannot be operated with a satisfactory service on commercial terms (so-called Public Service Obligation (PSO) routes).

Aviation is crucial for ensuring that the population throughout the country has access to health services, education and other public services, efficient work travel, private travel, opportunities for the development of the tourism industry, and the transport of mail and time-critical goods. Aviation is a significant industry that contributes to value creation in Norway. Aviation is also valuable to society because of the accessibility it provides. The Avinor network of airports ensures good regional accessibility throughout the country. Over 90 % of the population have access to an airport within 90 minutes driving time.

Oslo Airport is Norway's main airport and the most important hub in the Norwegian airport network. It is also the most important source of revenue in the co-financing model of Avinor's airports. The development of Oslo Airport is therefore important for the airports and air routes throughout Norway. The route services from Oslo Airport contribute to increased international accessibility, both for passengers and for air freight, including seafood.

2.13 Norway – an arena for testing and development of zero- and low-emission aircraft

In April 2024 Avinor and CAA Norway entered a cooperation agreement on establishing Norway as an international arena for testing and demonstration of zero- and low-emission aircraft. The purpose of the agreement is to facilitate accelerated phase-in by reducing barriers to testing and demonstration of zero and low emission aircraft. Avinor provides infrastructure, airspace, and access to energy, while CAA Norway offers regulatory facilitation – including establishing a comprehensive Regulatory Sandbox.

The extensive network of airports in Norway and close and good cooperation between Avinor as airport operator and responsible for the airspace, and the Civil Aviation Authority as regulator and authority means that Norway is in a unique position to facilitate testing and demonstration of new technology at an early stage. The test arena will, in principle, cover the entire country. Specific geographical locations for the establishment of test facilities will be decided in dialogue with market participants, based on their needs, as well as assessments of technological maturity.

Interested manufacturers, producers, and operators must be able to submit an operating concept and respond to predefined qualification criteria.

By facilitating for the operation of zero- and low-emission aircraft in a tailored eco-system, Norway is taking a systemic approach to enable faster and more efficient innovation processes. Maintaining a level playing field, developing new knowledge and building competency are key factors for the initiative. International Test Arena Norway can contribute to bringing adequate solutions to the Norwegian market at an earlier stage, and it will be an important step towards zero emission and low-emission aviation globally. There is currently no equivalent test arena in an operational environment in the world. Hence, a test arena will be an instrument for achieving the goal of fossil-free Norwegian aviation by 2050.

3. Section 1 – ECAC/EU Common section for European State Action Plans

3.1 Executive summary

The European Section of this action plan, which is common to all European State Action Plans, presents a summary of the actions taken collectively in the 44 States of the European Civil Aviation Conference (ECAC) to reduce CO_2 emissions from the aviation system.

Aviation is a fundamental sector of the European economy, and a very important means of connectivity, business development and leisure for European citizens and visitors. For over a century, Europe has led the development of new technologies, and innovations to better meet society's needs and concerns, including addressing the sectorial emissions affecting the climate.

Since 2019, the COVID-19 pandemic has generated a world-wide human tragedy, a global economic crisis and an unprecedented disruption of air traffic, significantly changing European aviation's growth and patterns and heavily impacting the aviation industry. The European air transport recovery can nevertheless be an opportunity to accelerate its contribution to the achievement of the global climate ambitions.

In 2023, the number of flights in Europe reached 92% of the 2019 (pre-COVID) levels, owing to the continuous recovery since the outbreak and the strengthening volumes during summer. Ukraine's airspace has remained closed since February 2022, with neighbouring airspace absorbing more traffic (and diverted flights overloading the busy South-East axis). The start of the conflict in the Middle East (October 2023) has affected various flows that were unable to overfly the zone. Geopolitical crises have also had an impact on flows in the South Caucasus, especially overflights. At the moment of drafting this plan, the level of uncertainty of how these crises will impact international air traffic in the long-term is still high, so the assessments made might be revised in the next update, as more accurate data of such impacts are expected to be available. EUROCONTROL is publishing regular comprehensive assessments of the latest traffic situation in Europe, and such best-available data have been used for the preparation of the European common section of this action plan.

The common section includes an updated description and assessment of the collective European efforts taken to mitigate the climate impacts of aviation, as well as the description of future measures driving to additional CO_2 savings.

Aircraft related technology

European members have worked together to best support the progress in the ICAO Committee on Aviation Environmental Protection (CAEP). This contribution of resources, analytical capability and leadership has undoubtedly facilitated leaps in global certification standards that have helped drive the markets demand for technology improvements. Europe is now fully committed to the implementation of the 2016 ICAO CO_2 standard for newly built aircraft and on the need to review it on a regular basis in light of developments in aeroplane fuel efficiency.

Environmental improvements across the ECAC States are knowledge-led and at the forefront of this is the Clean Sky EU Joint Technology Initiative (JTI) that aims to develop and mature breakthrough “clean technologies”. The second joint undertaking (Clean Sky 2 – 2014-2024) had the objective to reduce aircraft emissions and noise by 20 to 30% with respect to the latest technologies entering into service in 2014. The European Partnership for Clean Aviation (EPCA) will follow in the footsteps of Clean Sky2.

This activity recognises and exploits the interaction between environmental, social and competitiveness aspects with sustainable economic growth. Funding and its motivation

are critical to research and the public private partnership model of the EU Research and Innovation programme underpins much that will contribute to this and future CO_2 action plans across the ECAC region.

The main efforts under Clean Sky 2 include demonstrating technologies: for both large and regional passenger aircraft, improved performance and versatility of new rotorcraft concepts, innovative airframe structures and materials, radical engine architectures, systems and controls, and consideration of how we manage aircraft at the end of their useful life. This represents a rich stream of ideas and concepts that, with continued support, will mature and contribute to achieving the goals on limiting global climate change.

Sustainable Aviation Fuels (SAF)

ECAC States are embracing the introduction of SAF in line with the 2050 ICAO Vision and are taking collective actions to address the many current barriers for SAF widespread availability or use in European airports. It has been proven fit for purpose and the distribution system has demonstrated its capacity to handle SAF. At European Union level, the ReFuelEU Aviation Regulation, which applies since 1 January 2024 will boost the supply and demand for SAF in the EU, while maintaining a level playing field in the air transport market. ReFuelEU Aviation aims to put air transport on the trajectory of the EU’s climate targets for 2030 and 2050, as SAF are one of the key short- and medium-term tools for decarbonising aviation.

The common European section of this action plan also provides an overview of the current sustainability and life cycle emissions requirements applicable to SAF in the European Union’s States as well as estimates of life cycle values for several technological pathways and feedstock. Collective work has also been developed through EASA on addressing barriers of SAF penetration into the market. The European Research and Innovation programme is also giving impulse to innovative technologies to overcome such barriers as it is highlighted by the number of recent European research projects put in place and planned to start in the short-term.

Improved Air Traffic Management

The Single European Sky (SES) policy of the European Union is designed to overhaul Air Traffic Management (ATM) across Europe. This initiative is geared towards digitising services, enhancing capacity, cutting ATM costs, and boosting safety, alongside reducing the environmental impact by 9.3% by 2040. The SES framework includes multiple elements, such as the development and implementation of cutting-edge technical and operational ATM solutions.

The SESAR programme, divided into three phases—SESAR 1 (2008-2016), SESAR 2020 (starting in 2016), and the ongoing SESAR 3 (2021-2031)—is central to advancing these solutions. By the end of the SESAR 3 Wave 2, the solutions developed and validated are expected to yield fuel savings per flight within the ECAC area between 3.6% (180.9 kg, at V3 maturity level only) to 4.6% (227.8 kg, with full and partial V3 maturity benefits considered), translating directly into comparable CO_2 reductions.

Market Based Measures (MBM)

Recognising the need for a global, market-based measure for aviation emissions (to incentivise and reward good investment and operational choices), ECAC Member States have been strong supporters of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Pursuant to their 2016 Bratislava Declaration, ECAC member States have voluntarily participated in the scheme since its pilot phase in 2021 and have encouraged other States to follow suit.

To implement CORSIA while preserving the environmental integrity of EU law, the EU ETS Directive was amended in 2023. It extended the restriction of the EU ETS geographical scope to flights between States of the European Economic Area (EEA)[2] and departing flights to the United Kingdom and Switzerland until the end of 2026. EEA States apply the EU Emissions Trading System (EU ETS), while both Switzerland and the United Kingdom implement their own emissions trading systems.

Overall, 500 aircraft operators are regulated under these cap-and-trade market-based measures aimed at limiting CO_2 emissions. In the period 2013 to 2020, the EU ETS has saved an estimated 200 million tonnes of intra-European aviation CO_2 emissions.

ECAC Scenarios for Traffic and CO_2 Emissions

Despite the current extraordinary global decay on passengers' traffic due to the COVID-19 pandemic, hitting the European economy, tourism and the sector itself, aviation is expected to continue to grow in the long-term, develop and diversify in many ways across the ECAC States. Air cargo traffic has not been impacted as the rest of the traffic and thus, whilst the focus of available data relates to passenger traffic, similar pre-COVID forecasted outcomes might be anticipated for cargo traffic both as belly hold freight or in dedicated freighters. Analysis by EUROCONTROL and EASA have identified the most likely scenario of influences on future traffic and modelled these assumptions out to future years. Based on this traffic forecast, fuel consumption and CO_2 emissions of aviation have been estimated for both a theoretical baseline scenario (without any mitigation action) and a scenario with implemented mitigation measures that are presented in this action plan.

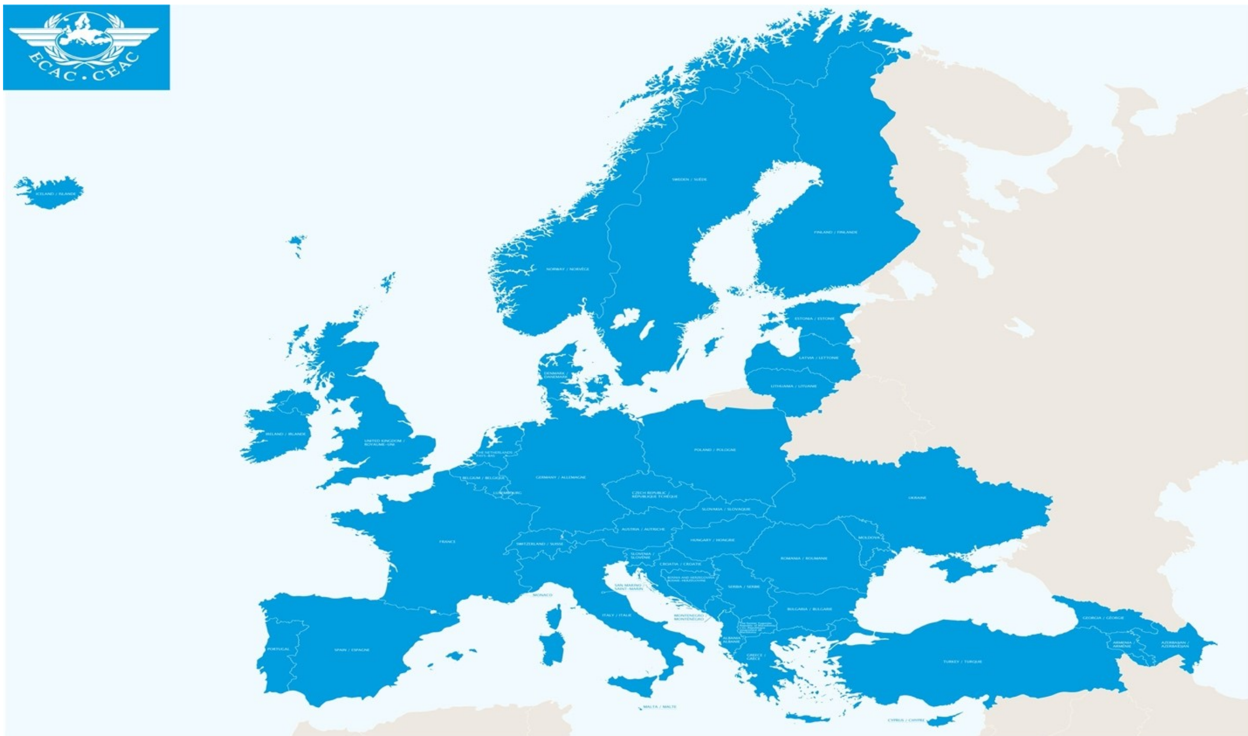
Under the baseline assumptions of traffic growth and fleet rollover with 2023 technology, CO_2 emissions would significantly grow in the long-term for flights departing ECAC airports without mitigation measures. Modelling the impact of improved aircraft technology for the scenario with implemented measures indicates an overall 21% reduction of fuel consumption and CO_2 emissions in 2050 compared to the baseline. Whilst the data to model the benefits of ATM improvements may be less robust, they are nevertheless valuable contributions to reduce emissions further. Overall CO_2 emissions, including the effects of new aircraft types and ATM-

[2] Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

related measures, are projected to improve to lead to a 29% reduction in 2050 compared to the baseline.

The potential of market-based measures and their effects have been simulated in detail in the common section of this action plan (Chapter 4), but they will help reach the goal of carbon-neutral growth. As further developments in policy and technology are made, further analysis will improve the modelling of future emissions.

A: ECAC Baseline Scenario and estimated benefits of implemented measures



1. ECAC Baseline Scenario

The baseline scenario is intended to serve as a reference scenario for CO_2 emissions of European aviation in the absence of any of the mitigation actions described later in this_document. The following sets of data (2010, 2019, 2023) and forecasts (for 2030, 2040 and 2050) were provided by EUROCONTROL for this purpose:

- European air traffic (includes all commercial and international flights departing from ECAC airports, in number of flights, revenue passenger kilometres (RPK) and revenue tonne-kilometres (RTK));
- its associated aggregated fuel consumption; and
- its associated CO_2 emissions.

The sets of forecasts correspond to projected traffic volumes in a 'Base' scenario, corresponding to the most-likely scenario, while corresponding fuel consumption and CO_2 emissions assume the technology level of the year 2023 (i.e. without considering reductions of emissions by further aircraft related technology improvements, improved ATM and operations, sustainable aviation fuels or market-based measures).

Traffic Scenario 'Base'

As in all forecasts produced by EUROCONTROL, various scenarios are built with a specific storyline and a mix of characteristics. The aim is to improve the understanding of factors that will influence future traffic growth and the risks that lie ahead. The latest EUROCONTROL Aviation Long-Term Outlook to 2050[3] has been published in 2024 and inspects traffic development in terms of Instrument Flight Rule (IFR) movements to 2050.

In the latter, the scenario called 'Base' is constructed as the 'most likely' scenario for traffic, most closely following the current trends. It considers a moderate economic growth with regulation reflecting environmental, social and economic concerns to address aviation sustainability. This scenario follows both the current trends, and what are seen as the most likely trends into the future.

Amongst the models applied by EUROCONTROL for the forecast the passenger traffic sub-model is the most developed and is structured around five main groups of factors that are taken into account:

- **Global economy** factors represent the key economic developments driving the demand for air transport.
- Factors characterizing the **passengers** and their travel preferences change patterns in travel demand and travel destinations.
- **Price of tickets** set by the airlines to cover their operating costs influences passengers' travel decisions and their choice of transport.
- More hub-and-spoke or point-to-point **networks** may alter the number of connections and flights needed to travel from origin to destination.
- **Market structure** considers a detailed analysis of the fleet forecast and innovative projects, hence the future size of aircraft used to satisfy the passenger demand (modelled via the Aircraft Assignment Tool).

Table 1 below presents a summary of the social, economic and air traffic related characteristics of three different scenarios developed by EUROCONTROL. The year 2023 served as the baseline year of the 30-year forecast results[4] (published in 2024 by EUROCONTROL). Historical data for the year 2010 and 2019 are also shown later for reference.

[3] EUROCONTROL Long-Term Aviation Outlook to 2050, EUROCONTROL, December 2024. (link to the report https://www.eurocontrol.int/publication/eurocontrol-forecast-2024-2050)

[4] EUROCONTROL Long-Term Aviation Outlook to 2050, EUROCONTROL, December 2024. (link to the report https://www.eurocontrol.int/publication/eurocontrol-forecast-2024-2050)

Table 1. Summary characteristics of EUROCONTROL scenarios

	High	***Base***	*Low*
7-year flight forecast 2024-2030	High ↗	Base →	Low ↘
Passenger			
Demographics (Population)	Aging UN Medium-fertility variant	Aging UN Medium-fertility variant	Aging UN Zero-migration variant
Routes and Destinations	Long-haul ↗	No Change →	Long-haul ↘
High-Speed&Night trains (new & improved connections)	32 HST/29 NT city-pairs faster implementation	31 HST/29 NT city-pairs	26 HST city-pairs later implementation.
Economic conditions			
GDP growth	Stronger ↗	Moderate →	Weaker ↘↘
EU Enlargement	+7 States, Later	+7 States, Earliest	+7 States, Latest
Free Trade	Global, faster	Limited, later	None
Price of travel			
Operating cost	Decreasing ↘↘	Decreasing ↘	No change →
Price of CO_2 in Emission Trading Scheme	Moderate, increasing ↗	Moderate, increasing ↗	Moderate, Increasing ↗
Price of oil/barrel	Moderate	Moderate	High
Price of SAF	Relatively High ↗	Relatively High ↗	Highest ↗↗
Structure			
Network	Hubs: Mid-East ↗↗ Europe ↘ Türkiye ↗ Point-to-point: N-Atlantic. ↘	Hubs: Mid-East ↗↗ Europe & Türkiye ↗ Point-to-point: N-Atlantic ↗, European Secondary Airports. ↗	No change →
Market Structure	Industry fleet forecast, Clean Aviation and STATFOR assumptions	Industry fleet forecast, Clean Aviation and STATFOR assumptions	Industry fleet forecast, Clean Aviation and STATFOR assumptions
Fuel mix	In line with ReFuelEU Aviation (2%SAF in 2025 to 70% in 2050)	In line with ReFuelEU Aviation (2% SAF in 2025 to 70% in 2050)	5 years behind ReFuelEU Aviation (0.5%SAF in 2025 to 42% in 2050)

Update of the EUROCONTROL Aviation Long-Term Outlook to 2050

In November 2023, EUROCONTROL started to work on an update of its EUROCONTROL Aviation Long-Term Outlook to 2050 (EAO). It is an update of the previously published EAO[5] (April 2022), covering the long-term flights and CO_2 emissions forecast to 2050, which was based on 2019 historical flight data. The 2024 edition of the EAO forecast is now based on the latest available actual flight data (2023) and uses the EUROCONTROL seven-year forecast (2024-2030). It includes a complete review of the fleet forecast assumptions as well as a review of other inputs: high-speed rail network development, impact of Sustainable Aviation Fuels (SAF) mandate, jet fuel and CO_2 allowances on ticket prices, as well as future airport capacity constraints.

EUROCONTROL also provides an update of its modelling framework and traffic environmental assessment with the IMPACT model including:

- an updated technological freeze baseline operations forecast using only growth and replacement in-production aircraft in the baseline year (traffic and fleet baseline scenario) from 2023 to 2050;
- an updated baseline passenger data (Eurostat). Additional data sources may be required to cover the ECAC region;
- Latest versions of the Aircraft Noise and Performance (ANP) database, BADA, ICAO Aircraft Engine Emissions Database (AEEDB), - versions of March 2024;
- Updated assumptions on future technologies, operational efficiency, SAF (e.g. based on the CAEP/13 Environmental Trends complemented with information on emerging technologies).

Figure 1 below shows the ECAC scenario of the passenger flight forecasted international departures for both historical (solid line) and future (dashed line) years.

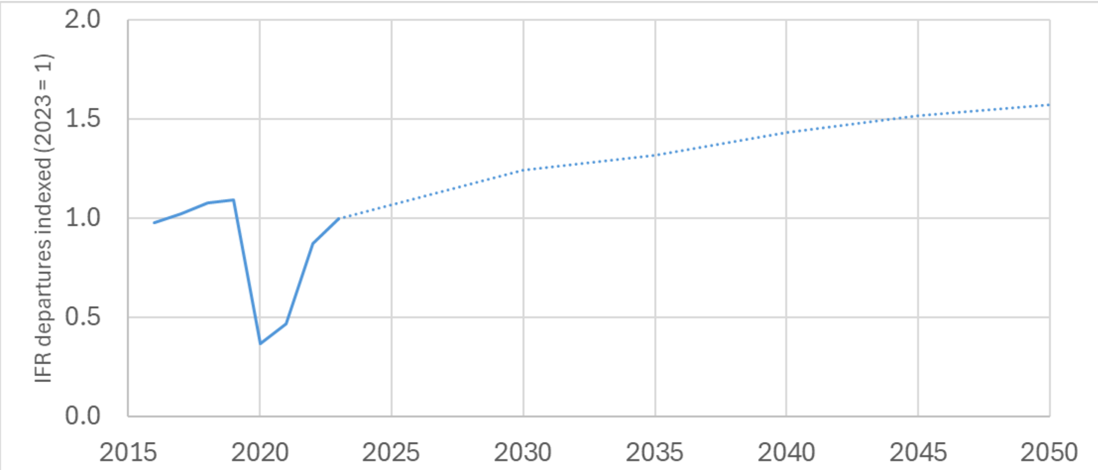


Figure 1. Updated EUROCONTROL 'Base' scenario of the passenger flight forecast for ECAC international departures from 2024 to 2050.

[5] EUROCONTROL Aviation Outlook to 2050, EUROCONTROL, April 2022.

Further assumptions and results for the baseline scenario

The ECAC baseline scenario was generated by EUROCONTROL for all ECAC States. It covers all commercial international passenger flights departing[6] from ECAC airports, as forecasted in the aforementioned traffic 'Base' scenario. The number of passengers per flight is derived from Eurostat data.

EUROCONTROL also generates a forecast for all-cargo flights in its baseline scenario. However, no information about the freight tonnes carried is available. Hence, historical and forecasted cargo traffic have been extracted from another source (ICAO[7]). This data, which is presented below, includes both belly cargo transported on passenger flights and freight transported on dedicated all-cargo flights.

Historical fuel burn and emission calculations are based on the actual flight plans from the PRISME[8] data warehouse used by EUROCONTROL, including the actual flight distance and the cruise altitude by airport pair. These calculations were made with a subset of total passenger traffic (with available and usable information in the flight plans) covering 98% in 2010, and 99% in 2019 and 2030. Determination of the fuel burn and CO_2 emissions for historical years is built up as the aggregation of fuel burn and emissions for each aircraft of the associated traffic sample characteristics. Fuel burn and CO_2 emission results consider each aircraft's fuel burn in its ground and airborne phases of flight and are obtained by use of the EUROCONTROL IMPACT environmental model, with the aircraft technology level of each year.

Forecast years (until 2050) fuel burn and modelling calculations use the 2023 flight plan characteristics as much as possible, to replicate actual flown distances and cruise levels, by airport pairs and aircraft types. When not possible, this modelling approach uses past years traffics too, and, if needed, the ICAO CAEP forecast modelling. The forecast fuel burn and CO_2 emissions of the baseline scenario for forecast years use the technology level of 2023. The usable forecast passenger traffic for calculation represents 99.7% of the total available passenger traffic.

For each reported year, the revenue per passenger kilometre (RPK) calculations use the number of passengers carried for each airport pair multiplied by the great circle distance between the associated airports and expressed in kilometres. Because of the coverage of the available passenger estimation datasets (Scheduled, Low-cost, Non-Scheduled flights, available passenger information, etc.) these results are determined for 96% of the historical passenger traffic in 2010, 97% in 2019, 99% in 2023, and around 99% of the passenger flight forecasts.

From the RPK values, the passenger flights RTK can be calculated as the number of tonnes carried by kilometres, assuming that one passenger corresponds to 0.1 tonne. The fuel efficiency represents the amount of fuel burn divided by the RPK for each available airport pair with passenger data, for the passenger traffic only. Therefore, the fuel efficiency can only be calculated for city pairs for which the fuel burn and the RPK values exists[9]. The following tables and figures show the results for this baseline scenario, which is intended to serve as a reference

[6] International departures only. Domestic flights are excluded. A domestic is any flight between two airports in the State, regardless of the operator or which airspaces they enter en-route. Airports located in overseas are attached the State having the sovereignty of the territory. For example, France domestic include flights to Guadeloupe, Martinique, etc.

[7] ICAO Long-Term Traffic Forecasts, Cargo, Europe, International (excluding Russian Federation, Belarus and Greenland), 2021.

[8] PRISME is the name of the EUROCONTROL data warehouse hosting the flight plans, fleet and airframe data.

[9] Dividing the Fuel by the RPK results of the tables presented in this document is not suitable to estimate the fuel efficiency (traffic coverage differences). The presented result has been calculated on an airport pair basis.

case by approximating fuel consumption and CO_2 emissions of European aviation in the absence of mitigation actions.

Table 2. Baseline forecast for international traffic departing from ECAC airports

Year	Passenger Traffic (IFR movement) (million)	Revenue Passenger Kilometres[10] RPK (billion)	All-Cargo Traffic (IFR movements) (million)	Freight Tonne Kilometres transported[11] FTKT (billion)	Total Revenue Tonne Kilometres[12] RTK (billion)
2010	4.71	1,140	0.198	41.6	155.6
2019	5.88	1,874	0.223	46.9	234.3
2023	5.38	1,793	0.234	49.2	228.5
2030	6.69	2,176	0.262	55.9	273.5
2040	7.69	2,588	0.306	69.0	327.8
2050	8.46	2,928	0.367	86.7	379.5

Table 3. Fuel burn and CO_2 emissions forecast for the baseline scenario

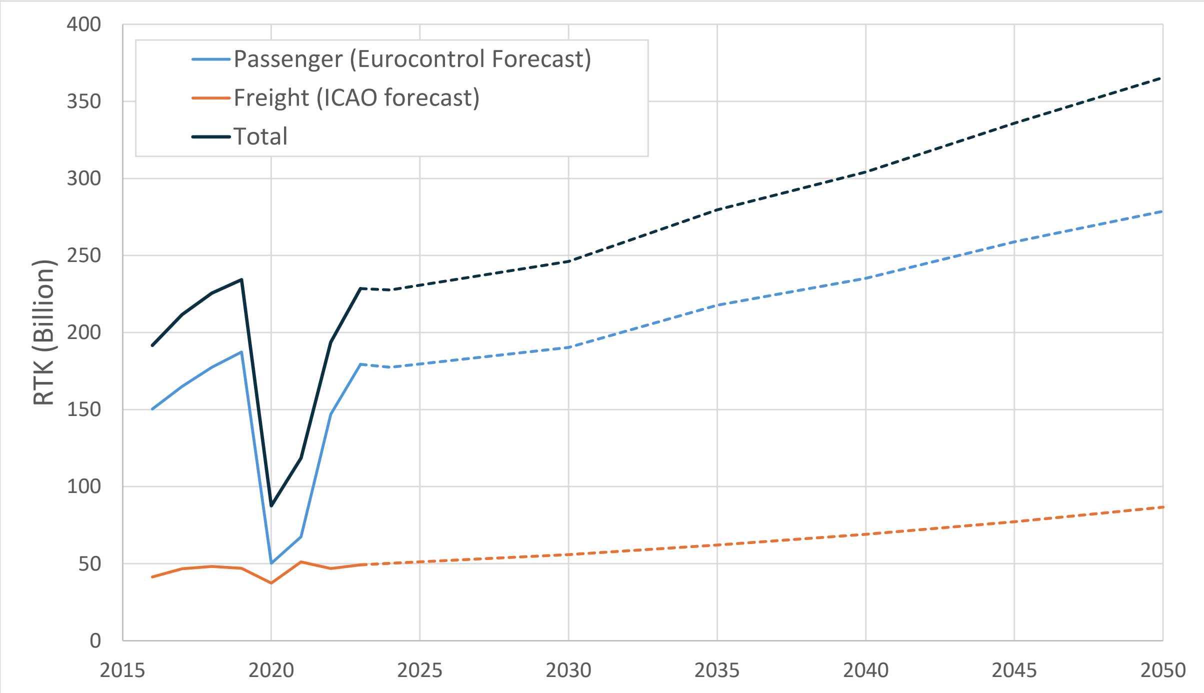
Year	Fuel Consumption (10^9kg)	CO_2 emissions (10^9kg)	Fuel efficiency (kg/RPK)	Fuel efficiency (kg/RTK)
2010	38.08	120.34	0.0327	0.327
2019	53.30	168.42	0.0280	0.280
2023	48.41	152.96	0.0268	0.268
2030	54.46	172.10	0.0250	0.250
2040	62.19	196.52	0.0240	0.240
2050	69.79	220.54	0.0238	0.238
For reasons of data availability, results shown in this table do not include cargo/freight traffic.				

[10] Calculated on the basis of Great Circle Distance (GCD) between the airports of the available passenger reports (subset of the global traffic; from 97% in 2010 up to 99% for the forecast years).

[11] Includes passenger and freight transport (on all-cargo and passenger flights).

[12] A value of 100 kg has been used as the average mass of a passenger incl. baggage (ref: ICAO).

Figure 2. Forecasted traffic until 2050 (assumed both for the baseline and implemented measures scenarios)



Although data are not shown in **Table 2**, the number of flights between 2019 and 2023 in **Figure 2** is reflecting the impact of the COVID-19 starting in 2020. If the passenger segment has been drastically affected by the outbreak, the freight segment seemed more immune.

As detailed by the **Table 3**, from 2010 to 2019, the CO_2 emissions increased from 120 to 168 million tonnes, corresponding to an annual growth rate of 3.8%. In 2023, due to the impact of the COVID-19 crisis on the traffic, the CO_2 emissions were lower than the 2019 level, with 153 million tonnes. For the forecast years, the estimated CO_2 emissions of the ECAC Baseline scenario would increase from 172 million tonnes in 2030 to 220 million tonnes in 2050 (corresponding to annual growth rate of 1.25%).

The fuel efficiency improvement is expected to be less important in the forecast years (annual growth rate of 0.4% between 2023 and 2050) than between 2010 and 2023 (1.5% per year), mainly due to the entry into service of the new generation aircraft families (e.g. MAXs, NEOs).

2. ECAC Scenario with Implemented Measures: Estimated Benefits

To improve fuel efficiency and to reduce future air traffic emissions beyond the projections in the baseline scenario, ECAC States have taken further action. Assumptions for a top-down assessment of the effects of mitigation actions are presented here, based on modelling results by EUROCONTROL and EASA. Measures to reduce aviation's fuel consumption and emissions will be described in the following chapters.

For reasons of simplicity, the scenario with implemented measures is based on the same traffic volumes as the baseline case, i.e. updated EUROCONTROL's 'Base' scenario described earlier. Unlike in the baseline scenario, the effects of aircraft-related technology development and improvements in ATM/operations as well as SAF are considered here for a projection of fuel consumption and CO_2 emissions up to the year 2050.

Effects of **improved aircraft technology** are captured by simulating fleet roll-over and considering the fuel efficiency improvements of the expected future aircraft types with conventional engines (e.g. Boeing 777X, reengineered Airbus A321Neo, etc..) and powered by hybrid electric and hydrogen engines. The simulated future fleet of aircraft has been generated using the Aircraft Assignment Tool[13] (AAT) developed collaboratively by EUROCONTROL, EASA and the European Commission. The retirement process of AAT is performed year by year, allowing the determination of the number of new aircraft required each year.

This technical improvement is modelled by a constant annual improvement of fuel efficiency of 1.16% per annum is assumed for each aircraft type, with entry into service from 2024 onwards. This rate of improvement corresponds to the 'Advanced' fuel technology scenario used by CAEP to generate the fuel trends for the Assembly. This modelling methodology is applied to the years 2030 to 2050. In addition, the entry into service of hybrid electric and hydrogen aircraft types in the traffic induce a percentage of baseline fuel consumption reduction ramping up from 0% in 2035 to 5% in 2050.

The effects of improved **ATM efficiency** are captured in the Implemented Measures Scenario based on the European ATM Master Plan, managed by SESAR 3. This document defines a common vision and roadmap for ATM stakeholders to modernise and harmonise European ATM systems, including an aspirational goal to reduce average CO_2 emission per flight by 5-10% (0.8-1.6 tonnes) by 2035 through enhanced cooperation. Improvements in ATM system efficiency beyond 2023 were assumed to bring reductions in full-flight CO_2 emissions gradually ramping up to 5% in 2035 and 10% in 2050. These reductions are applied on top of those coming from aircraft/engine technology improvements.

The yet un-estimated benefits of Exploratory Research projects[14] are expected to increase the overall future fuel savings.

While the effects of **introduction of SAF** were modelled in previous updates on the basis of the European ACARE goals[15], the expected SAF supply objectives for 2020 were not met. In the current update, the SAF benefits are modelled as a European regional common measure applied to the EU27+EFTA international traffic. It assumes that the minimum shares of SAF laid down in ReFuelEU Aviation Regulation would be met in the base scenario. According to the Regulation, the percentage of SAF used in air transport gradually ramps from 2% in 2025, up to 20% in 2035 and 70% in 2050. A decarbonation factor value of 70% of CO_2 emissions is expected for synthetic aviation fuels and 65% for aviation biofuels. As the SAF-related calculations can only be applied for countries that are expected to implement regional regulations (e.g. ReFuelEU Aviation), **the tank-to-wake Net CO_2 emissions are reported in the Appendix A of this document for EU27+EFTA international traffic only**.

However, numerous initiatives related to SAF (e.g. ReFuelEU Aviation) are largely described in **Section B Chapter 2** and it is expected that future updates will include an assessment of its benefits as a collective measure.

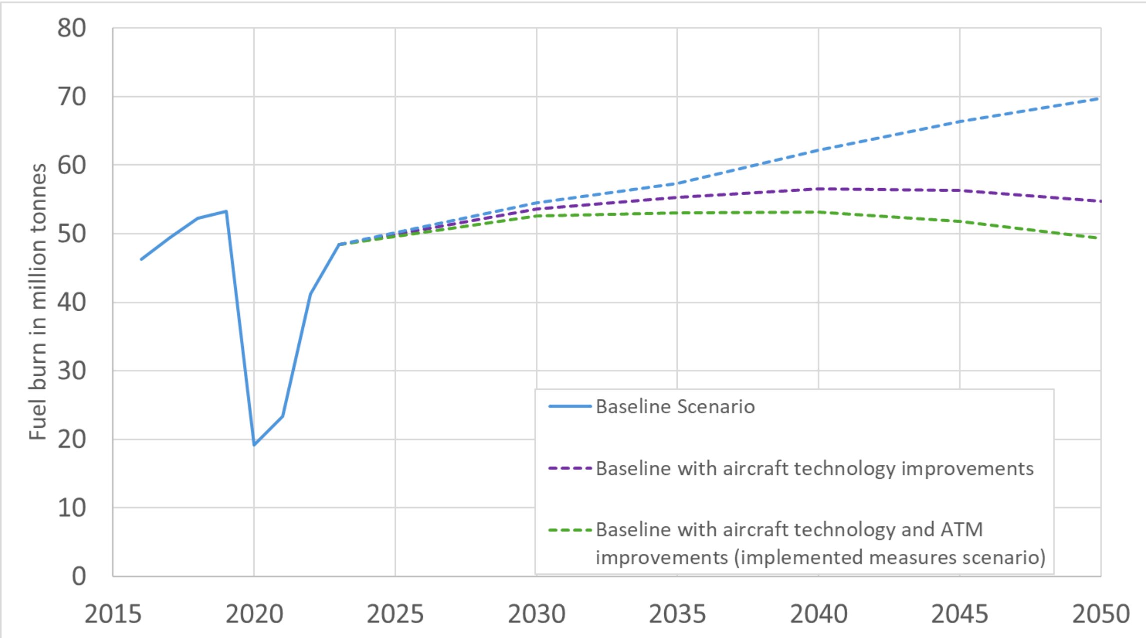
[13] https://www.easa.europa.eu/domains/environment/impact-assessment-tools
[14] See SESAR Exploratory Research projects - https://www.sesarju.eu/exploratoryresearch.
[15] https://www.acare4europe.org/sria/flightpath-2050-goals/protecting-environment-and-energy-supply-0

Effects on aviation's CO_2 emissions of **market-based measures** including the EU Emissions Trading System (ETS) with the linked Swiss ETS, the UK ETS and the ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) have not been modelled explicitly in the top-down assessment of the implemented measures scenario presented here. CORSIA aims for carbon-neutral growth (CNG) of aviation, and this target is therefore shown in **Figure 4**[16].

The EU ETS quantifications are described in more details in Section B Chapter 4.

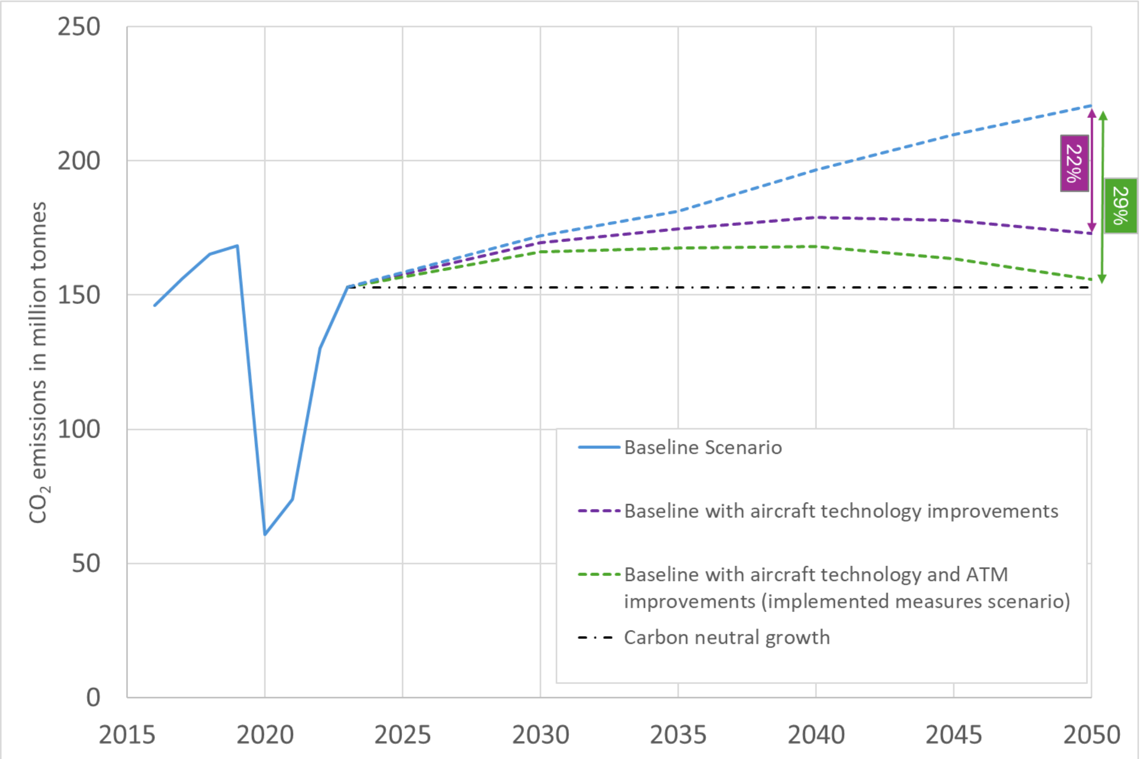
Tables 4-6, **Figure 3** and **Figure 4** summarize the results for the scenario with implemented measures. It should be noted that **Table 4** and **Table 6** show direct combustion emissions of CO_2 (assuming 3.16 kg CO_2 per kg fuel). More detailed tabulated results are found in **Appendix A**, including results expressed in equivalent CO_2 emissions on a well-to-wake basis (for comparison purposes of SAF benefits).

Figure 3. Fuel consumption forecast for the baseline and implemented measures scenarios (international passenger flights departing from ECAC airports).



[16] Note that in a strict sense the CORSIA target of CNG is aimed to be achieved globally (and hence not necessarily in each world region).

Figure 4. CO_2 emissions forecast for the baseline and implemented measures scenarios



As shown in **Figure 3** and **Figure 4**, the impact of improved aircraft technology indicates an overall 22% reduction of fuel consumption and CO_2 emissions in 2050 compared to the baseline scenario. Overall CO_2 emissions, including the effects of new aircraft types (conventional, hybrid electric and Hydrogen) and ATM-related measures, are projected to lead to a 29% reduction in 2050 compared to the baseline.

Table 4. Fuel burn and CO_2 emissions forecast for the Implemented Measures Scenario (new aircraft technology and ATM improvements only)

Year	Fuel Consumption (10^9kg)	CO_2 emissions (10^9kg)	Fuel efficiency (kg/RPK)	Fuel efficiency (kg/RTK)
2010	38.08	120.34	0.0327	0.327
2019	53.30	168.42	0.0280	0.280
2023	48.41	152.96	0.0268	0.268
2030	52.57	166.11	0.0241	0.241
2040	53.20	168.11	0.0205	0.205
2050	49.29	155.75	0.0168	0.168
For reasons of data availability, results shown in this table do not include cargo/freight traffic.				

As detailed in **Table 5**, under the currently assumed aircraft and ATM improvement scenarios, the fuel efficiency is projected to lead to a 37% reduction from 2023 to 2050. The annual rate of fuel efficiency improvement is expected to be at 1.5% between 2023 and 2030 and reach 2% between 2040 and 2050. However, aircraft technology and ATM improvements alone will not be sufficient to meet the post-2020 carbon neutral growth objective of ICAO, nor will the use of alternative fuels, even if Europe's ambitious targets for alternative fuels (SAF) are met. This confirms that additional action, particularly market-based measures, are required to fill the gap.

Table 5. Average annual fuel efficiency improvement for the Implemented Measures Scenario (new aircraft technology and ATM improvements only)

Period	Average annual fuel efficiency improvement (%)
2010-2023	-1.50%
2023-2030	-1.51%
2030-2040	-1.60%
2040-2050	-1.98%

The **Table 6** below summarises the cumulated effects of each implemented measure. It identifies the weight of the technical improvement on the reduction of CO_2 emissions (from 2% in 2030 to 22% in 2050 compared to the Baseline scenario). The overall impact of the implemented measures (aircraft technology improvements and ATM) shows a reduction of CO_2 emissions by 29% in 2050 compared to the Baseline scenario.

Table 6. Summary of CO_2 emissions forecast for the scenarios described in this chapter

Year	CO_2 emissions (10^9 kg)			% improvement by Implemented Measures (full scope)
	Baseline Scenario	Implemented Measures Scenario		
		Aircraft technology improvements only	Aircraft technology and ATM improvements	
2010	120.34			
2019	168.42			
2023	152.96			
2030	172.10	169.50	166.11	-3%
2040	196.52	178.84	168.11	-14%
2050	220.54	173.06	155.75	-29%
For reasons of data availability, results shown in this table do not include cargo/freight traffic.				

The section **Appendix A** of this document provides the detailed results for each scenario, Baseline, and by implemented measure, as well as the CO_2 equivalent and EU27+EFTA Net CO_2 emissions

B: Actions taken collectively in Europe

1. TECHNOLOGY AND DESIGN

   1.1 Aircraft emissions standards

   1.2 Research and development: Clean Sky and the European Partnership for Clean Aviation

2. SUSTAINABLE AVIATION FUELS (SAF)
3. AIR TRAFFIC MANAGEMENT AND OPERATIONAL IMPROVEMENTS
4. MARKET-BASED MEASURES
5. ADDITIONAL MEASURES

1.TECHNOLOGY AND DESIGN

- There have been a limited number of new certified large transport aircraft and engine types over the last few years with marginal environmental improvements, while deliveries of the latest generation of aircraft continue to penetrate the European fleet.
- Certification of all in-production aircraft types against the ICAO CO_2 standard is required by 1 January 2028, which is leading to an increase in activities within this area.
- Environmental technology standards will be important in influencing new aircraft-engine designs and contributing to future sustainability goals.
- In February 2025 the ICAO CAEP is aiming to agree on new aircraft noise and CO_2 limits that would become applicable in the next five years.
- ICAO independent experts medium-term (2027) and long-term (2037) technology goals were agreed in 2019 and are becoming outdated.
- Emissions data measured during the engine certification process acts as an important source of information to support modelling of operational emissions in cruise.
- There have been further developments within the low carbon emissions aircraft market (e.g. electric, hydrogen), with support from the Alliance for Zero-Emissions Aircraft to address barriers to entry into service and facilitate a potential reduction in short / medium-haul CO_2 emissions of 12% by 2050.
- EASA has published noise measurement Guidelines and Environmental Protection Technical Specifications in order to respond to the emerging markets of Drones and Urban Air Mobility.
- EASA has launched a General Aviation Flightpath 2030+ program to accelerate the transition of propulsion technology, infrastructure and fuels to support sustainable operations.
- Horizon Europe, with a budget of €95 billion, is funding collaborative and fundamental aviation research, as well as partnerships (e.g. Clean Aviation, Clean Hydrogen) who are developing and demonstrating new technologies to support the European Green Deal.

The European Union Aviation Safety Agency (EASA) develops and implements aircraft environmental certification standards [1, 2, 3, 4] that manufacturers have to comply with in order to register their products within the EU and EFTA States.

The recent certification of new types of large transport aircraft and engines has continued to be focused on performance improvement packages for aircraft certified in the 2010s (e.g. Airbus A350, A330neo and A320neo; Boeing 737MAX and 787). The penetration of these aircraft types into the European fleet has slowed due to reduced annual deliveries following the COVID crisis and the average margin to the latest noise standard of the new deliveries is levelling off. In contrast, there has been increased research and certification activity in emerging markets such as zero carbon emission aircraft (e.g. electric and hydrogen powered aircraft).

1.1 Aircraft environmental standards

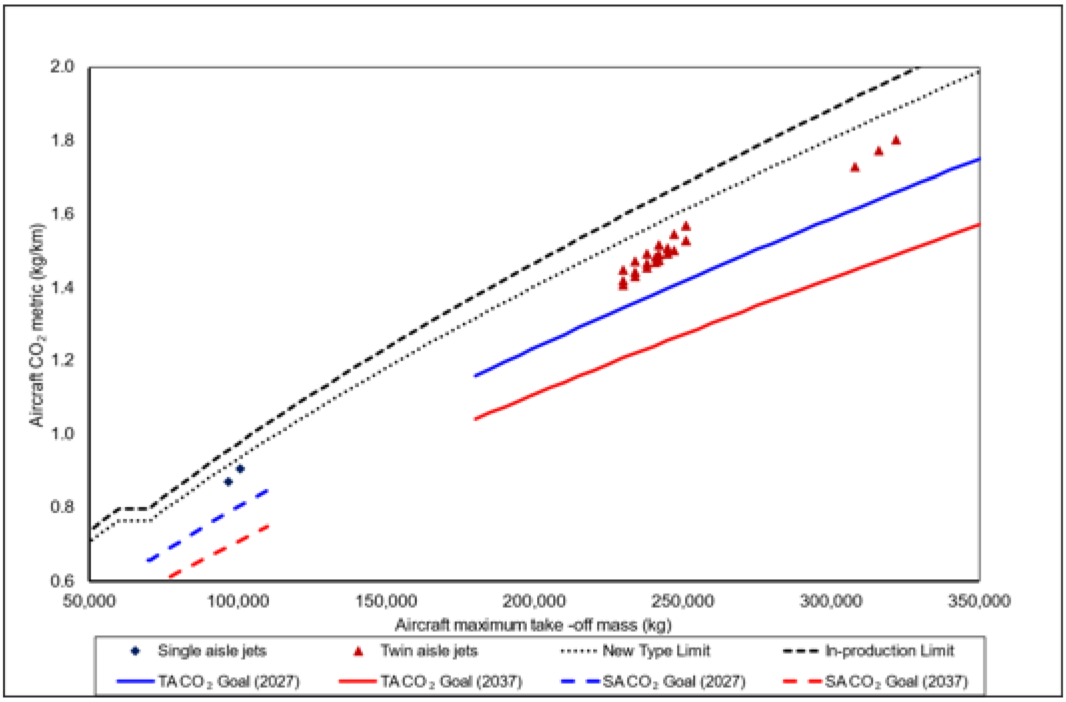
1.1.1 Aircraft CO_2 emissions

Since 1 January 2020, new aircraft types have to comply with a new type CO_2 standard[17], although no aircraft has been certified against this standard as of the start of 2025. The focus thus far has been on certifying in-production aircraft types against a less stringent in-production CO_2 standard as all aircraft have to be certified against this new requirement if they wish to continue to be produced beyond 1 January 2028.

As of the end of 2024, Airbus continues to be the only manufacturer to have certified in-production aircraft types, such as the A330-800neo and -900neo variants (Figure 1.4), and so the availability of certified CO_2 data remains limited [5]. In light of the approaching production cut-off deadline in 2028, certification of other aircraft types is ongoing by EASA and other regions of the world have also implemented the CO_2 standard into their legislation with it becoming effective in the US on 16 April 2024. The 2019 ICAO Independent Experts Panel goals for leading edge CO_2 emissions performance in 2027 and 2037 would need to be reviewed soon for them to remain relevant.

[17] ICAO Annex 16, Volume III to the Chicago Convention contains international aircraft CO_2 standards. The CO_2 metric is a specific air range-based metric (kg fuel per km flown in cruise) adjusted to take into account fuselage size.

Figure 1.1 Certified aircraft CO_2 emissions performance



ICAO dual Noise / CO_2 standard setting

A revision of the ICAO Annex 16 standards for aircraft noise and CO_2 emissions is currently being considered by the ICAO Committee on Aviation Environmental Protection (CAEP). This is the first time that CAEP standard setting has reviewed two standards at the same time in the form of an integrated dual stringency process taking into account design trade-offs at the aircraft level. The environmental benefits and associated costs of a broad range of options for more stringent new type standards have been assessed for an applicability date in the next 5 years. A recommendation by CAEP on new noise and CO_2 limits is due at the CAEP/13 meeting in February 2025.

Considering the long-term development and in-service timescales of new aircraft types, it will be important to set an updated new type CO_2 standard that will influence the fuel efficiency of future designs and effectively contribute to the ICAO Long-Term Aspirational Goal of net zero carbon emissions from international aviation by 2050 [6].

1.2 Low carbon emissions aircraft

In recent years, EASA has received an increasing number of enquiries with regard to the certification of novel aircraft configurations and sources of propulsion with zero carbon emissions in operation when produced with renewable energy.

1.2.1 Electric propulsion

Regarding Vertical take-off and landing Capable Aircraft (VCA – otherwise known as Urban Air Mobility or Advanced Air Mobility vehicles), EASA has recently published two Environmental Protection Technical Specifications (EPTS), which both underwent public consultation. The first EPTS, published in 2023, addresses VCA with non-tilting rotors [7], covering designs such as the Volocopter VoloCity or Airbus CityAirbus. The second EPTS, published in 2024, was for VCA powered, at least partially, by tilting rotors [8], covering designs such as the Lilium Jet. These two EPTS cover the majority of VCA designs currently envisioned and will be utilized in the corresponding noise certification programs. They were derived from legacy noise standards for large helicopters and tilt rotors, adapted to the VCA characteristics and expanded on to include hover condition measurement points. The same noise limits as for large helicopters are being used until more data can be collected. Ultimately, an EU Delegated Act will aim at incorporating the content of these EPTS into EASA noise regulations.

While applications to EASA for electric powered aircraft have increased, there have been few completed general aviation programs since the noise certification of the Pipistrel Velis Electro in 2020, aside from the LAK-17 self-launching sailplane in 2023, due to continuing challenges in increasing battery energy density to reduce weight and increase range. For both products, the legacy noise standards of ICAO Annex 16, Chapter 10 were used with small adjustments. This technology can lead to a 10-decibel noise reduction compared to equivalent piston-engine aircraft, which is perceived as 50% quieter.

EASA Innovative Air Mobility Hub

The EASA Innovative Air Mobility (IAM) Hub [9] is a unique digital platform, developed by a dedicated Task Force that brings together all actors in the European system including cities, regions, National authorities, the EU, operators and manufacturers. The primary goal is to facilitate the safe, secure, efficient, and sustainable implementation of IAM (e.g. Drones, UAMs) practices.

The platform currently comprises of five modules, including Drone and eVTOL Design, Rules and Regulations, Knowledge and Info Cards, Operational Information and Geographical Data such as population data. Various strategies have been deployed to mitigate the environmental impacts from UAS and VCA (e.g. regulations, no-fly zones, geofencing, altitude restrictions, remote identification) with a goal to balance the benefits of these new technologies with the need to protect EU citizens. A methodology to underpin a full life-cycle environmental assessment of IAM aircraft, known as Environmental Footprint Aviation, is also being developed [10].

1.2.2 Hydrogen-powered Aircraft

The potential of hydrogen to power carbon-free flight has rekindled interest in this alternative fuel, with green hydrogen being relatively easy to produce, provided sufficient renewable energy is available. In particular, there has been a strong interest in the potential of hydrogen used in conjunction with fuel cells and electric motors for regional / short-haul aviation, where the weight of batteries needed for energy storage is currently seen by many as restrictive.

Pioneers in the field have advanced their flight test activity, with H2FLY conducting the world's first piloted flight of a liquid hydrogen powered electric aircraft in September 2023, using their HY4 demonstrator aircraft, operating from Maribor in Slovenia. Other notable flights include ZeroAvia's flight test campaign using a Dornier 228 with the left side propeller powered by their ZA600 prototype engine and, most recently, Beyond Aero achieved France's first manned fully hydrogen-electric flight, using a retrofit model G1 SPYL-XL to demonstrate their technology.

Although the headlines have primarily been related to these aforementioned flight tests using fuel cells, there has also been demonstrable progress on hydrogen combustion technology with Rolls Royce, Safran and GE all successfully running ground tests in this field.

1.2.3 Alliance for Zero Emission Aviation

The Alliance for Zero Emission Aviation (AZEA) was launched in June 2022 and aims to prepare the aviation ecosystem for the entry into service of hydrogen and electric aircraft [10]. It contains 181 Members representing industry, standardisation and certification agencies, research bodies, environmental interest groups and regulators. AZEA members jointly work to identify barriers to entry into commercial service of these aircraft, establish recommendations and a roadmap to address them, promote investment projects and create synergies and momentum amongst members.

In June 2023, AZEA published an overview of the current aviation regulatory landscape for hydrogen and electric aircraft [11], which describes the activities that EASA is doing to adapt the aviation regulatory framework to facilitate the entry into the market of aircraft that use electric or hydrogen propulsion. To support the introduction of disruptive technologies, innovative concepts (including ground and air operations) or products, whose feasibility may need to be confirmed, and for which an adequate regulatory framework does not yet exist or is not mature, EASA is engaging with future applicants through various Innovation Services [12].

With performance-based regulations there is a higher need for supporting industry standards for regulatory compliance and interoperability. As such, AZEA has also published a document mapping existing standards and committees working in this area, including EUROCAE, SAE and ASTM [13]. Further work to identify where new standards are needed is on-going and will serve as a resource for Standards Development Organizations and industry stakeholders to identify opportunities for collaboration and harmonization of activities.

In January 2024, AZEA published its Concept of Operation (CONOPS) for the introduction of electric, hybrid-electric and hydrogen powered aircraft [14]. This addresses the challenges and opportunities arising from the integration of these new market segments into the European aviation system, covering all components of the European Air Traffic Management network, in particular airports. The CONCOPS is expected to reassessed once robust aircraft performance data becomes available.

The AZEA vision "Flying on Electricity and Hydrogen in Europe" published in June 2024 [15] has developed a baseline scenario that, while recognising that long-haul flights relying on these power sources cannot be anticipated before 2050, predicts approximately 5000 electric and hydrogen aircraft (excluding urban air mobility vehicles and helicopters) will be delivered to European operators between now and 2050, leading to a reduction in short and medium-haul CO_2 emissions of 12%. While there are considerable challenges requiring the collaboration of all stakeholders, beyond these hurdles is an opportunity to reshape the aviation sector and to pioneer a sustainable future.

Figure 1.2 ATAG indicative overview of where low- and zero-carbon energy could be deployed in commercial aviation alongside that of SAF [16]

	2020	2025	2030	2035	2040	2045	2050
Commuter » 9-19 seats » < 60 minute flights » <1% of industry CO_2	SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF
Regional » 50-100 seats » 30-90 minute flights » ~3% of industry CO_2	SAF	SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF
Short haul » 100-150 seats » 45-120 minute flights » ~24% of industry CO_2	SAF	SAF	SAF	SAF potentially some Hydrogen	Hydrogen and/or SAF	Hydrogen and/or SAF	Hydrogen and/or SAF
Medium haul » 100-250 seats » 60-150 minute flights » ~43% of industry CO_2	SAF	SAF	SAF	SAF	SAF potentially some Hydrogen	SAF potentially some Hydrogen	SAF potentially some Hydrogen
Long haul » 250+ seats » 150 minute + flights » ~30% of industry CO_2	SAF	SAF	SAF	SAF	SAF	SAF	SAF

1.3 Supersonic aircraft

Following the retirement of Concorde in 2003, several manufacturers have been looking into developing supersonic business jets, with some currently looking at an entry into service date of around 2030. Key environmental challenges to address include the use of significantly more fuel on a per passenger kilometre basis compared to subsonic commercial aircraft [17], and noise, specifically the impact of the sonic boom generated when flying at supersonic speed.

1.4 General Aviation Sustainability Roadmap

EASA is dedicated to making General Aviation (GA) more sustainable. Building on the success of the past GA Roadmap, the Agency has launched the new GA Flightpath 2030+ program in 2024 [18]. GA is seen as a cradle for development, testing, and industrialization of innovations that, when tested and implemented operationally, can drive improvements across the entire aviation sector in safety and sustainability.

The 'Greener Faster' initiative is designed to achieve sector-wide agreement on what sustainable GA means and how everyone can work together to accelerate the transition of GA propulsion technology, infrastructure and fuels to support sustainable operations and the objective of carbon-free aviation by 2050. This will be complemented by the 'Fly Direct' initiative that aims to optimize GA operations in the airspace by removing unnecessary operational restrictions, allowing aircraft to safely navigate the most efficient and environmentally friendly routes.

1.5 Research and Innovation Programmes

Aviation environmental research is embedded in European, National and industry research programmes. At EU level, most research is currently funded through 'Horizon Europe' (2021-2027) with an initial budget of €95.5 billion [19]. Aviation specific research contributes primarily to the European Green Deal and the EU's digital and competitiveness strategies across all three Horizon Europe pillars.

- **Pillar I**: European Research Council science, which often advances the limits of science and technology (e.g. new materials, breakthrough physical processes, artificial intelligence and quantum computing, sensor technologies);
- **Pillar II**: Cluster 5 aviation programme has been the foundation of aeronautics research for over 35 years, including relevant partnerships (e.g. Clean Aviation, Clean Hydrogen and SESAR), industry-led technology demonstrators and Cluster 4 synergies (Digital, Industry and Space); and
- **Pillar III**: European Innovation Council research actions, with emphasis on supporting and connecting SMEs and the aviation supply chain.

The collaborative and fundamental Pillar II Cluster 5 aviation environmental research develops and derisks technologies up to a Technology Readiness Level (TRL) 4, to be taken further by Horizon Europe partnerships, national or industry programmes. The current research is focused on:

- lightweight, multifunctional and intelligent airframe and engine parts
- holistic digital framework for optimized design, manufacturing and maintenance
- uncertainties quantification for design, manufacturing and operation
- ultra-efficient aircraft propulsion
- electrified and hydrogen-enabled propulsion
- fuel-flexible combustion systems and cryogenic liquid hydrogen storage
- better understanding and mitigating non-CO_2 emissions, with emphasis on contrails
- reduction of NOx, and particulate matter emissions
- Noise reduction technologies and abatement procedures

One such Horizon Europe project is HESTIA [20] that focuses on increasing the scientific knowledge of the hydrogen-air combustion of future hydrogen-fuelled aero-engines. Another example is BeCoM [21] which addresses the uncertainties related to the forecasting of persistent contrails and their weather-dependent individual radiative effects, in order to develop recommendations on how to implement strategies that enable air traffic management to reduce aviation's climate impact. Further information on the extensive projects funded under Horizon Europe research programme can be found on the European Commission website [22].

Clean Sky 2 (part of 'Horizon 2020' – 2014 to 2020)

The Clean Sky 2 projects (2014-2024) had a combined public and private budget of around €4 billion, with EU funding up to €1.75 billion [23]. Its objectives were to develop, demonstrate, and accelerate the integration of technologies capable of reducing CO_2, NO_X and Noise emissions by 20 to 30% compared to 'state-of-the-art' aircraft in 2014.

The benefits and potential impact from Clean Sky 2 research at the aircraft, airport and fleet level are evaluated through a dedicated Technology Evaluator function with key assessment and reporting duties. The final assessment by the Technology Evaluator was performed in 2024 [24] and the results are summarised in Table 1.1.

Table 1.1 Final Clean Sky 2 Technology Evaluator Assessment Results

Mission Level Assessment				
Concept Model	**Assessment**	**CO_2[1]**	**NOx[1]**	**Noise[2]**
Long Range (LR+)	1st	-13%	-38%	<-20%
	2nd	**-18.2%**	**-44.9%**	**-20.1%**
Short-Medium Range (SMR+ & SMR++)	1st	-17% to -26%	-8% to -39%	-20% to-30%
	2nd	**-25.8% to -30.4%**	**-2.3% to -5.1%**	**-11.5% to -16.3%**
Regional (TP90 -TP130 - MM TP70)	1st	-20% to -34%	-56% to -67%	-20% to -68%
	2nd	**-25% to -32.5%**	**-44% to -60%**	**+14% to -44%**
Commuter[3] & BJ	1st	-21% to -31%	-27% to -28%	-20% to-50%
	2nd	**-17.3% to -19.6%**	**-16.5% to -51.5%**	**-19% to -31%**

(1) CO_2 and NO_x values per passenger-kilometre.
(2) Averaged Perceived Sound Volume Reduction (EPNLdB) according to ICAO Annex 16 conditions for fixed-wing aircraft (Chapter 10 for CS-23 aircraft and Chapter 14 for CS-25 aircraft). 20% noise reduction is equivalent to 3dB reduction. 30% of noise reduction is equivalent to 5dB reduction.
(3) Only fossil fuel concepts, excluding the innovative E-Short Take-Off and Landing (STOL) hybrid-electric commuter concept.

Airport Level Assessment			
Assessment	**CO_2**	**NO_x**	**Noise Area**
1st	-8% to-13.5%	-6.5% to -10.5%	-10% to-15%
2nd	**-11.5 to -15%**	**-10.5 to -14.5%**	**-8% to -17% (Lden[1])**

(1) Surface area Reduction of Lden contours for 60-65 dB(A) noise levels at the European airports considered.

Fleet Level Assessment			
Assessment	**CO_2**	**NO_x**	**Fleet Renewal**
1st	-14% to-15%	-29% to -31%	70% to 75% (ASK)
2nd	**-14.5%**	**-29%**	**71.4% (ASK)** **61.6% (a/c)**

Clean Aviation (part of 'Horizon Europe' – 2021 to 2027)

Clean Aviation was established in November 2021 under EU Horizon Europe to support the EU ambition of climate neutrality by 2050 [25]. The Clean Aviation programme aims to develop disruptive aircraft technologies that will deliver net greenhouse gas (GHG) reductions of no less than 30%, compared to 2020 state-of-the-art aircraft. The targets have been extended to CO_2 and non-CO_2 effects (nitrogen oxides, water vapour, particulates, contrails, etc.) and EASA is working with Clean Aviation to convey these benefits in the context of the ICAO Annex 16 environmental certification requirements. The technological and industrial readiness aims to allow deployment of these new aircraft no later than 2035, enabling 75% of the world's civil aviation fleet to be replaced by 2050.

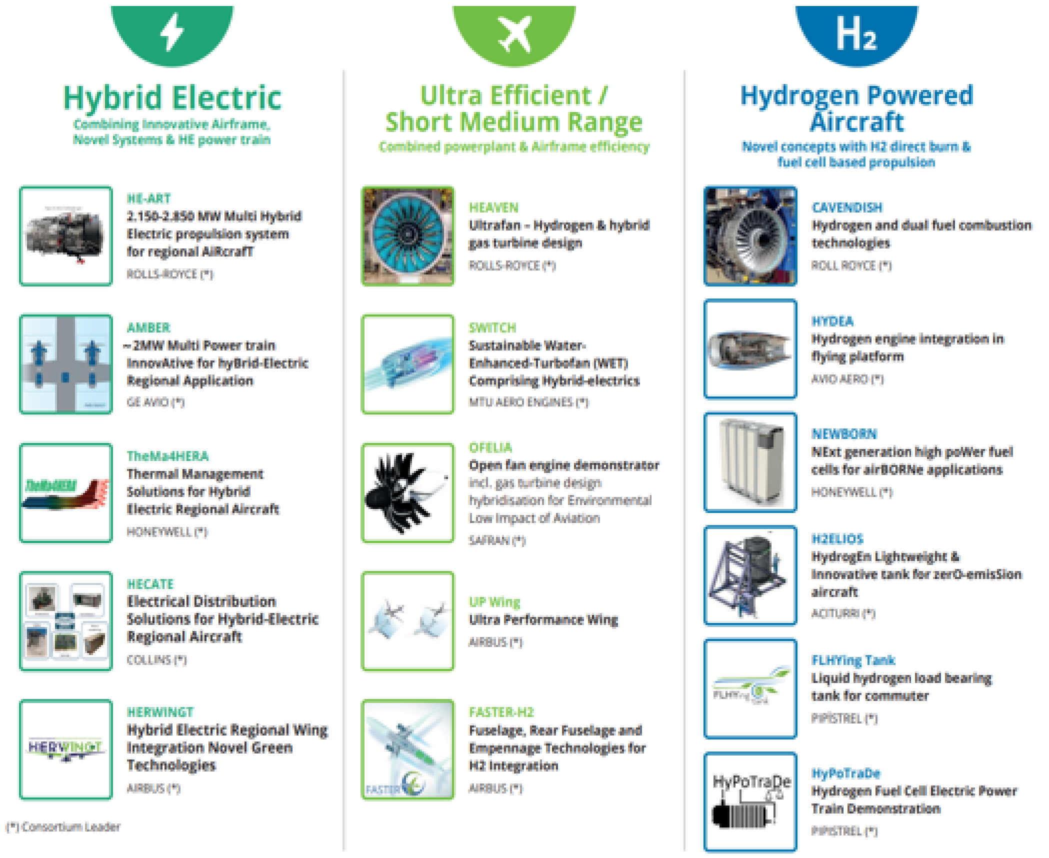
Clean Aviation will focus on three key areas of hybrid electric and full electric architectures, ultra-efficient aircraft architectures and disruptive technologies to enable hydrogen-powered aircraft. The targeted performance levels are summarised in Table 1.2 [26].

Table 1.2 Clean Aviation Targets

Aircraft Category	Key technologies and architectures to be validated at aircraft level in roadmaps	Entry Into Service Feasibility	CO_2 Emissions reduction (technology based)[28]	Net CO_2 Emissions reduction (i.e. including SAF effect)[29]	Current share of air transport system emissions
Regional Commercial Aircraft	> Hybrid-electric (SAF + Batteries) coupled with highly efficient aircraft configuration	~2035	-30%	-86%	~5%
	> Same with H2-electric power injection (Fuel Cells electric generation)	Beyond 2035	Up to -50%	Up to -90%	
Short-Medium Range Commercial Aircraft	Advanced ultra-efficient aircraft configuration and ultra-efficient gas turbine engines	~2035	-30%	-86%	~50%
Hydrogen-Powered Commercial Aircraft	Full hydrogen-powered aircraft (H2 Fuel Cells or H2-combution)	~2035	-100%	N/A	N/A

28. Improvement targets are defined as CO2 reduction compared to 2020 state-of-the-art aircraft available for order/delivery.
29. Assumes full use of SAF at a state-of-the-art level of net 80% carbon footprint reduction (and where applicable, zero-carbon electric energy for batteries charging and green hydrogen production).

Figure 1.3 Initial projects launched in 2023 to deliver important technology bricks in all three areas



STAKEHOLDER ACTIONS

AeroSpace and Defence Industries Association of Europe (ASD)

ASD includes 25 major European companies and 25 National Associations as our members, with an overall representation of up to 4,000 companies across 21 European countries. In 2022, ASD Members employed 921,000 people and generated a turnover of €261 billion.

UltraFan® Technology Demonstrator

Rolls-Royce has successfully run its UltraFan® technology demonstrator to maximum power during 2023. The initial stage of the test was conducted using 100% Sustainable Aviation Fuel (SAF). UltraFan® delivers a 10% efficiency improvement over the Trent XWB engine and a 25% efficiency gain since the launch of the first Trent engine. Testing has been supported by various partners, including the EU Clean Sky programmes.

Hydrogen Fuel Cells

Airbus has performed ground testing to achieve the milestone of running a fuel cell engine concept at full power (1.2 MegaWatts). This is the most powerful fuel cell test ever in the aviation sector, coupling 12 fuel cells to reach the output needed for commercial use. In addition, the Non-Propulsive Energy demonstrator, HyPower, will use a fuel cell containing ten kilograms of gaseous hydrogen generated from renewable sources to produce electricity when tested on board an Airbus A330 in standard operating conditions. It aims to reduce the emissions of CO_2, NO_X and noise levels associated with a traditional APU.

RISE Open Fan

SAFRAN is developing the CFM RISE Open Fan engine demonstrator combining lightweight equipment and advanced technologies such as hybrid electric systems. An open fan architecture has the potential to reduce fuel consumption and CO_2 emissions by more than 20% compared to today's most efficient engines. This advanced, new generation open fan architecture is expected to be able to fly at the same speed as current single-aisle aircraft (up to Mach 0.8) with a noise signature that will meet anticipated future regulations.

Flight testing of the RISE Open Fan is being done in collaboration with Airbus using their A380 Flight Test Demonstrator that aims to mature and accelerate the development of advanced propulsion technologies. The programme objectives include enhanced understanding of engine/wing integration and aerodynamic performance as well as propulsive system efficiency gains, evaluating acoustic models, and ensuring compatibility with 100% Sustainable Aviation Fuels.

List of Resources

[1] EU (2018), Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency.

[2] ICAO (2023), Annex 16 to the Convention on International Civil Aviation — Environmental Protection, Volume I, 8th Edition, Amendment 14 — Aircraft Noise.

[3] ICAO (2023), Annex 16 to the Convention on International Civil Aviation —Environmental Protection, Volume II, 5th Edition, Amendment 11 — Aircraft Engine Emissions.

[4] ICAO (2023), Annex 16 to the Convention on International Civil Aviation —Environmental Protection, Volume III, 1st Edition, Amendment 1 — Aeroplane CO_2 Emissions.

[5] EASA (2025), EASA Aeroplane CO_2 Emissions Database.

[6] ICAO (2025), ICAO Long Term Global Aspirational Goal (LTAG) for International Aviation.

[7] EASA (2023), Environmental Protection Technical Specifications applicable to VTOL-capable aircraft powered by non-tilting rotors.

[8] EASA (2024), Environmental Protection Technical Specifications applicable to VTOL-capable aircraft powered by tilting rotors.

[9] EASA (2025), Environmental Footprint Aviation Study for Drones & eVTOLs.

[10] AZEA (2025), Alliance for Zero Emission Aircraft.

[11] AZEA (2023), Current aviation regulatory landscape for aircraft powered by hydrogen or electric propulsion.

[12] EASA (2025), Innovation Services.

[13] AZEA (2023), Current Standardisation Landscape.

[14] AZEA (2024), Concept of Operation for the Introduction of Electric, Hybrid-electric and Hydrogen powered Zero Emission Aircraft.

[15] AZEA (2024), Flying on electricity and hydrogen in Europe.

[16] ATAG (2021), Waypoint 2050 Second Edition.

[17] ICCT (2022), Environmental limits on supersonic aircraft in 2035.

[18] EASA (2025), General Aviation Flightpath 2030+.

[19] EU (2025), Horizon Europe.

[20] EU (2025), HESTIA Horizon Europe project.

[21] EU (2025), BeCoM Horizon Europe project.

[22] EU (2025), EU Research Projects.

[23] Clean Sky 2 (2014), Council Regulation (EU) No 558/2014 of 6 May 2014 establishing the Clean Sky 2 Joint Undertaking.

[24] Clean Sky 2 (2024), Technology Evaluator.

[25] Clean Aviation (2021), Council Regulation (EU) 2021/2085 establishing the Joint Undertakings under Horizon Europe.

[26] Clean Aviation (2024), Strategic Research & Innovation Agenda.

2. SUSTAINABLE AVIATION FUELS

- ReFuelEU Aviation sets minimum supply mandate for Sustainable Aviation Fuels (SAF) in the EU, starting with 2% in 2025 and increasing to 70% in 2050.
- A sub-mandate for synthetic aviation fuels, starting at 0.7% in 2030 and increasing to 35% in 2050, underlines their significant potential for emissions reductions.
- All SAF supplied under the ReFuelEU Aviation mandate must comply with the sustainability and greenhouse gas emissions saving criteria as set out in the Renewable Energy Directive (RED) and the revised Gas Directive.
- The ICAO CAAF/3 conference agreed in 2023 on a global aspirational vision to reduce CO_2 emissions from international aviation by 5% in 2030 through the use of SAF, low-carbon aviation fuels and other aviation cleaner energies.
- As of 2024, SAF production represented only 0.53% of global jet fuel use. Significant expansion of production capacity is required to meet future mandates and goals.
- SAF must meet international standards to ensure the safety and performance of aviation fuel. Various types of SAF have been approved, with ongoing efforts to increase blending limits and support the use of 100% drop-in SAF by 2030.
- SAF has the potential to offer significant CO_2 and non-CO_2 emissions reductions on a lifecycle basis compared to conventional jet fuels, primarily achieved during the production process using sustainable feedstock. However, various factors such as land use changes can negatively impact the overall lifecycle emissions.
- The upscaling of SAF has generated concerns about potential fraudulent behaviour whereby products labelled as meeting RED sustainability requirements are not compliant.
- Various measures have been put it place to support the achievement of European and ICAO goals on SAF, including a European Clearing House, financial incentives, research programmes and international cooperation.
- SAF production capacity currently under construction could supply the 3.2 Mt of SAF required under ReFuelEU Aviation in 2030, but would be required to ramp up quickly thereafter.

- SAF prices are currently 3 to 10 times more expensive than conventional fuel although they are expected to reduce substantially as production technologies scale up.

2.1 SAF Developments

The last few years have seen significant developments in the European sustainable aviation fuels landscape. With the adoption of the ReFuelEU Aviation Regulation [1], European legislators are ensuring a level playing field for sustainable air transport by establishing minimum mandates for fuel suppliers starting in 2025, including sub-mandates for e-fuels. Together with a growing number of initiatives and mandates outside of Europe, the market is now at a pivotal point and an ambitious increase of production capacity will be required to meet this mandate.

2.2 What are Sustainable Aviation Fuels?

A Sustainable Aviation Fuel (SAF) is a sustainable, non-conventional, alternative to fossil-based jet fuel. Several definitions and terminology apply, depending on regulatory context, feedstock basis, and production technology.

According to the ReFuelEU Aviation Regulation, SAF are defined as various types of drop-in aviation fuels (Table 2.1). For instance, aviation biofuels mean biofuels as defined in the Renewable Energy Directive (RED) [2] and excluding fuels produced from food and feed crops as well as other feedstock specified in Article 4 of the Regulation. Finally, for synthetic aviation fuels, a variety of terminologies are used, such as liquid Renewable Fuels of Non-Biological Origin (RFNBO) in ReFuelEU Aviation, but also Electrofuels, e-Fuels and Power-to-Liquid (PtL).

Both ReFuelEU Aviation and the EU Emission Trading System (ETS) use the RED as their basis and all eligible fuels need to comply with the sustainability and greenhouse gas (GHG) emissions reduction criteria set out in the RED.

Table 2.1 ReFuelEU Aviation aviation fuel categories

Type of ReFuelEU Aviation fuel	Definition in RFEUA Article	Comments
Categories of sustainable aviation fuels (SAF)		
Synthetic aviation fuels	Art 3(12)	Renewable fuel of non-biological origin in Directive (EU) 2018/2001
Advanced aviation biofuels	Art 3(8)(a)	Produced from the feedstock listed in Part A Annex IX of Directive (EU) 2018/2001
Aviation biofuels	Art 3(8)(b)	Produced from feedstock listed in Part B Annex IX of Directive (EU) 2018/2001
Other aviation biofuels	Art 3(8)(c)	Produced from feedstock not listed in Annex IX of Directive (EU) 2018/2001 and

		except for those produced from food and feed crops
Recycled carbon aviation fuels	Art 3(9)	Produced from waste streams of non-renewable origin which are not suitable for material recovery
Categories of other eligible renewable and low-carbon aviation fuels under RFEUA		
Low-carbon hydrogen for aviation	Art 3(15)	Produced from non-fossil non-renewable sources
Renewable hydrogen for aviation	Art 3(16)	Renewable fuel of non-biological origin in Directive (EU) 2018/2001
Synthetic low-carbon aviation fuels	Art 3(13)	Produced from non-fossil non-renewable sources
Other aviation fuels under RFEUA		
Conventional aviation fuel	Art 3(14)	Aviation fuels produced from fossil non-renewable sources of hydrocarbon fuels (e.g. crude oil)

Standardisation process for qualification of new SAF production pathways

The reliable performance of aviation fuel is essential to the safe operation of aircraft and is a matter of airworthiness requiring harmonised international practices. What is commonly referred to as "aviation turbine fuel", is a highly specified technical material, characterised by many chemical and physical properties defined by technical specifications, such as the ASTM D1655 and DEF STAN 91-091 [3, 4]. These specifications are developed and maintained by ASTM International and United Kingdom Ministry of Defence (UK MOD) respectively, with support from stakeholder groups such as Original Equipment Manufacturers (OEMs), fuel producers, fuel suppliers, airline operators and regulatory bodies. These fuel standards list the requirements for Jet A/Jet A-1, which is aviation turbine fuel for use within gas turbine engines.

Qualified production pathways are listed in ASTM D7566 [5], which sets out the standard specification for "aviation turbine fuel containing synthesized hydrocarbons", meaning fuels that are of non-conventional origin. Each type of production pathway is defined in terms of feedstock, conversion technology, fuel specification properties, and maximum blending fraction. After fulfilling blending requirements in ASTM D7566 Table 1 the fuel is redeclared and treated as an ASTM D1655 Jet A/Jet A-1 fuel.

As of October 2024, eight SAF production processes have been standardized by ASTM and consequently been adopted by other fuel standards [5]. In addition, three pathways for the co-processing of renewable feedstocks in petroleum refineries are qualified [3] with a feedstock blending limit of up to 24% (see Table 6.2).

Table 2.2 Drop-in SAF qualified production pathways

Production pathway	Feedstocks[18]	Certification name	Maximum SAF share
Biomass Gasification + Fischer-Tropsch (Gas+FT)	Energy crops, lignocellulosic biomass, solid waste	FT-SPK[19]	50%
Hydroprocessed Esters and Fatty Acids (HEFA)	Vegetable and animal fat	HEFA-SPK	50%
Direct Sugars to Hydrocarbons (DSHC)	Conventional sugars, lignocellulosic sugars	HFS-SIP[20]	10%[21]
Biomass Gasification + FT with Aromatics	Energy crops, lignocellulosic biomass, solid waste	FT-SPK/A[22]	50%
Alcohol to Jet (AtJ)	Sugar, starch crops, lignocellulosic biomass	ATJ-SPK	50%
Catalytic Hydrothermolysis Jet (CHJ)	Vegetable and animal fat	CHJ or CH-SK[23]	50%
HEFA from algae	Microalgae oils	HC-HEFA-SPK[24]	10%
AtJ with Aromatics	Sugar, starch crops, lignocellulosic biomass	ATJ-SKA	50%
FOG Co-processing	Fats, oils, and greases	FOG	5%
FT Co-processing	Fischer-Tropsch (FT) biocrude	FT	5%
Hydroprocessed Lipids Co-processing	Hydroprocessed vegetable oils, animal fats, used cooking oils	Hydroprocessed Lipids Co-processing	10%

In order to be included in ASTM D7566, novel SAF production pathways need to go through a thorough qualification process specified in ASTM D4054 [6]. This process includes the testing of fuel samples, ranging from small-scale laboratory tests with a limited amount of fuel to full rig- and engine-testing that requires thousands of litres. The resulting research reports are then reviewed and approved by the OEMs before being proposed as ballot for inclusion of a new Annex to ASTM

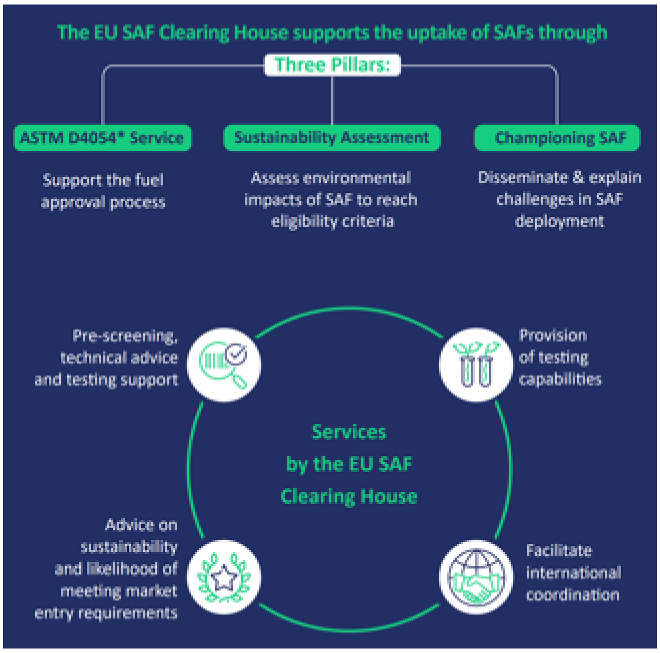
[18] The listed feedstocks are technologically feasible for the specific production pathway, but not necessarily applicable under certain regulations (e.g. ReFuelEU Aviation).
[19] FT-SPK: Fischer-Tropsch synthesised paraffinic kerosene.
[20] HFS-SIP: hydroprocessed fermented sugars to synthetic iso-paraffins.
[21] TRL 7-8 for conventional sugar feedstock; TRL 5 for lignocellulosic sugar feedstock.
[22] FT-SPK/A: Fischer-Tropsch synthesised paraffinic kerosene with Aromatics.
[23] CH-SK: catalytic hydrothermolysis synthesised kerosene.
[24] HC-HEFA-SPK: Synthesised paraffinic kerosene from hydrocarbon-hydroprocessed esters and fatty acids.

D7566. This is both expensive and time-consuming for all involved stakeholders, which has led to the setup of several SAF Clearing Houses to support this process (see Textbox).

EU SAF Clearing House

The EU SAF Clearing House [7], which is funded by the EU and managed by EASA, is a 'one stop' knowledge centre providing all the information, data and stakeholder connections needed by fuel producers seeking to advance through the ASTM qualification process described above and contribute to the production and supply of sustainable aviation fuels.

Each of the approved SAFs within the ASTM D7566 Annexes has its own characteristics and is tapping into certain categories of feedstock. To be able to produce enough SAF to meet the future needs of the aviation sector, more pathways that tap into new feedstock that have good sustainability characteristics and are economically viable, are required.



There is substantial work being done within fuel standard committees to increase the blending limits for both SAF and the co-processing of renewable feedstock in conventional refineries. For the latter, there are ambitions to increase the limit to 30% by 2025 as the existing infrastructure can be immediately deployed to increase the sustainable share in aviation fuels and support fulfilling the mandates without requiring major investments. The research work required to remove the blending limit and enable the use of 100% SAF is ongoing (see textbox).

Two Options for 100% SAF: Drop-in and Non-Drop-in

Approved SAF currently have associated maximum blending ratios (Table 2.2) that may limit the ability to use larger amounts of SAF in the future. As such, dedicated task groups within fuel standard committees are assessing two options to facilitate the use of 100% SAF in aircraft with an initial timeline of having fuel standards ready by latest 2030:

a. 100% Drop-In SAF: Jet Fuel Fully Comprised of Synthesized Hydrocarbon as a drop-in replacement which is identical to Jet A/Jet A-1

b. 100% Non-Drop-In SAF: Non-Drop-In Fully Synthetic Aviation Jet Fuel is aromatic free fuel, which is close to Jet A/Jet A-1 but would be a different fuel.

The 100% Drop-In SAF will be a modification to the existing ASTM D7566. One option to realize such a fuel is to blend two or more SAFs to produce a fuel with characteristics that are fit for purpose in terms of 100% use. Another option is the adaptation of currently used raw materials and production processes to produce a fully formulated 100% SAF in a single process stream (e.g. AtJ, FT- SPK/A and CHJ) or the use of new raw materials and processes yet to be developed and approved. In the last two years, the successful use of 100% Drop-In SAF was demonstrated in experimental flights by different commercial airlines in tight cooperation with OEMs and airworthiness authorities.

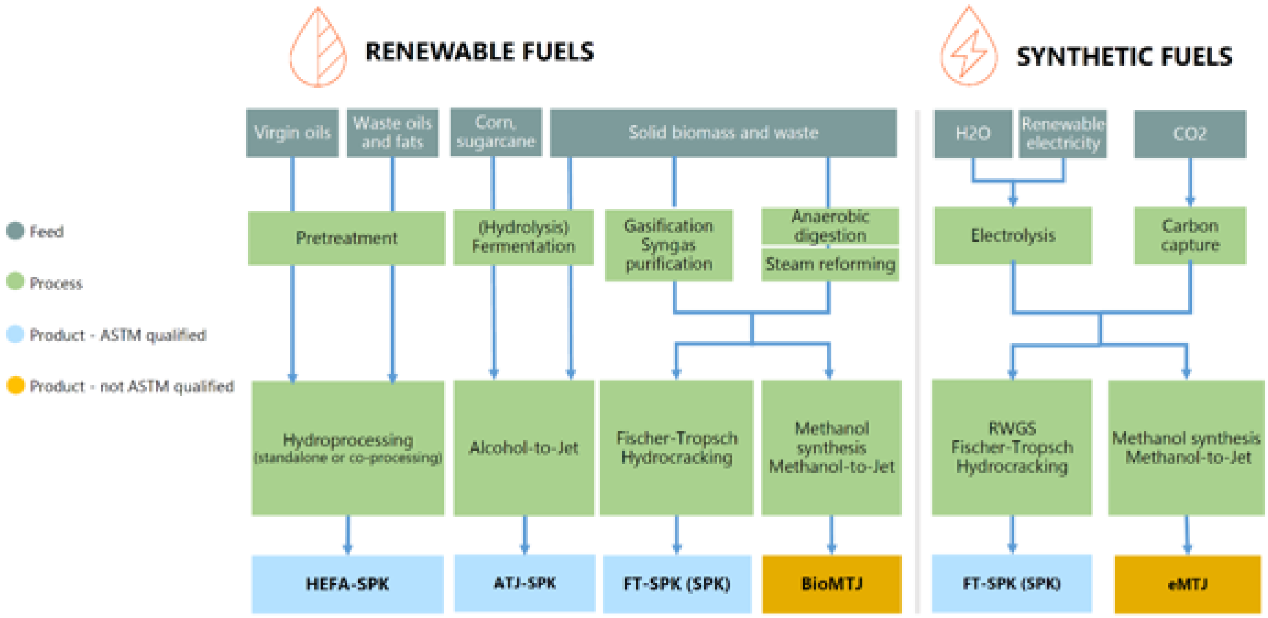
The 100% Non-Drop-In SAF would be a new fuel standard specification. It could be used in designated aircraft/engines only and would require a separate supply chain. A major motivation for this new fuel type would be to significantly reduce emissions that contribute to non-CO_2 climate impacts and local air quality. For (non-aromatic) 100% Non-Drop-In SAFs a series of research and test flights proved their positive effects on emissions and contrail formation. Furthermore, valuable data was collected that will support the specification of a 100% Non-Drop-In SAF.

A collaborative effort across the aviation ecosystem aims to maximize global impact, with standardization and technical readiness currently in progress. Ongoing impact analysis focuses on fuel production, while further studies are necessary to address infrastructure challenges associated with 100% Non-Drop-In SAF.

With a variety of feedstock categories that can be used to produce SAF, the production can be tailored to the specific circumstances of a country and thereby support diversification of fuel supplies. Four of the production pathways that are expected to play a major role in the future are Hydroprocessed Esters and Fatty Acids (HEFA) (TRL[25] 8-9), Alcohols to Jet (AtJ) (TRL 7-8), Biomass Gasification with Fischer-Tropsch (Gas+FT)

(TRL 6-8) and Power-to-Liquid (PtL) (TRL 5-8). New production pathways and suitable feedstocks are being developed. Methanol-to-Jet is one promising technology that is being worked on by several companies and is currently going through the qualification process. The advantage of this pathway is that it can be used both with biomass feedstock as well as a conversion technology for Power-to-Liquid fuels.

Figure 2.1 Main SAF production pathways with similar building blocks [8]



[25] Technology Readiness Level.

Hydroprocessed Esters and Fatty Acids (HEFA). Currently the most viable option to produce SAF due to its commercial and technical maturity. Feedstocks include waste and residue fats, such as vegetable oil, used cooking oil, and animal fats, as well as purpose-grown crops like jatropha and camelina. These feedstocks are processed with hydrogen to remove oxygen and create hydrocarbon fuel components. However, supply will be limited by the availability of sustainable feedstock and competition from other sectors, such as road. In addition, with growing demand there is a risk of potential fraud from the use of feedstock that does not comply with the sustainability criteria (see Textbox on Sustainable Certification Schemes).

Alcohols to Jet (AtJ) and Biomass Gasification with Fischer-Tropsch (Gas+FT). AtJ fuels can be produced from agricultural residues and crops and the renewable fraction of municipal waste via an alcohol synthesis. Gas+FT converts biogas or syngas from similar feedstocks into fuel. Both methods can be produced with or without aromatics. Aromatics are essential for the performance of certain aircraft engine components (e.g. seals) but have environmental drawbacks in terms of particulate matter emissions. On the other hand, the production with aromatics would enable future 100% drop-in SAF production (see textbox) once the two pathways develop and are commercially available in the EU for aviation fuel production.

Power-to-Liquid (PtL). These fuels offer one of the highest potentials to scale-up production capacity in the future. While not being limited by sustainable biomass availability, they are reliant on access to sufficient additional renewable energy electricity, and an energy efficient conversion process, to achieve significant CO_2 emission reductions. Water and electricity are used in an electrolyser to generate hydrogen, which is then combined with CO_2 to create syngas. This syngas can then be further converted to SAF via the Fischer-Tropsch (FT) pathway or the Methanol-to-Jet pathway (currently in the ASTM D4054 qualification process). The CO_2 required for the PtL process can be obtained from industrial waste gases, biomass, or direct air capture (DAC). With DAC, the CO_2 is directly captured from the air through filters. As the concentration of CO_2 in the air is low, this process is very energy intensive but offers high CO_2 emission reduction potential, once the technology has further matured.

2.3 How sustainable are SAF?

Sustainability criteria

Table 2.3 provides an overview of the sustainability criteria used within both the RED [2] and the ICAO Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) [9].

Table 2.3 SAF sustainability criteria

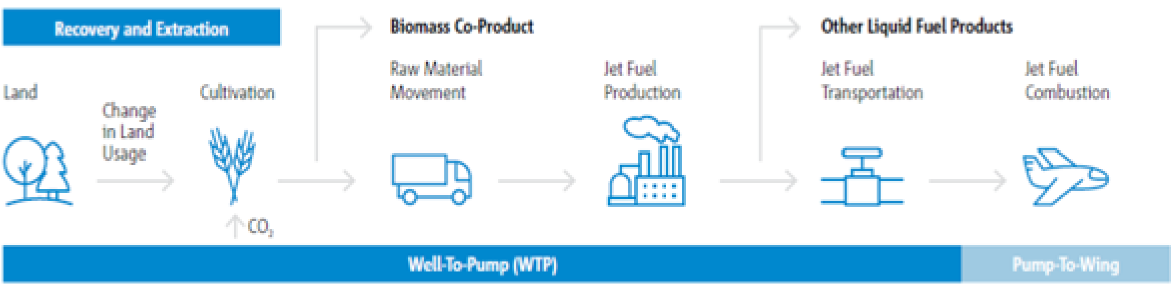
Scheme	**Sustainability criteria**
Renewable Energy Directive (2023), Article 29	• *GHG reductions* – GHG emissions on a life cycle basis from biofuels must be lower than from the fossil fuel they replace (fossil fuel baseline = 94 g CO_2e/MJ): at least 50% lower for installations older than 5 October 2015, 60% lower for installations after that date and 65% lower for biofuels produced in installations starting operation after 2021. For renewable fuels from non-biological origin, and recycled carbon fuels, the savings shall be at least 70%. • *Land use change* – Carbon stock and biodiversity: raw materials for biofuels production cannot be sourced from land with high biodiversity or high carbon stock (i.e., primary and protected forests, highly biodiverse grassland, wetlands and peatlands). Other sustainability issues covered by the reporting obligation are set out in the Governance regulation [10] and can be covered by certification schemes on a voluntary basis. There are also constraints on forest management. • There are additional criteria that are applicable and ensure that electricity used for the production of renewable hydrogen and RFNBOs is of renewable and additional origin. • There are also limitations on biomass production from feedstocks with high indirect land use change (ILUC) risk and using feedstock that could otherwise be used for food, in order to prevent inappropriate land usage and risk to food security.

CORSIA Sustainability Criteria for CORSIA eligible fuels (November 2022)	For batches produced on or after 1 January 2024, the following Sustainability Criteria are applicable: • *GHG reductions* – CORSIA eligible fuel / SAF must achieve net GHG emissions reductions of at least 10% compared to the baseline life-cycle emissions values for aviation fuel on a life cycle basis (fossil fuel baseline = 89 g CO_2e/MJ), including an estimation of ILUC and/or DLUC emissions. • *Carbon Stock* - CORSIA eligible fuel / SAF will not be made from biomass obtained from land converted after 1 January 2008 that was primary forest, wetlands, or peat lands and/or contributes to degradation of the carbon stock in primary forests, wetlands, or peat lands as these lands all have high carbon stocks. • *Permanence* – The emissions reductions attributed to CORSIA SAF should be permanent. Practices will be implemented that monitor, mitigate and compensate any material incidence of non-permanence resulting from carbon capture and sequestration (CCS) activities. There are additional criteria that are applicable and are addressing the following themes: Water, Soil, Air, Conservation (biodiversity), Waste and chemicals, Human and labour rights, Seismic and Vibrational Impacts, Human and labour rights, Land use rights and land use, Water use rights, Local and social development and Food security.

GHG emissions reductions

The emissions reductions from drop-in SAF in a lifecycle analysis (LCA) are predominately achieved during the production process and more precisely through the use of sustainable feedstock. The greenhouse gases (GHG) emissions in terms of gCO_2e/MJ from its combustion in an aircraft engine are effectively the same as that those of fossil fuels. Many variables can influence the overall results of the LCA (Figure 2.2), but given historic concerns surrounding biofuel sustainability, it is encouraged to calculate actual life cycle emission values rather than applying a default value.

Figure 2.2 Components of typical well-to-wing LCA for biofuel-based jet fuel



Overestimations of GHG emissions reductions can occur if potential land use changes are not properly considered. Direct Land Use Changes (DLUC) occur when existing land is converted for the growth of feedstock for biofuel, while Indirect Land Use Change (ILUC) occurs when agricultural land used for food or feed is converted to biofuel production and the displaced production shifts to previously non-agricultural land, such as forests or grasslands [11]. Land use change, both direct and indirectly caused by crop displacements, can potentially negate any GHG savings from biofuels, or even release more CO_2-equivalent emissions than what the biomass subsequently grown on that land is able to reduce. Wastes and residues are conventionally considered as having zero DLUC or ILUC associated emissions.

The update to the RED in 2023 has tightened the rules around land use, emphasizing the protection of biodiverse areas and placing stricter controls on land conversion, and imposing restrictions on feedstocks with the higher ILUC risk. Bioenergy production is restricted on lands with high biodiversity value, such as primary forests, highly biodiverse grasslands, and areas designated for nature protection purposes. ReFuelEU Aviation is more stringent than RED by excluding feed and food crops, palm and soy-derived materials, palm fatty acid distillate (PFAD), soap stock and its derivatives as eligible.

Figure 2.3 provides an overview of modelled emissions under CORSIA for approved SAF production pathways as of March 2024, separated into Core LCA and ILUC values. Work is ongoing to approve the methodology for calculating the GHG emissions reductions for Power-to-Liquid fuels, where the main lever for emission reductions is the source of electricity to obtain the hydrogen and the source of carbon, which are both required for PtL fuels.

SAF and non-CO_2 emissions

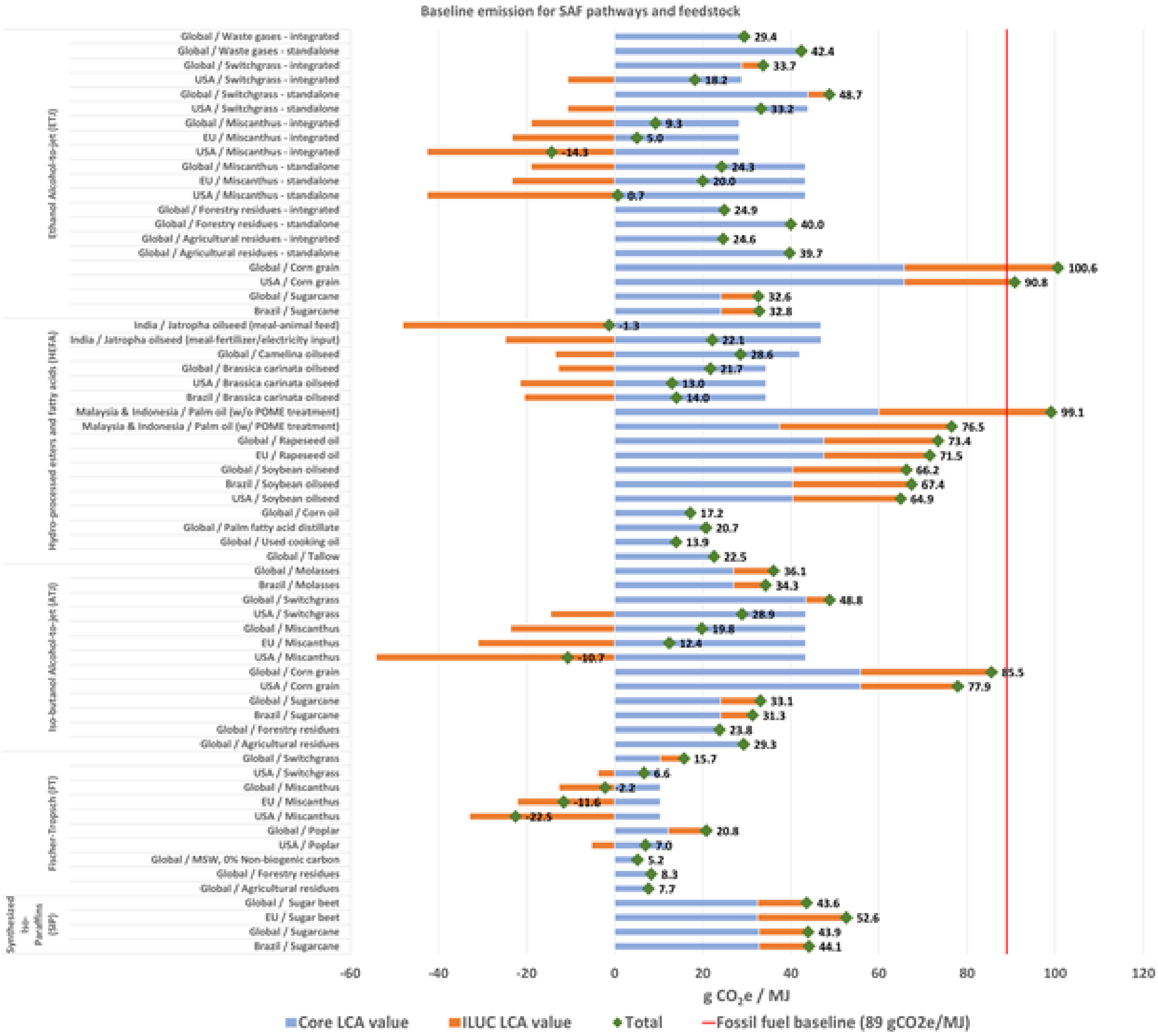
Aviation non-CO_2 emissions refer to pollutants other than carbon dioxide (CO_2) that have a climate impact, including nitrogen oxides (NO_X), aerosol particles (soot and sulphur-based) and water vapour. Some types of SAF have the potential to offer significant non-CO_2 emissions reductions [12, 13].

While it is recognised that aviation non-CO_2 emissions contribute to the overall climate impact, these non-CO_2 effects are currently only estimated with low confidence and substantial uncertainties. The revised EU ETS Directive requires aircraft operators to monitor and report once a year on the non-CO_2 aviation effects.

Research projects, such as AVIATOR and RAPTOR [14, 15] have shown that the use of certain types of SAF could have positive impacts on local air quality [16] due to lower levels of sulphur and aromatic content which contribute to volatile and non-volatile particulate matter (nvPM) emissions. Evidence of contrail reduction when using SAF has been collected and scientifically acknowledged since 2015 (ECLIF I) and further substantiated in the ECLIF II and ND-MAX projects (2018) [17].

In-flight measurements between 2021 and 2024 during the European ECLIF III and VOLCAN I and II research projects extended the studies by using 100% Drop-In and 100 % Non-Drop-In SAF in both modern rich-burn and learn-burn combustors. These tests demonstrated a significant contrail reduction due to lower nvPM emissions and ice crystal formations, thereby indicating positive effects on climate change mitigation through the use of SAF [18].

Figure 2.3 LCA emissions for CORSIA eligible SAF pathways and feedstock compared to CORSIA fossil fuel reference value (89 g CO_2e/MJ) [19][26]



Sustainability Certification Schemes – Combatting fraudulent practices.
With so much emphasis being placed on SAF to help reduce aviation emissions, the 'S' in SAF needs to live up to its promise and ensure the effective delivery of emission reductions while avoiding unintended negative environmental and social impacts of its production, thus contributing to the credibility of the sector. Major regulatory frameworks, such as the EU RED and CORSIA, therefore make use of Sustainability Certification Schemes (SCS). The objective of SCS is to ensure that SAF meet the required sustainability criteria by controlling the compliance with the sustainability requirements along the SAF value chain on a lifecycle basis. Audits are performed by ISO-accredited third-party certification bodies along the complete value chain, from raw material extraction to delivery of SAF to its point of use. In these audits, the auditor focuses on checking each economic operator's compliance with a defined

[26] Two different ATJ conversion plant layouts can be considered. The integrated plant layout assumes co-locating the ATJ process with ethanol production and emissions reductions as a result of heat integration. The standalone configuration assumes that ethanol is taken from the market or a separate ethanol production facility.

set of sustainability criteria as well as traceability (Chain of Custody) and life cycle emissions criteria, thus ensuring that SAF is produced in accordance with the relevant regulatory requirements (e.g. as per the EU RED or CORSIA).

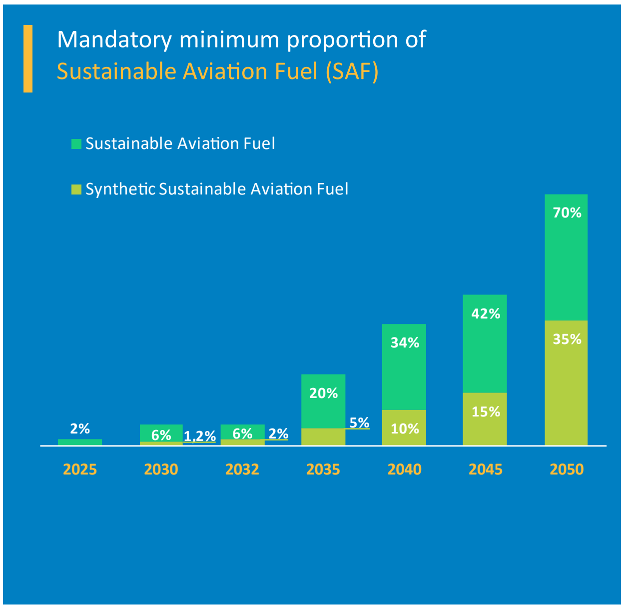
In recent years, SAF and biofuels upscaling has generated growing concerns about the fraudulent trading of non-sustainable feedstock or biofuels in the EU [20, 21]. Fraudulent behaviour may ensue whereby products are labelled as meeting sustainability requirements even when they are non-compliant. This is highly problematic insofar as these practices threaten both the effectiveness and credibility of climate and renewable energy policies.

NGOs and European biofuel producers have repeatedly warned against dubious imports and raised concerns about the effectiveness of the certification schemes, which in part led to the development of the EU Union Database that will increase the transparency and reliability of the tracking system of renewable fuels along their supply chains. The Union Database is appropriately integrated in the reporting process of SAF supplied to EU airports under the ReFuelEU Aviation Regulation and the EU ETS Directive.

In response to these concerns, certification schemes have generally increased their efforts to enhance the credibility of the system, including unannounced integrity audits at randomly selected plants and economic operators. As a result, some sustainability certificates were withdrawn or temporarily suspended. They have also put in place a transaction database that is linked with the EU Union Database to prevent the relabelling of sustainability declarations, a mapping tool to support risk identification for auditors, specific guidance materials for waste and residue materials and evaluations of the technical feasibility of processing plants to deal with low-grade advanced waste/residue material [22].

2.4 SAF Policy Actions

ReFuelEU Aviation



The ReFuelEU Aviation Regulation sets out EU-level harmonised obligations on aviation fuel suppliers, aircraft operators and Union airports for scaling up SAF used for flights departing from all EU airports above a certain annual traffic thresholds (passenger traffic above 800,000 or freight traffic above 100,000 tons). Starting in 2025, aviation fuel suppliers are required to supply a minimum of 2% blend of SAF with conventional fossil-based fuels to Union airports and this gradually increases to at least 70% by 2050. Synthetic aviation fuels are subject to an ambitious sub-mandate, starting with 1.2% in 2030, 2% in 2032 and reaching 35% in 2050 [1]. Aircraft operators departing from EU airports must also refuel with the aviation fuel necessary to operate the flight. This avoids the excessive emissions related to extra weight and minimises the risks of carbon leakage caused by so-called ‘economic tankering’ practices. Between 2025 and 2034, aviation fuel suppliers can supply the minimum shares of SAF as an average over all the aviation fuel they have supplied across Union airports for that reporting period. This flexibility mechanism allows the industry to develop the production and supply capacity accordingly and the fuel suppliers to meet their obligations in the most cost-effective way without reducing the overall ambition. The Commission's Report will identify and assess the developments on SAF production and supply on the Union aviation fuel market, as well as assess possible improvements or additional measures to the existing flexibility mechanism, such as setting a potential accounting and trading mechanism for SAF (a so-called 'book and claim' system). [27]

In order to support the achievement of the ReFuelEU Aviation supply mandate, the EU has put in place various regulatory, financial and other supporting measures, including:

- A zero emissions rating of RED-compliant SAF used under the EU Emissions Trading System (ETS);
- A maximum of 20 million extra ETS (with an estimated value of €1.6 billion) allowances will be allocated to aircraft operators during 2024 to 2030 for the uplifting of SAF to also cover part of, or all of the price difference with fossil kerosene, depending on the type of SAF and the uplift location;
- A fuel tax structure under the proposed revision of Energy Taxation Directive that would incentivise SAF over fossil kerosene through preferential tax rates;
- A flight emissions label laying down harmonized rules for the estimation of airline emissions taking into account SAF uptake;
- The inclusion in the EU Taxonomy of SAF production and uptake to improve access to green finance;
- R&D and deployment financing support under Horizon Europe, Innovation Fund, InvestEU programmes to de-risk SAF production at all technology maturity stages;
- The accelerated qualification of new SAF technologies and approval of new production plants through creation of EU SAF Clearing House and inclusion of SAF in the Net Zero Industry Act proposal;
- Cross-sectoral cooperation in the Renewable and Low-Carbon Fuels Value Chain Industrial Alliance (RLCF Alliance). The RLCF Alliance, as the industrial pillar of ReFuelEU Aviation to support SAF supply, and emergence of SAF projects and match-making with potential fuel offtakers, is open to all stakeholders.

ICAO Conference on Aviation Alternative Fuels (CAAF/3)

The third ICAO Conference on Aviation Alternative Fuels (CAAF/3) was held in November 2023, during which ICAO Member States agreed on the ICAO Global Framework for SAF, Lower Carbon Aviation Fuels (LCAF) and other Aviation Cleaner Energies. This includes a collective global aspirational vision to reduce CO_2 emissions from international aviation by 5% in 2030 with the increased production of SAF, LCAF and other initiatives [23]. Building blocks in terms of policy and planning, regulatory framework, implementation support and financing will be key in achieving this goal. The vision will be continually monitored and periodically reviewed, including through the convening of CAAF/4 no later than 2028, with a view to updating the ambition on the basis of market developments in all regions.

The ReFuelEU Aviation Regulation also foresees a thorough monitoring and reporting system of SAF supply and usage that will provide an overview of the European SAF market and form part of future editions of this report. This reporting is linked with an enforcement mechanism consisting of penalties imposed by Member States for the cases of non-compliance from fuel suppliers and aircraft operators.

First in 2027 and every four years thereafter, the European Commission will present a detailed assessment of the SAF market and the possible need to revise the scope of the Regulation, the eligible fuels, the minimum shares and the level of fines for non-compliance. It will also include an assessment of possible support mechanisms for production and uptake of SAF.

ECAC States policy actions

Switzerland set out a SAF strategy with the goal that SAF shall contribute a minimum of 60% to net CO_2 reductions in Swiss civil aviation by 2050, contributing to the Swiss goal of reaching net-zero CO_2 emissions in 2050. It is accompanied by a legislative proposal that includes a blending mandate and provision of funding for the development of SAF production pathways, planned to enter into force in 2025. To avoid market distortion, the mandate shall be aligned with ReFuelEU Aviation. Turkey is also planning to develop dedicated SAF regulations to incentivize its uptake [24]. The United Kingdom SAF policy includes a SAF Mandate to drive an ambitious ramp-up of SAF in the aviation fuel supply, starting with 2% in 2025, increasing linearly to 10% in 2030 and reaching 22% in 2040. The Mandate includes a cap on the amount of HEFA SAF used to meet obligations, and there is a separate obligation for power-to-liquid fuels, starting in 2028 with 0.2% of the total fuel supply and reaching 3.5% in 2040. [25].

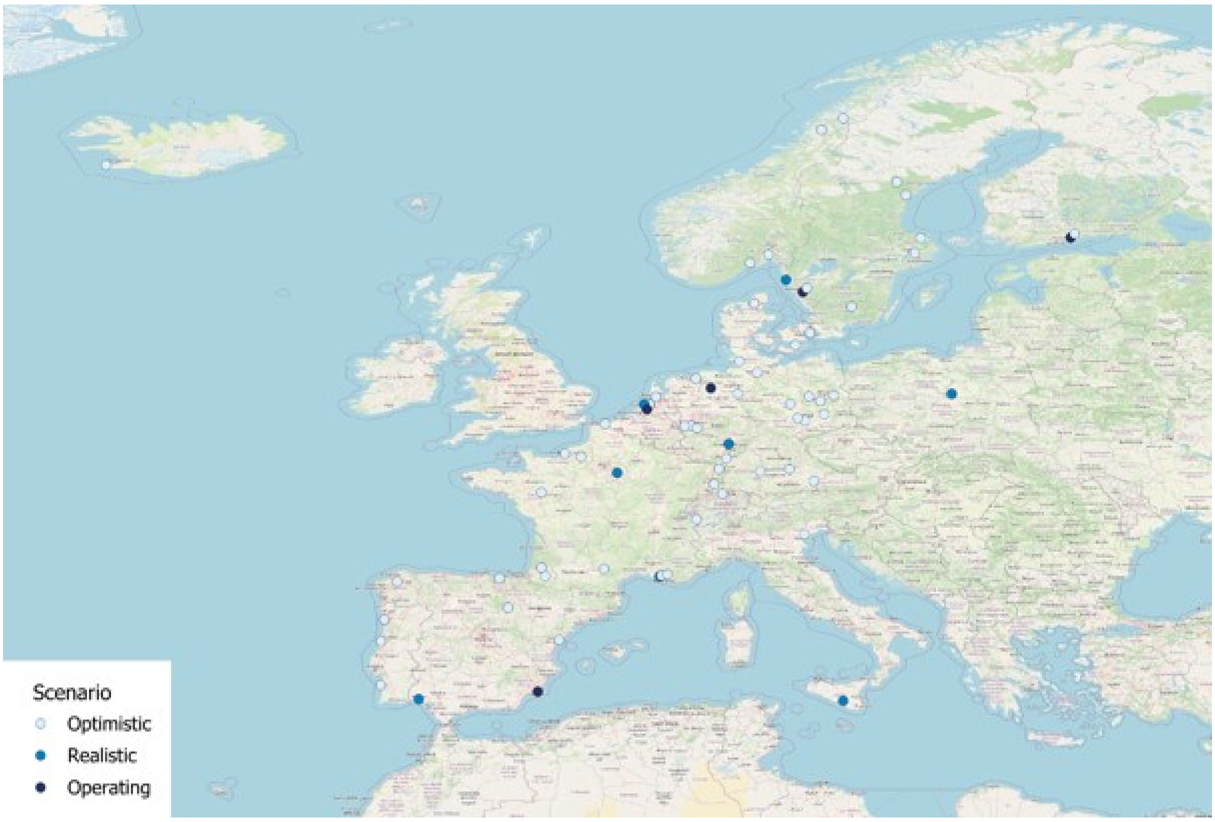
2.5 SAF Market

Global SAF production represented only 0.53% of jet fuel use in 2024, up from 0.2% in 2023 [26, 27, 28]. The EU SAF market, incentivized following the adoption of the ReFuelEU Aviation Regulation and the revision of the EU ETS and the RED, is now in a transition phase. The regulation requires a significant expansion of the production capacity in order to avoid the EU market becoming overly reliant on imports. Starting in 2025, fuel suppliers are mandated to supply a growing amount of SAF to Union airports. EASA is tasked with monitoring and reporting under the regulation and will produce annual reports, which will include a status of the evolving SAF market.

Current and future SAF production capacity

According to information collated with the support of ReFuelEU Aviation Member State Network (Figure 2.5), established by EASA to support the implementation of the Regulation, the current annual SAF production capacity in the EU is just above 1 million tonnes (Mt). Almost all this SAF production is HEFA and does not account for co-processing production using sustainable feedstock in fossil fuel plants, for which there is not enough reliable information. This could be considered to be an 'operating scenario'.

Figure 2.5 Projected EU SAF facilities in 2030 under the Optimistic scenario



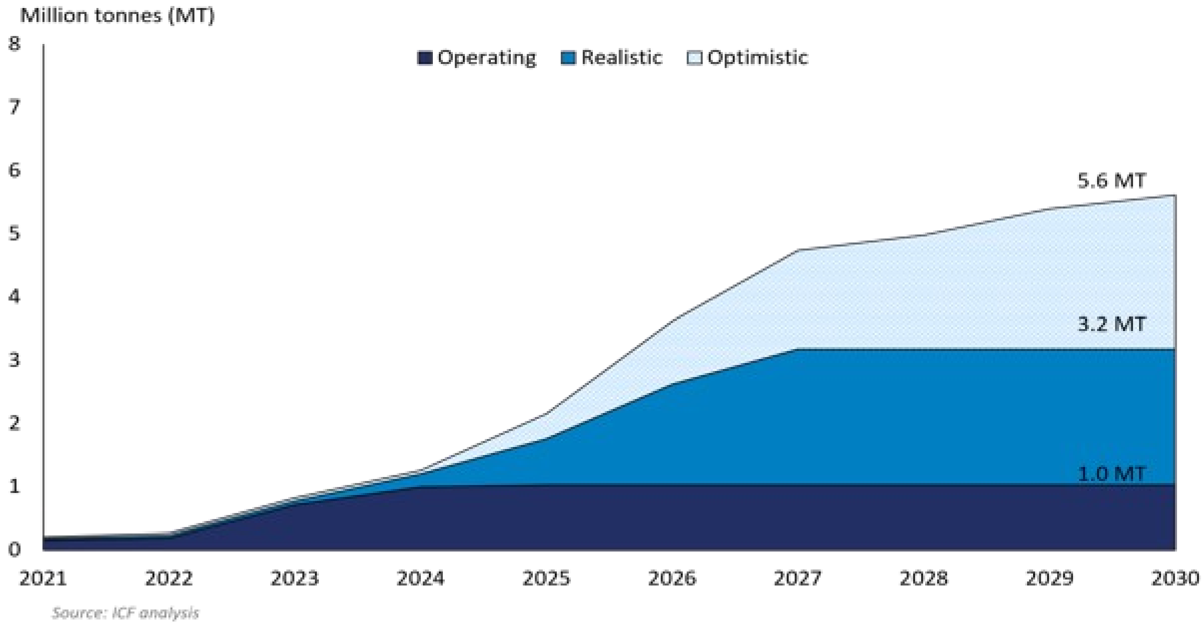
If facilities that are currently under construction are taken into account, the amount of SAF production capacity in 2030 could reach 3.5 Mt. This could be considered a 'realistic scenario'. Again, almost all this production would be dominated by the HEFA production pathway and does not include any Power-to-Liquid (PtL) production, as no plant has yet evolved beyond a pilot stage. Other studies come to different conclusions, mostly due to a different set of assumptions and methodologies. The recent SkyNRG Market Outlook from June 2024 [29] estimates 3.8 Mt by 2030, including 0.3 Mt of PtL as well as some co-processing production, while IEA predicts roughly 3.8 Mt by 2038 [30]. In both cases, a significant acceleration in the construction of PtL plants will be needed to meet the first sub-mandate of 0.7% in 2030.

In addition to the operating and realistic scenarios, both the ReFuelEU Aviation Member State Network and the SkyNRG Market Outlook collected information to build up an 'optimistic scenario'.

This includes all projects in the pipeline to be in operation by 2030 and includes PtL projects, leading to a projected SAF capacity of 5.9 Mt and 5.5 Mt respectively.

Figure 2.6 illustrates all of the above scenarios out to 2030. While the realistic scenario (3.5 Mt) would be able to meet the projected demand of the 6% mandate by 2030 (2.8 Mt), significant growth in production capacity is required to fulfil the very ambitious ramp-up to 20% in the subsequent 2030-2035 period.

Figure 2.6 Projected EU SAF capacity in 2030 by scenario



Beyond 2030, projections of production capacity are more challenging and the potential SAF production will depend on the availability of feedstocks (e.g. HEFA, green hydrogen, renewable energy). The aviation industry will be competing with other sectors as part of the economy wide decarbonization efforts where these feedstocks could be used to directly decarbonize the primary energy supply. As a result, securing these sources of renewable energy will be critical to ensure the ramp-up of PtL SAF production within Europe. There are positive signals in particular from the solar industry, where the growth of global installation capacity is accelerating faster than anticipated and becoming the largest source of new electricity, with solar capacity doubling every three years and hence growing ten-fold every decade [31]. Overall, renewable energy passed 30% of the total global energy supply for the first time in 2023 [32]. By the 2030s, solar energy is likely to become the biggest source of electrical power and by the 2040s it may be the largest source of all energy [31].

Another limiting factor for SAF deployment towards 2050 is the capital expenditure required to build the production facilities. It is estimated that between 500-800 SAF facilities[27] will be needed globally by 2050, which, assuming €1.8 billion per facility, would result in around €36 billion capital expenditure annually between 2025 and 2050 [29].

Estimations of the future SAF landscape have concluded that indeed PtL fuels have the potential to cover 50% of the global SAF production capacity by 2050. Whereas HEFA production will be

[27] Assuming 0.3 – 0.5 Mt average SAF output per year per facility.

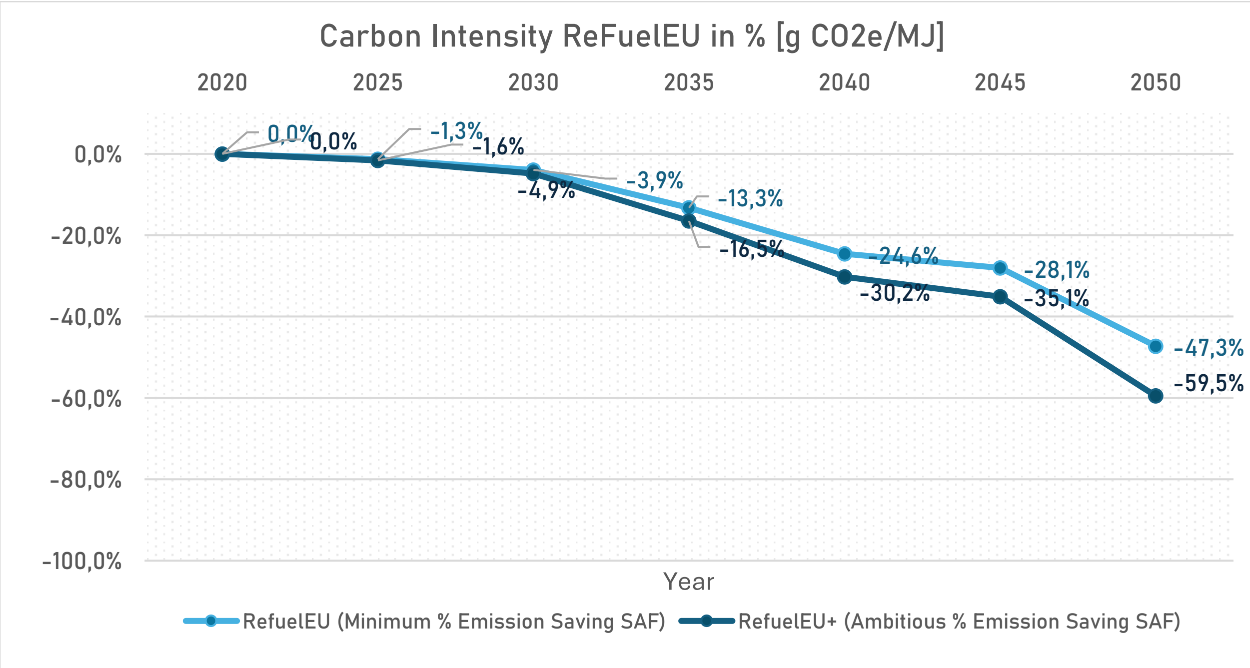
around 7% and AtJ / FT the remaining 43%. Projections by region also highlight the varying availabilities for feedstocks in the different parts of the world [33].

CO_2 emissions reductions

To estimate the potential CO_2 emission savings from the ReFuelEU Aviation Regulation, a comparison has been made between the carbon intensity reduction of global aviation fuel taking into account the SAF supplied and the EU RED fossil fuel baseline intensity of 94 gCO_2e/MJ.

Two scenarios were assessed, a 'minimum' emissions saving and a more 'ambitious' scenario. The scenarios differ in the assumed emission reductions achieved by the (advanced) biofuels mandate and the RFNBO (PtL) fuel sub-mandate. The minimum scenario assumes a 65% and 70% emission reduction for biofuels and RFNBOs over their lifecycle respectively, which aligns with the minimum requirements set out in the ReFuelEU Aviation Regulation [1]. The second, more ambitious scenario assumes 80% and 90% emission reductions respectively for the two SAF types.

Figure 2.8 % CO_2eq emissions reductions from the uptake of SAF under ReFuelEU Aviation scenarios



SAF Price

The price of SAF is one of the most critical factors when it comes to its uptake, as fuel costs currently represent a large share of the operational cost of aircraft operators (approx. 30%). In 2023, the price of conventional jet fuel averaged around €816 per tonne and is a figure that is readily available from Price Reporting Agencies (PRA) indexes [34].[28, 29] When assessing the prices for ReFuelEU Aviation eligible SAF, a differentiation was made with SAF that are currently available on the market, and SAF for which only production cost estimations can be performed due to the market not being mature enough yet. For the former, only aviation biofuels that are produced from

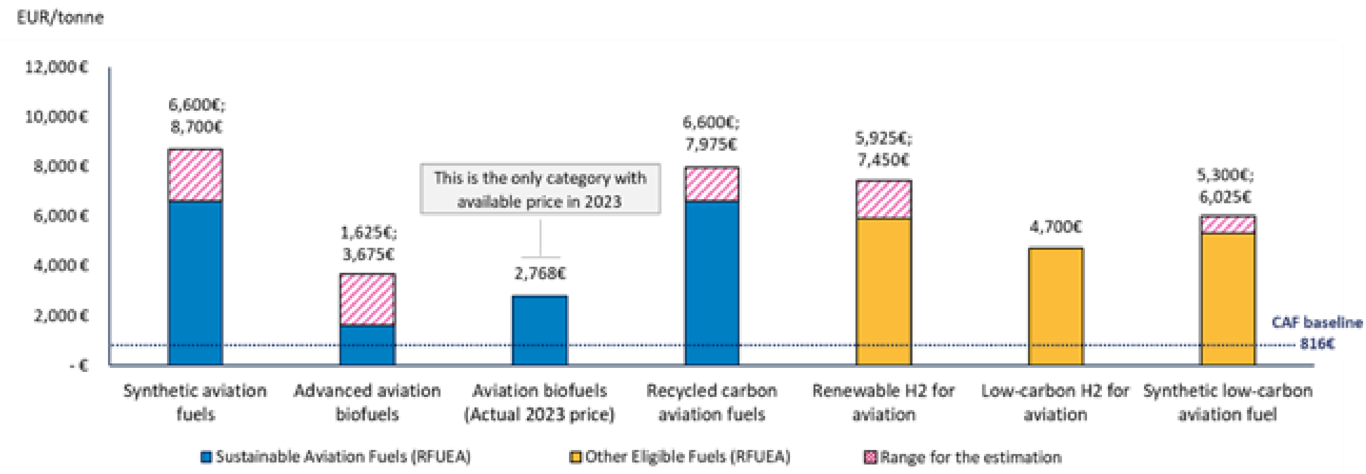
[28] Price Reporting Agencies (PRA) used as data source: S&P Global Commodity Insights (Platts), Argus Media and General Index.
[29] With the density of kerosene of around 0.8 g/cm3, this results in a price of around 1.02€/l.

feedstock listed in Part B Annex IX of the Renewable Energy Directive have a market availability in 2023. The average price for these SAF was around €2768 per tonne in 2023, using as a reference the relevant indexes from the PRAs.

For fuels that had no market availability in 2023, production cost estimations were developed based on feedstock, energy and technology deployment costs resulting in prices that range from €1600 per tonne for advanced aviation biofuels to €8700 per tonne for PtL fuels. Figure 6.9 illustrates the estimated price ranges for the different eligible fuels under ReFuelEU Aviation in 2023. These production costs are expected to reduce substantially as emerging SAF and hydrogen production technologies scale up, and associated costs reduce.

Especially for PtL fuels, for which the energy price is a key cost driver, the differences in energy prices across Europe may play a role in where the production is most attractive and competitive for such fuels in the future [35, 36].

Figure 2.9 Estimated prices and production costs in 2023 for ReFuelEU Aviation eligible fuels



STAKEHOLDER ACTIONS

Central Europe Pipeline System: First delivery of SAF

The Central Europe Pipeline System (CEPS) [37] is the largest fuel supply system in NATO and crosses Belgium, France, Germany, Luxemburg and the Netherlands and comprises of approx. 5,300 km of pipeline. It delivers jet fuel to major civil airports such as Frankfurt, Brussels, Luxembourg, Zurich and Schiphol (Amsterdam). Following the permission of NATO, the connected airports have been able to receive SAF blends through CEPS since 2023.

Neste cooperated with Brussels Airlines to deliver sustainable aviation fuel to the airline at Brussels Airport on January 1, 2023. This marked the first time that SAF was supplied to an airline at a European airport using the NATO CEPS. It showcases how existing fuel infrastructure can be used to supply SAF to airports.

Delivering CORSIA certified SAF to airlines [38]

In July 2022, Neste delivered the first ever CORSIA certified batch of SAF (Neste MY Sustainable Aviation Fuel™) to American Airlines at San Francisco International Airport in July 2022. This was part of a pilot to certify SAF as a CORSIA Eligible Fuel that can be used by an airline to meet its emissions obligation under the Carbon Offsetting and Reduction Scheme for International Aviation ('CORSIA'), which is a market-based measure to lower CO_2 emissions for international flights and reduce aviation's contribution to climate change.

First flight in history with 100% sustainable aviation fuel on a regional commercial aircraft [39]

Regional aircraft manufacturer ATR, Swedish airline Braathens Regional Airlines and Neste have collaborated to enable the first ever 100% SAF-powered test flight on a commercial regional aircraft.

The flight took place in Sweden in July 2022 and is part of the 100% SAF certification process of ATR aircraft that started in September 2021.

Bringing together airlines and corporates [40]

Project Runway is an initiative launched by SkyNRG in June 2024 and brings together airlines and corporates to provide easy access to SAF. The project will support airlines in navigating the complexities of SAF procurement and provide an effective way to reduce their greenhouse gas emissions. Project Runway facilitates airlines access to SAF and allows them to share the SAF price premium with ambitious corporates aiming to reduce their own Scope 3 aviation emissions.

Modular Power-to-X plants [41]

The modular chemical plants for power-to-X and gas-to-liquid applications developed by INERATEC use hydrogen from renewable electricity and greenhouse gases such as CO_2 to produce, among other products, Power-To-Liquid fuels. The modular approach is being used for the first time in a pioneer plant and large-scale industrial PtL project in Germany. The modular concept of the plants allows scalability over several stages, keeping the planning and construction efforts manageable and improving the cost-benefit ratio.

First trans-Atlantic flight on 100% Drop-In Sustainable Aviation Fuel [42]

In 2023, Virgin Atlantic Flight 100 flew on 100% SAF from London to New York, marking the culmination of a year of collaboration to demonstrate the capability of SAF as a safe drop-in replacement for fossil derived jet fuel that is compatible with today's engines, airframes, and fuel infrastructure. Flown on a Boeing 787, using Rolls-Royce Trent 1000 engines, the flight marked a world first on 100% Drop-In SAF by a commercial airline across the Atlantic. The SAF used was 88% HEFA (Hydroprocessed Esters and Fatty Acids) made from waste fats and 12% SAK (Synthetic Aromatic Kerosene) made from plant sugars. It is estimated that the use of SAF reduced nvPM emissions by 40% and CO_2 emissions by 64%, as well as an overall improvement in fuel burn efficiency as the SAF produced 1% more energy compared to the same mass of fossil fuel.

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3. AIR TRAFFIC MANAGEMENT AND OPERATIONAL IMPROVEMENTS

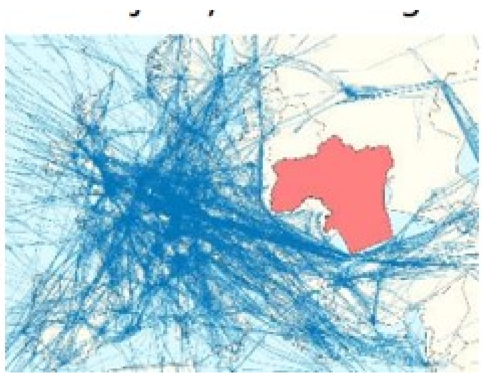
- The Single European Sky (SES2+) proposal of the Commission was formally adopted by the Council and the European Parliament in 2024, although only modest progress was made and various issues were left unresolved.
- Implementation of SES2+, and a focus on continuous improvement to address unresolved issues, is critical to enhance capacity, efficiency and sustainability.
- RP4 (2025-2029) SES performance targets reflect the ambition to enhance environmental performance, as does the desire to develop improved environmental monitoring indicators while building up resilience and strengthening capacity.
- It is recognized that the SES performance scheme needs to be improved in terms of the ATM-related performance indicators for environment. Work is ongoing to identify a more robust KPI which, after a period of monitoring and analysis during RP4, will be ready for performance target setting in RP5.
- Updated SES ATM Master Plan has been aligned with the RP4 ambitions such that ANSPs invest in technologies to provide greener, smarter and more effective air traffic.
- Ambitious environmental performance targets cannot be achieved unless the ATM system supports and incentivises all stakeholders to optimize the efficiency of their operations.
- 400 million tonnes of CO_2 emissions (9.3% less CO_2 per flight) could be saved with the completion of the SES ATM Master Plan vision by 2050.
- The war in Ukraine and the Middle East conflict, and the subsequent impact on EU airspace, has made it more difficult to assess whether ATM actions towards improving environmental performance indicators have resulted in tangible benefits.
- During busy periods, Air Traffic Controllers may need to use alternative procedures to maintain required aircraft separation, thereby limiting the capacity to accommodate fuel

efficient Continuous Descent Operations.

- Total gate to gate CO_2 emissions broken down by flight phase indicates that highest emissions originate from cruise phase (62.9%) and climb phase (23.2%).
- The implementation of cross-border, free route airspace (FRA) significantly improves en-route environmental performance. Up to 94,000 tonnes of annual CO_2 emissions are estimated to be saved by 2026 through the Borealis Alliace FRA implementation among 9 States.
- Air traffic control strikes in 2023 had a significant environmental impact with an additional 96,000 km flown and 1,200 tonnes of CO_2 emissions due to knock-on effects across neighbouring States and the wider SES Network.
- SESAR study estimated that €1 invested in Common Project 1 (CP1) ATM functionalities during 2023 resulted in €1.5 in monetizable benefits and 0.6 kg of CO_2 savings, and these benefits are expected to increase overtime as CP1 is fully implemented.

3.1 Single European Sky

In the last few years, air traffic has continued to recover following the COVID pandemic and the number of flights to or from EU27+EFTA airports was 8.35 million during 2023. This is a 8.5% increase compared to 2022 (7.69 million) but still 9.1% below the level of 2019 (9.19 million). Growth rates at the State level have been unevenly distributed due to changes in traffic flows resulting from the war in Ukraine since 2022, changes in holiday traffic and less domestic traffic in several States.



The closure of Ukraine's airspace to commercial traffic was amplified by reciprocal airspace bans for Russian and many Western operators. While most of the European traffic is not directly affected by the airspace closures, east-west flights between Europe and Asia that previously travelled through Russian airspace need to divert, which adds travel time and fuel burn thereby lowering flight efficiency.

In 2004, the Commission launched the Single European Sky (SES) [1] representing a holistic framework to harmonise and improve the performance of Air Traffic Management (ATM) in terms of safety, capacity, cost-efficiency and the environment. The SES builds on five interrelated pillars: economic regulation, airspace organisation/network management, technological innovation, safety and Human Dimension. The SESAR (Single European Sky ATM Research and Development) project is the technological innovation pillar of the SES aiming to modernise ATM through the innovation cycle of defining, developing and deploying innovative technological systems and operational procedures. The goal is to achieve the 'digital European sky' defined in the European ATM Master Plan [2], which is a common roadmap to establish Europe as the most efficient and environmentally friendly sky in the world. It includes the goal to reduce the average CO_2 emission per flight by 9.3% (600 kg) by 2050. A key element in achieving that is goal is the deployment of Common Project One (CP1) [25], which facilitate service provision along optimized routes from gate to gate and thereby reduce both CO_2 and non-CO_2 emissions.

The SES has evolved over time and has significantly benefited ATM in Europe. Nevertheless, a profound reform of the SES was considered necessary to more effectively reach the above-mentioned objectives, which led to the Commission launching the 'SES2+' proposal in 2020. The process for adopting the SES2+ was challenging and heavily discussed, but a political agreement was finally reached between the European Parliament and the Council and the new Regulation was adopted in 2024.

While the SES2+ outcome strengthens economic performance regulation and incentivises environmental performance by establishing the Performance Review Body (PRB) on a permanent basis, only modest progress was made and many issues were left unresolved. For example, the Network Manager[30] lacks the means to ensure that ANSPs deliver the promised and much needed capacity to the network when demand from airlines is high. In addition, while SESAR has enhanced coordination between stakeholders through the ATM innovation cycle, the transition from development to deployment of SESAR solutions by ANSPs, airport operators and airspace users across Europe has proven difficult and subsequently led to insufficient progress in modernising the ATM system. This may be due to national requirements in airspace design and security issues, thereby making it complex in identifying universal solutions for monopolistic and state-owned Air Navigation Service Providers (ANSPs). All these points could contribute to challenges in terms of adopting technological innovation, responsiveness to demand and cost base adjustments, and cooperation between ANSPs.

The goal of climate neutrality by 2050 calls for the EU to ensure decarbonisation of the air transport sector. Likewise, the Zero Pollution Action Plan includes goals for reducing impacts from noise and air quality. Ambitious targets such as these cannot be achieved unless the ATM system supports and incentivises air navigation service providers (ANSPs), airport operators and aircraft users to optimize the efficiency of their operations and thus reduce excess fuel burn and emissions to a minimum.

Enhanced airspace organisation that minimises the inefficient use of available airspace, primarily through improved airspace and air traffic control sector design and effective airspace management procedures (civil-military coordination), are additional ATM tools to enable and allow for fuel efficient flight trajectories. Continuous improvement should be fostered at both local and network level.

While a significant progress has already been made in the ATM domain, it is important to now implement the SES2+ reform and focus on continuous improvements in infrastructure and operational procedures, notably through closer cooperation between all stakeholders and faster deployment of SESAR solutions.

[30] Commission Implementing Decision (EU) 2019/709 [4] renewed the appointment of EUROCONTROL as Network Manager (NM) for the period 2020-2029. EASA continues to act as the competent authority that certifies and oversees the NM. The NM coordinates operational stakeholders in order to manage demand through flow and capacity management, thereby optimising the network performance to limit unnecessary fuel burn and emissions.

3.2 SES environmental performance and targets

Overall context

Reference Period 2 (RP2)	2015-2019
Reference Period 3 (RP3)	2020-2024
Reference Period 4 (RP4)	2025-2029
Reference Period 5 (RP5)	2030 -2034

The SES Performance and Charging Scheme [6] defines key performance indicators (KPIs) for air navigation services and network functions, which are used for performance target setting at Union-wide and local levels in the key performance areas (KPAs) of environment, safety, cost efficiency and capacity. SES Performance Scheme Reference Periods (RP) are divided into five-year periods. This report captures the results of RP2 and RP3, while highlighting intentions for RP4 and preparations for future RP5 changes (e.g. safety monitoring but no KPA, climate and environmental KPA). The environmental performance dimension of SES involves both target setting to drive improvements as well as and the monitoring and reporting on environmental performance indicators.

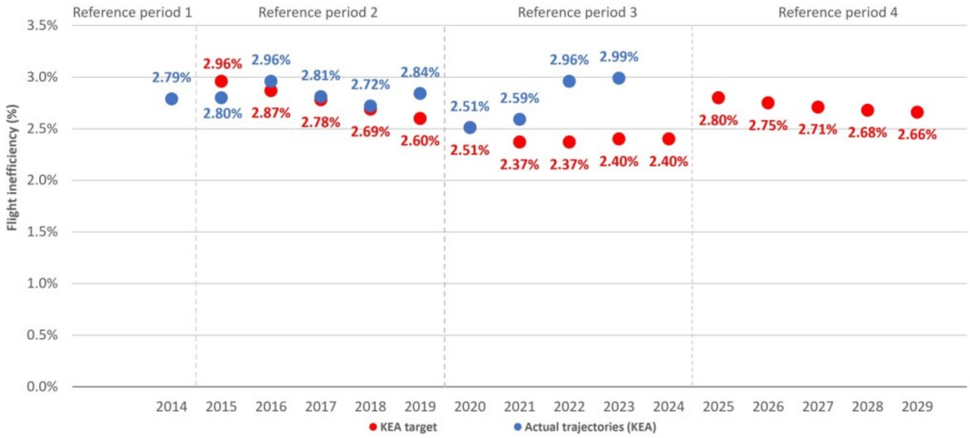
Key Performance Indicator for environment (with targets)

During RP3, environmental performance has been measured through one KPI, namely horizontal en-route flight efficiency of the actual flight path (KEA). KEA measures the additional distance flown in comparison to the great circle distance (shortest distance between two airports).

The higher the KEA inefficiency value, the worse the performance. However, other factors such as wind, weather, airspace structures, and network constraints influence the optimum trajectory. One of the objectives of the SES2+ proposal from the Commission was to develop a more suitable KPI on environmental performance for RP4. However, due to the duration of the negotiations and adoption of the SES2+ legislation, this was not possible and is now planned for RP5.

Following the COVID pandemic, environmental performance measured against the KEA KPI deteriorated significantly in 2022 and 2023 (Figure 3.1). EU Member States were not able to meet, by a wide margin, the Union-wide environmental performance targets set for 2022 (2.37%) and for 2023 (2.40%). Unfortunately, the impact of the war in Ukraine and the subsequent restrictions in parts of EU airspace made it more difficult to assess whether ATM actions towards improving the KEA actually resulted in tangible benefits. The PRB estimates that over 26 million kilometres of additional distance was flown in 2022 as a result of missing the Union-wide target by 0.59%. This equates to approximately 118 million kilograms of excess fuel burnt (375 million kilograms of CO_2).

Figure 3.1 KEA horizontal en-route flight inefficiency and targets for 2014 to 2029



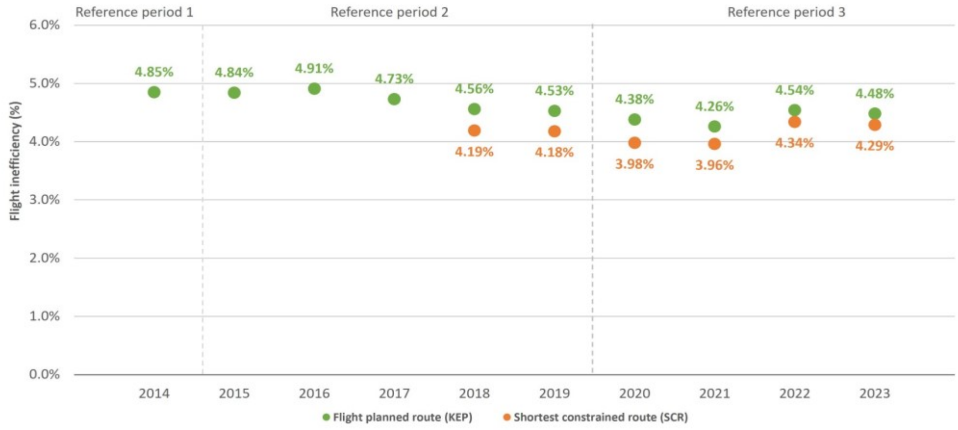
Performance Indicators for monitoring (without targets)

The Performance Scheme includes various indicators that are only monitored at either EU-level or local level but with no binding targets. These include the average horizontal en-route flight efficiency of the last filed flight plan trajectory (KEP)[31] and the shortest constrained trajectory (KES/SCR)[32]. As with all other indicators, KEP and KES/SCR (Figure 4.2) have been significantly affected by the war in Ukraine leading to general increases of inefficiency during 2022 and 2023, although there has been a reduction in the delta between KES/SCR and KEP. As with KEA, it is recognized that more suitable indicators are needed to give a clearer indication on the effectiveness of ANSP and Network Manager actions.

[31] The difference between the length of the en-route part of the last filed flight plan trajectory and the corresponding portion of the great circle distance, summed over all IFR flights within or traversing the European airspace.

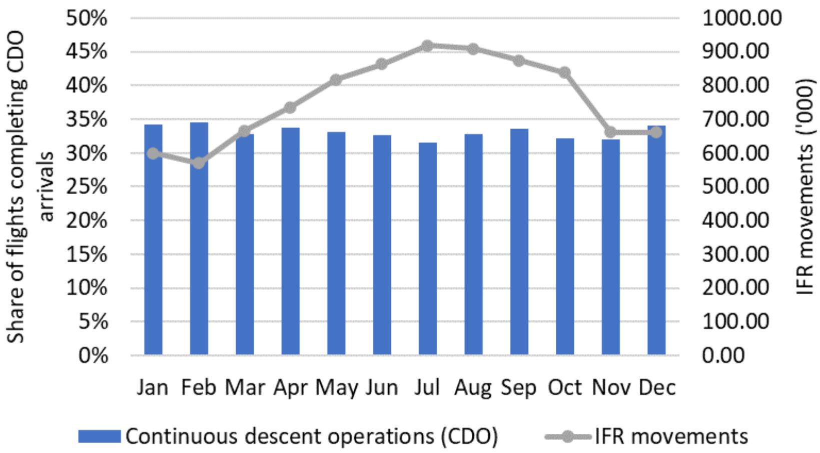
[32] The difference between the length of the en-route part of the shortest constrained route available for flight planning, as calculated by the path finding algorithms and flight plan validation systems of the Network Manager, measured between the exit and entry points of two terminal manoeuvring areas, and the corresponding portion of the great circle distance summed over all IFR flights within or traversing the European airspace.

Figure 3.2 KEP horizontal en-route flight inefficiency and KES/SCR for 2014 to 2023



The share of flights completing Continuous Descent Operations (CDOs) in 2023 fell by only 0.03% compared to 2022 data. The trend in terms of monthly share of CDO flights during 2023 (Figure 4.3) was fairly steady at around 30-35%, even during the summer period with a significantly higher number of flights. Air Traffic Controllers (ATCOs) will endeavour to clear aircraft for a CDO when they can guarantee safe separation all the way to final approach. However, during busy periods, ATCOs may need to use alternative ATC procedures to maintain the required separation, such as radar vectoring and speed control, which are not compatible with CDOs. As such, Figure 3.3 illustrates that there is a limited capacity to accommodate CDOs during busier periods.

Figure 3.3 CDO vertical flight efficiency indicator for 2023



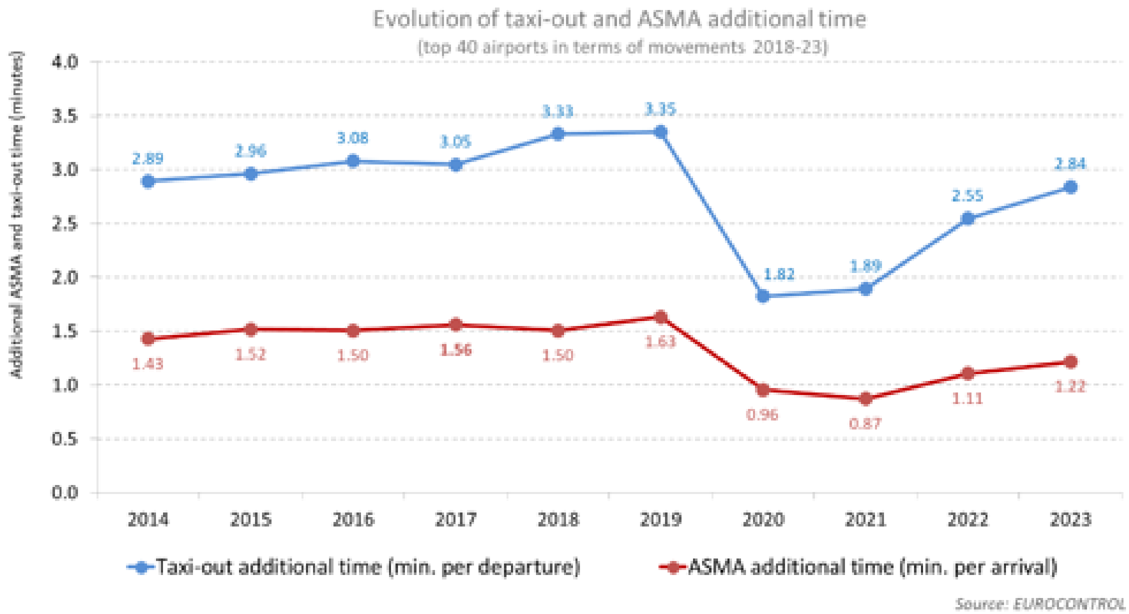
Restrictions on the number of CDOs are linked to the current ATM system. It is expected that with future Time-Based Operations (TBO), more CDOs would be facilitated by embedding them in aircraft fuel efficient trajectories.

Additional time in the Arrival Sequencing and Metering Area (ASMA time)

Additional ASMA time, otherwise known as airborne holdings, has a direct impact in terms of increased fuel burn. There is a clear interest in finding a balance between regulating arrivals by absorbing delays on the ground and airborne delays during the approach phase. Airborne delays allow for tactical management of the arrival flow, potentially optimizing the approach sequence and maximizing runway throughput. However, excessive airborne delays are unnecessary and have a clear impact on emissions. As per ASMA, extended taxi-out durations contribute to higher fuel consumption and CO_2 emissions. Recognizing that establishing a departure sequence enhances runway efficiency and that airports may occasionally need to clear stands for arriving flights, striking a balance between ATC pre-departure delays to regulate runway traffic and added taxi-out times is essential for minimizing environmental impacts.

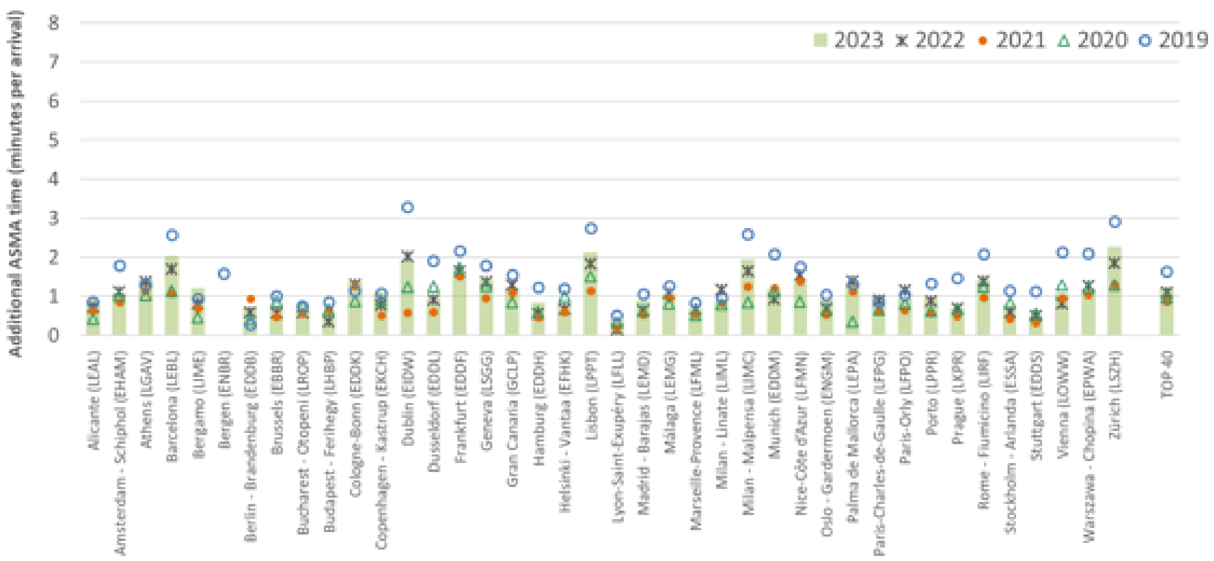
The evolution of both indicators follows a similar trend (Figure 3.4) with a slight increase during 2014-2019 followed by a significant decrease due to the drastic reduction in traffic during COVID. Traffic has since recovered such that it is only 10% below 2019 at the 40 busiest EU27+EFTA airports in 2023, while additional ASMA and taxi-out times are also increasing at the same time.

Figure 3.4 Average additional ASMA and taxi-out times for the busiest EU27+EFTA 40 airports in terms of flight movements



Significant variations exist between the top 40 busiest EU27+EFTA airports in terms of additional ASMA time (Figure 3.5).

Figure 3.5 ATM related inefficiencies on the arrival flow (AMSA) at the 40 busiest EU27+EFTA airports (2019-2023)



Forthcoming Reference Period 4 (2025-2029)

It remains essential for the ATM industry to maintain and even strengthen its commitment to contribute to the achievement of the European Green Deal goals and a more sustainable future of the aviation. The RP4 Union-wide performance targets [42] reflect the ambition of enhancing environmental performance and sustainability while building up resilience and strengthening capacity as well as reducing costs. It is also should be noted that PRB has developed a Traffic Light System to assess Member States environmental performance [43].

The PRB advice to the European Commission regarding the performance indicators for RP4 placed a focus on improving the ATM environmental performance by prioritising actions which enable airspace users to fly the most fuel-efficient trajectories, and thus reduce the fuel burn gate-to-gate [41]. In the interest of better flight efficiency in European airspace, all efforts need to be made by ANSPs and the Network Manager to support fuel-efficient trajectories, avoiding detours and delays due capacity hotspots.

Given the interdependency between the environment and capacity KPAs, it is crucial to address the long-term capacity shortages faced by certain ANSPs in order to enable the required environmental performance improvements. Such capacity issues have been observed since the second SES Reference Period (2015-2019), and they have re-emerged during the recovery from the COVID-19 crisis due to insufficient ATCOs in the core area of Europe to adequately meet traffic demand.

Recognising the forecasted traffic growth during RP4, which may impact the complexity of operations, and the continued consequences of the war in Ukraine, the future RP4 environmental targets improve following a step-wise approach with KEA targets reducing from 2.80% for 2025 to 2.66% for 2029. Progress has also been made in the development of new and revised performance monitoring indicators (PIs), including within the environmental area, that draw on the results of a study conducted by the Commission. These are currently being discussed by the Single Sky Committee with a view to their possible use during RP4.

Preparations for Reference Period 5 (2030-2034)

The new rules to be developed for the performance and charging scheme on the basis of the SES2+ Regulation will start to apply during RP5. This includes a single key performance area that would cover both environmental and climate aspects, as well as a requirement for binding targets for terminal air navigation services provided that adequate environmental indicators are identified and put in place.

The SES performance and charging scheme aims to capture the relationship between flight routing and environmental impacts, and existing indicators were previously regarded as reasonable proxy measures to incentivise ANSP efficiency. However, limitations with the current environmental KPI/PIs have been identified and were confirmed during the COVID pandemic, when some Member States were unable to meet their environmental targets despite a dramatic reduction in traffic. These weaknesses should be borne in mind when drawing conclusions on the basis of the existing KEA KPI, especially when considering the performance achieved at the level of an individual EU Member State's airspace.

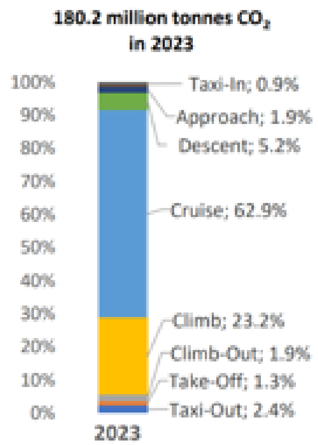
It is recognized that the SES performance scheme needs to be improved in terms of the ATM-related performance indicators for environment. KEA does not provide the needed granularity at national level to specifically assess the contribution of ATM to environmental efficiency. However, while this main KPI is not considered fit for purpose, gaining agreement on alternative has proved complicated. Work is now ongoing to find a more robust KPI which, after a period of monitoring and analysis during RP4, will be ready for performance target setting in RP5 and beyond.

3.3. Operational performance indicators

Total gate to gate CO_2 emissions

The total gate to gate CO_2 emissions within the EUROCONTROL area [39], or the part of the trajectory within the airspace for flights to and from the area, were 180.2 million tonnes in 2023, which represents an increase of 14% over 2022. Figure 3.6 illustrates the breakdown of these CO_2 emissions by flight phase and, as expected, the cruise and climb phases have the highest share of emissions with 63% and 23% respectively. While much less inefficiencies are detected in the climb phase than in the descent phase, and consequently more attention was given to the descent phase, it is important to note that even a small percentage of inefficiency during the climb can result in a significant amount of additional CO_2.

Figure 4.6 Total CO_2 emissions by flight phase within the EUROCONTROL area during 2023

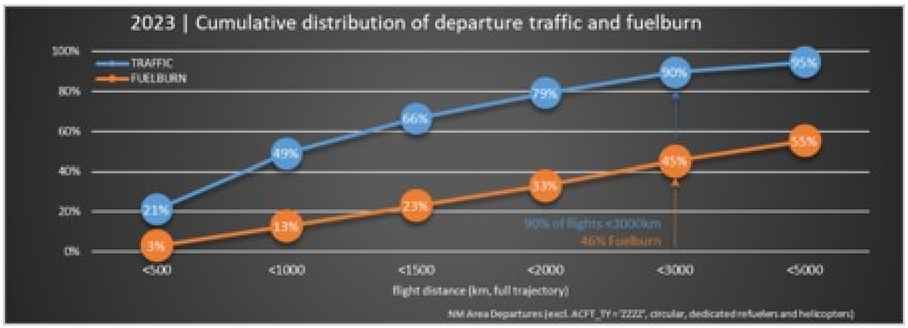


Network Fuel Burn

The SES Network Manager (NM) has developed an Excess Fuel Burn (XFB) metric as a measure of the fuel inefficiency on a particular route for a particular aircraft type, compared to a reference based on the best performer on that city pair / aircraft type combination.

Subsequently, the NM has enhanced its fuel burn dataset with fuel profiles for all flights, including fuel burn at specific points along the flight profile, and presents it in different ways on the NM's CO_2MPASS dashboard [30]. Figure 3.7 highlights that 95% of NM departures fly less than 5,000km and represent 55% of total fuel burn, meaning that just 5% of departures representing long-haul flights greater than 5,000km burn 45% of total fuel.

Figure 4.7 Cumulative distribution of departure and fuel burn in 2023



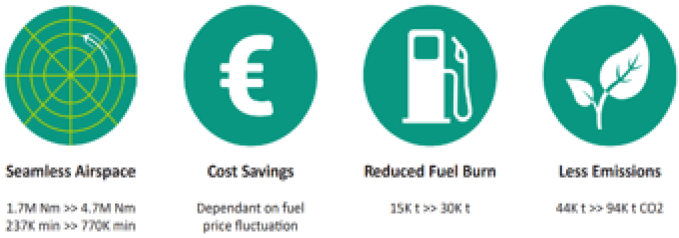
Free Route Airspace

Free Route Airspace (FRA) is a SESAR solution that is defined as a volume of airspace within which users may freely plan a route between any defined entry and exit points, subject to airspace availability [15]. The continuous implementation of FRA in Europe over the past years has been an enabler for improved flight efficiency, as it provides airlines with greater flexibility to file more efficient flight plans. However, FRA must not only be implemented but also applied by airlines to reap the benefits.

In line with the European ATM Master Plan and EC Regulation No. 2021/116, FRA implementation with cross-border dimension and connectivity to Terminal Manoeuvring Areas (TMA) should be completed by 31 December 2025. Cross-border FRA areas have been implemented between the following States:

- BALTIC FRA: Poland and Lithuania.
- BOREALIS FRA: Denmark, Estonia, Ireland, Iceland, Finland, Latvia, Norway, Sweden and United Kingdom.
- SECSI FRA: Albania, Austria, Bosnia and Herzegovina, Croatia, Montenegro, North Macedonia, Serbia and Slovenia.
- SEE FRA: Bulgaria, Czech Republic, Hungary, Republic of Moldova, Romania and Slovakia.
- BALTIC FRA and SEE FRA.
- SECSI FRA and FRA IT

The Borealis Alliance (a collaboration of ANSPs from Denmark, Estonia, Finland, Iceland, Ireland, Latvia, Norway, Sweden and the United Kingdom) is a pioneer in the implementation of a cross-border FRA among its nine national airspaces. Whilst implementation has been slowed down by the COVID crisis, full implementation is still planned by the end of 2026. The above figure illustrates the actual benefits of FRA achieved in 2018 and the estimated annual gains in 2026 with full FRA implementation.



Impact of strikes on European Aviation

Between 1 March and 9 April 2023, there were 34 days with industrial action impacting air transport in Europe, mostly in France but also, to a lesser extent, in Germany. As context, for the whole of 2022, there were 5 days of industrial action in France. The 34 days of strikes in 2023 potentially impacted 237,000 flights (flights to, from or across the countries mentioned above, mainly France). By comparison, the airspace closures in Europe resulting from the eruption of the Eyjafjallajökull volcano in 2010 (15-22 April) led to the disruption of some 100,000 flights.

In addition to the impact on passengers, strikes can also have a large environmental footprint. EUROCONTROL estimates that an extra 96,000 km were flown each strike day in 2023, with an average additional 386 tons of fuel burnt and 1,200 tons of CO_2 emissions [31]. The average cost to aircraft operators of cancellations and delays was €14 million per day.

Each Strike Day (during 7 March - 9 April)
96,000 additional km flown
386 tons of additional fuel burnt
1,200 additional tons of CO_2 emissions

As an example, on 12 March, around 40 flights had to extend their path by at least 370 km in order to avoid French airspace (when compared to their flight plans on 5 March, a non-strike day). These strikes also impacted up to 30% of flights across the continent, highlighting the disproportionate impact that disruptions in one country can have on neighbouring countries and the European Network as a whole. Although France does have minimum service provisions, preventing the complete closure of its ATC operations, these do not protect overflights. Minimum service regulations across Europe that protect overflights (such as are seen in, for example, Italy and Spain) would go some way to protect the flying public from the type of disruption as well as the associated environmental impact.

3.5 SESAR: Towards the digital European sky

SESAR Research and Development

The first SESAR Joint Undertaking was established in 2007 as the EU body responsible for the research and development phase of the SESAR innovation cycle. It has produced over 100 solutions with an estimated combined benefit that could enable a 4% reduction in CO_2 emissions per flight. The online SESAR solutions catalogue contains technical information on these solutions and their level of deployment as reported by European states [32].

The current SESAR 3 Joint Undertaking [36] has a 10-year mandate (2021-2031) to continue this work. During 2024, the European ATM Master Plan was updated to define the critical path for establishing Europe as the most efficient and environmentally friendly sky to fly in the world. It defines the Strategic Deployment Objectives and Development Priorities, providing a framework to facilitate the roll out of SESAR solutions and shaping the European position to drive the global agenda for ATM modernisation at ICAO level.

The implementation of a first critical sub-set of SESAR solutions is mandated by the Common Project 1 (CP1), ensuring a coordinated and timely deployment of key enablers for Trajectory-Based Operations (TBO) and for establishing a digital backbone for the Single European Sky (SES).

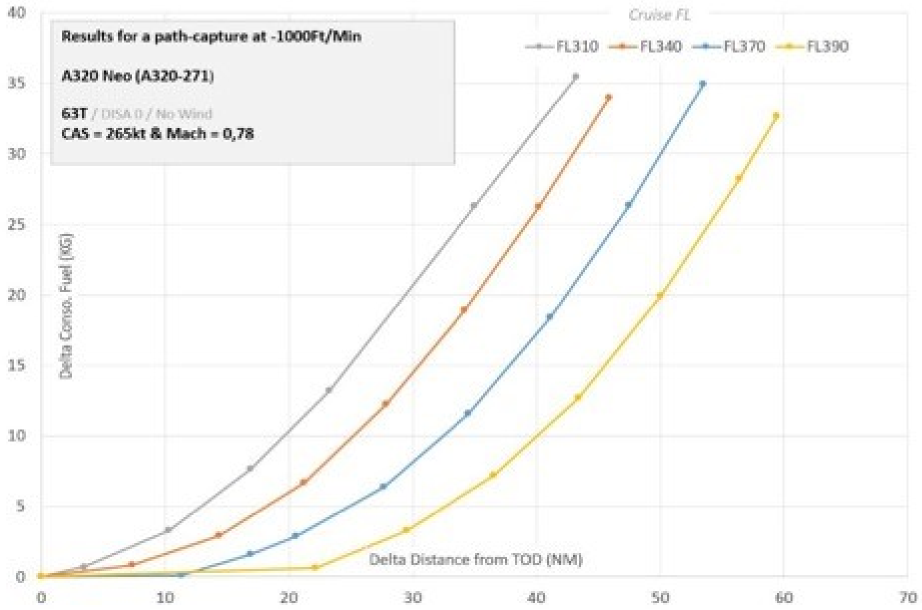
<u>Improvements in all phases of flight</u> SESAR addresses the full scope of aviation's environmental impacts, from CO_2 and non-CO_2 emissions to noise and air quality at every phase of flight.

- **TAXI phase**. During the ground part of the trajectory, a key objective is to reduce the engine-on time. Increasing the predictability of the take-off clearance time avoids waiting time at the runway holding point. In addition, single-engine taxi and engine-off taxi, where aircraft are towed by a sustainable taxi vehicle, can reduce overall engine emissions. The expected reduction of emissions from an engine-off taxi initiative can be over 50% that also was showed cased in ALBATROSS project [34].

- **CLIMB and DESCENT phases**. The focus in this phase is to leverage the availability of the optimum profile for each individual flight through the Extended Projected Profile (EPP), where aircraft tend to start their descent on average 35-70 nautical miles (nmi) before what would be their optimum Top-of-Descent (ToD) point[33]. This leads to long thrust descent, which is inefficient even if it does not include intermediate level-offs (Figure 3.8). The EPP provides visibility of the optimum top-of-climb and top-of-descent points on the ground, making it possible for air traffic controllers to facilitate a better trajectory. In addition, SESAR advocates a transition from conventional fixed arrival routes commonly used today, towards a more dynamic deployment of RNP (Required Navigation Performance) route structures within the Terminal Manoeuvring Area. Utilizing these dynamic routes increases capacity during peak periods, optimizes fuel consumption during off-peak hours, and decreases the noise footprint particularly during nighttime operations. Moreover, the adoption of these dynamic routes enables agile responses to fluctuations in operational conditions.

[33] SESAR Optimised Profile Descents Demonstration Report.

Figure 3.8 Increased fuel consumption as a function of the distance before the optimum Top of Descent that the descent phase is started, without intermediate level-offs (e.g. when a descent from cruise at FL370 is started 50nmi early, the additional fuel burn is 30 kg).



• **CRUISE phase**. Free route in the horizontal domain is already widely available in Europe. As such, the enhancement of vertical flight efficiency is a priority through the provision of sufficient airspace capacity for aircraft to fly at their optimum altitude. While the exact increase in emissions varies based on aircraft type and specific flight conditions, studies suggest that flying at lower altitudes can increase fuel consumption by approximately 6-12% compared to optimal cruising altitudes [21;22]. An increase in capacity can be achieved via digital and automation support for all ATM processes, including air traffic controllers, such as Dynamic Route Availability Document (RAD) that results in fewer vertical restrictions both at flight-planning and during the flight [33]. ATM may also evolve to support the deviation of flights to avoid cruising within airspace where non-CO_2 impacts are disproportionately high (referred to as eco-sensitive volumes).

The SESAR 3 Joint Undertaking has also provided support to operational stakeholders in the monitoring and management of their environmental performance in the planning, execution, and post-operation phases. At the airport level, this includes the full integration of environmental performance monitoring with the Airport Operations Plan (AOP) [35].

Trajectory optimisation in a digital environment

The deviation from the flight plan during the execution of the flight, for example by allowing an unplanned shortening of the flight path, allows fuel savings and reduced emissions for the flight concerned and its specific flight phase. However, this can have a negative impact on the predictability of the air traffic network, which in turn could have a negative impact on the environment. Trajectory-Based Operational (TBO) concepts ensure the free flow of information between air traffic management units and the Network Manager, allowing rapid sharing of trajectory information across the network and increased flexibility in the execution of the flight for airspace users.

The updated ATM Master Plan has defined the European TBO roadmap for the 2025–2045 period with the ambition of guaranteeing continuous and precise optimisation of all aircraft trajectories throughout their life cycle, from planning to execution, from gate to gate, even in congested airspace. With the potential introduction of zero emissions aircraft beyond 2035, their specific performance characteristics will also need to be considered in terms of any impact on the Network.

SESAR Deployment

The SESAR Deployment Manager [36] plans, synchronises, coordinates and monitors the implementation of the 'Common Projects' that mandate the synchronised deployment of selected ATM functionalities (AF) based on SESAR solutions. The current Common Project (CP1) [EU 2021/116] has 6 AF (Figure 3.9) aiming to reduce inefficiencies and thus generate fuel and CO_2 savings in different phases of the flight, especially cruise. The SESAR Deployment Programme [38] defines how the operational stakeholders will implement CP1 AF, which is due to be completed by 31 December 2027. The expected performance benefits from CP1 AF represent approximately 20% of the European ATM Master Plan performance ambitions for 2035 [40] and will be a critical step towards sustainable ATM-related aviation in Europe. 65% of CP1 CO_2 savings are expected to be found in the cruise phase, 25% in the descent phase and 10% in the taxi-out phase. By the end of 2023, [CP1] already delivered € 4.6bn worth of cumulative benefits. This value is set to reach € 19.4bn by 2030, once [the CP1] is fully deployed, whilst in a longer timespan [CP1] is expected to bring € 34.2bn worth of cumulative benefits by 2035 and € 52.3bn by 2040.

Figure 3.9 Overview of Common Projects 1 (CP1) ATM Functionalities

Table 3.10 below details the total CO_2 savings potential of concerned flights, that could be expected should all CP1 sub-AF concepts be deployed in the future ATM system with all technologies mature and realising their full benefits. The values in the table below represent an order of magnitude of CO_2 savings that can be expected from different sub-functionalities, and which highly depend on the specific conditions of the flight and the local situation.

Table 3.10 CO_2 savings per Common Project 1 ATM Functionality

CP1 Functionality		Fuel saving per flight concerned	CO2 savings per flight concerned	Time saving per flight concerned	% of ECAC flights concerned	Flight phase concerned
AF1	Departure Management Synchronised with Pre-departure sequencing	[2.9 – 10 kg]	[9.2 - 31.5 kg]	[0.5 – 1 min]	30%	Taxiing phase
	Initial/ extended AOP	[0.4 – 0.8 kg]	[1.2 - 2.5 kg]	[0.1 – 0.1 min]	70%	Taxiing phase
AF2	Airport Safety Nets	[0.1 – 3.1 kg]	[0.3 - 9.7 kg]	[0.01 – 0.01 min]	30%	Taxiing phase
AF3	ASM and A-FUA	[8 – 41.7 kg]	[25.2 - 131.3 kg]	[0.15 – 0.55 min]	10%	Cruising phase
	Enhanced Free Route Airspace Operations	[35 – 58 kg]	[110.2 - 182.7 kg]	[1 – 2 min]	75%	Cruising phase
AF4	Enhanced Short Term ATFCM Measures	n/a		[0.3 – 0.4 min]	5%	Pre departure phase
	Interactive rolling NOP	n/a		[0.2 – 0.3 min]	50%	Pre departure phase
AF5	Automated Support for Traffic Complexity Assessment and Flight Planning interfaces	n/a		[0.1 – 0.2 min]	70%	Pre departure phase
AF6	Initial AirGround Trajectory Information Sharing	[8 – 12 kg]	[25.2 - 37.8 kg]	[0.05 – 0.1 min]	90%	Cruising phase

The benefit-cost ratio (BCR) of the investment in CP1 AF shows the value of the investment by comparing the costs of a project with the benefit that it generates. In this case, it has been estimated that every euro invested into CP1 deployment brought 1.5 euros in return during 2023 to the stakeholders in terms of monetizable benefits, as well as 0.6 kg of CO_2 savings (Table 3.2). Furthermore, the BCR and CO_2 savings are expected to increase overtime as CP1 AF are fully implemented (Table 3.3).

Table 3.2 Benefit-Cost Ratio and CO_2 savings from CP1 AF implementation

	Already achieved			
Metric	**2023**	**2030**	**2035**	**2040**
Benefit-cost ratio[13]	**1.5**	3.8	5.9	8.0
CO_2 kg saved per € invested[14]	**0.6**	2.2	4.0	6.0

Table 3.3 Savings in fuel and CO_2 emissions per flight in 2023 and the forecast out to 2040

	Already achieved			
Metric	**2023**	**2030**	**2035**	**2040**
Fuel kg saved	**7.0 kg**	42.3 kg	47.0 kg	47.8 kg
CO_2 kg saved	**22.1 kg**	133.2 kg	147.9 kg	150.5 kg

STAKEHOLDER ACTIONS

Improving flight efficiency in Skyguide's airspace

Skyguide introduced Free Route Airspace (FRA) within the area under its responsibility at the end of 2022 (Switzerland and parts of France, Italy, Germany and Austria). One of the objectives of Skyguide's FRA project was to optimise flight trajectories between Switzerland and Germany, independent of airspace boundaries. A post-implementation analysis confirmed significant improvements in horizontal flight efficiency. Compared with the pre-COVID period, planned flight paths within Swiss airspace have been improved by 22%. As a result of cross-border FRA, horizontal flight efficiency performance at the Skyguide-DFS interface has also improved significantly, with planned and flown trajectories at the entry points improving by 16% and 19% respectively. In 2023, despite a 5% increase in traffic compared with 2022, planned and flown trajectories improved by 13% and 2% respectively, thanks mainly to Skyguide's cross-border FRA.

CiCERO – Citizen and Community Empowerment in Route Optimization

Austro Control, in collaboration with the Federal Government, is enhancing transparency and public involvement regarding air traffic noise in Austrian airspace. In 2024, an innovative public participation process was launched, inviting citizens to engage and actively shape instrument flight rules (IFR) arrival and departure procedure changes in Austria. Through this initiative, citizens can propose enhancements to existing IFR routes and provide valuable feedback on new or modified routes. Submissions are reviewed by an expert panel, ensuring every input is considered and assessed. In the first two months of operation, more than 500 inputs were recorded and processed. The entire process is transparently documented, with Austro Control keeping the public informed every step of the way. It aims to enhance quality of life by reducing noise and fostering a safer, punctual, and environmentally friendly air traffic system.

CONCERTO – Dynamic Collaboration to Generalize Eco-friendly Trajectories

The CONCERTO project aims to make eco-friendly trajectories an everyday occurrence in order to reduce the CO_2 and non-CO_2 impact of aviation. The project will look to integrate green air traffic control capacity into the system, and support stakeholders in balancing regularity and environmental performance at local and network levels. The project will do so by leveraging state-of-the-art climate science and data to allow ATM stakeholders to take their "eco-responsibility" to the next level. At the same time the project aims to demonstrate that mitigation measures can be deployed progressively at network level, in sync with scientific progress.

List of Resources

[1] EC (2004), Regulation (EC) No 549/2004 laying down the framework for the creation of the Single European Sky; **Regulation (EC) No 550/2004 of the European Parliament and of the Council of 10 March 2004 on the provision of air navigation services in the Single European Sky**; Regulation (EC) No 551/2004 of the European Parliament and of the Council of 10 March 2004 on the organisation and use of the airspace in the single European sky (the airspace Regulation)

[2] SESAR (2020), European ATM Master Plan.

[3] EU (2019), Regulation (EU) 2019/123 of 24 January 2019 laying down detailed rules for the implementation of air traffic management (ATM) network functions.

[4] EU (2019), Decision (EU) 2019/709 of 6 May 2019 on the appointment of the Network Manager for air traffic management (ATM) network functions of the Single European Sky.

[5] EU (2021), Regulation (EU) 2021/2085 of 19 November 2021 establishing the Joint Undertakings under Horizon Europe.

[6] EU (2019), Regulation (EU) 2019/317 of 11 February 2019 laying down a performance and charging scheme in the single European sky.

[7] PRB (2019), PRB Monitoring Report 2020.

[8] EU (2005), Regulation (EC) No 2150/2005 of 23 December 2005 laying down common rules for the flexible use of airspace.

[9] EU (2020), Regulation (EU) 2020/1627 of 3 November 2020 on exceptional measures for the third reference period (2020-2024).

[10] EUROCONTROL (2022), Route Availability Document (RAD).

[11] EUROCONTROL (2021), Environmental Assessment: European ATM Network Fuel Inefficiency Study.

[12] EUROCONTROL (2019), Fuel Tankering: Economic Benefits and Environmental Impact.

[13] ICAO (2014), Operational Opportunities to Reduce Fuel Burn and Emissions (Doc 10013).

[14] EUROCONTROL Network Manager (2022), Optimised operational performance.

[15] EUROCONTROL (2022), Free route airspace.

[16] EUOCONTROL (2021), European Route Network Improvement Plan (ERNIP) - Part 2.

[17] EUROCONTROL (2020), European Continuous Climb and Descent Operations Action Plan.

[18] EUROCONTROL (2022), Vertical flight efficiency at airports.

[19] SESAR Dreams Project (2020), Initial Trajectory Information Sharing.

[20] EUROCONTROL (2022), EUROCONTROL learning zone.

[21] SESAR (2021), SESAR Solutions Catalogue charting progress towards the Digital European Sky.

[22] SESAR (2020), Albatross Project.

[23] SESAR (2021), SESAR 3 Joint Undertaking Multiannual Work Programme 2022-2031.

[24[SESAR Deployment Manager (2022), SESAR Deployment Manager.

[25] EU (2021), Regulation (EU) 2021/116 - Common Project 1 Regulation.

[26] SESAR (2022), SORT - Improving runway throughput in one airport.

[27] SESAR (2022), ADSCENSIO - ADS-C Enables and supports improved ATM operations.

[28] SESAR (2021), Airbus - Fello'fly.

[30] EUROCONTROL (2024), CO_2MPASS Interactive Dashboard.

[31] EUROCONTROL (2023), Impact of strikes on European Aviation.

[32] SESAR (2021), SESAR Solutions Catalogue.

[33] SESAR (2024), Dynamic Route Availability Document (RAD).

[35] SESAR (2024), Airport Operations Plan (AOP).

[36] EU (2021), SESAR Single Basic Act.

[37] EU (2013), SESAR Deployment Framework.

[38] SESAR (2022), SESAR Deployment Programme 2022.

[39] EUROCONTROL (2025), EUROCONTROL Area.

[40] SESAR (2025), SESAR Deployment Manager.

[41] PRB(2024), PRB report - https://eu-single-sky.transport.ec.europa.eu/news/prb-advice-union-wide-targets-rp4-feedback-period-draft-commission-implementing-decision-opened-2024-03-25_en

[42] EC (2024), Commission Implementing Decision (EU) 2024/1688 of 12 June 2024 setting Union-wide performance targets for the air traffic management network for the fourth reference period from 1 January 2025 to 31 December 2029.

[43] PRB (2024), Traffic light system for environmental performance 2023.

4. MARKET-BASED MEASURES

- Market-based measures incentivise ‘in-sector’ emissions reductions from technology, operational measures and sustainable aviation fuels, while also addressing residual emissions through ‘out-of-sector’ measures.
- Emissions trading systems (e.g. ETS) have a greenhouse gas emissions cap covering various economic sectors, while offsetting schemes (e.g. CORSIA) compensate for emissions via reductions in other sectors but without an associated cap.
- During 2013 to 2023, the EU ETS led to a net CO_2 emissions reduction in aviation of 206 Mt through funding of emissions reductions in other sectors, of which 47 Mt in 2021-2023.
- EU ETS allowance prices have increased in the recent years, reaching an average annual price of more than €80 per tonne of CO_2 in 2022 and 2023.
- Revisions were agreed to the EU ETS in 2023, including a gradual phase-out of free allowances to airlines and a reduction to the aviation emissions cap from 2024 onwards.
- Monitoring, reporting and verification of CO_2 emissions under CORSIA began in 2019. As of 2025, 128 out of 193 ICAO States have volunteered to participate in the CORSIA offsetting scheme.
- Offsetting under the CORSIA scheme is expected to start in 2024. A total of 19Mt of CO_2 emissions are forecast to be offset for flights departing from Europe during CORSIA’s first phase in 2024-2026.
- The first emissions units have now been authorized for use in CORSIA, complying with the UNFCCC rules on avoidance of double-counting of emissions reductions.
- Technology to capture carbon from the air and store it underground is being developed to support the broader decarbonisation efforts of the aviation sector.
- The EU Taxonomy System sustainable finance initiative has been amended to include

aviation activities.

- No agreement has been reached on proposals to revise the Energy Taxation Directive to introduce minimum rates of taxation for intra-EU passenger flights.

Future goals to address the climate impact of the aviation sector are expected to be achieved by in-sector measures (technology, operations, fuels) that are incentivised by Market-based Measures (MBMs) through pricing of carbon emissions. This chapter provides an overview of the key MBMs that have been put in place for the aviation sector, including the EU's Emissions Trading System (ETS) and ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), as well as other sustainable finance initiatives.

4.1 EU Emissions Trading System

The cornerstone of the EU's policy to combat climate change is the EU Emissions Trading System. Various economic sectors (e.g. power, heat, manufacturing industries, maritime, aviation) have been included within this cap-and-trade system to incentivise CO_2 reduction within each sector, or through trading of allowances with other economic sectors included in the EU ETS where emission reduction costs are lower.

Aviation and the EU ETS

The EU decided to include aviation activities within the EU ETS in 2008 [1], and the system has been applied to aviation activities since 2012. As such, they are subject to the EU's greenhouse gas emissions reduction target of at least minus 55% by 2030 compared to 1990. The initial scope of the EU ETS covered all flights arriving at, or departing from, airports in the European Economic Area (EEA)34. However, flights to and from airports in non-EEA countries or in the outermost regions were subsequently excluded until the end of 2023 through a temporary derogation. This exclusion facilitated the negotiation of a global market-based measure for international aviation emissions at the International Civil Aviation Organisation (ICAO).

In July 2021, the European Commission adopted the 'Fit for 55' Legislative Package to make the EU's climate, energy, transport and taxation policies fit for achieving the 2030 greenhouse gas emissions reduction target. This included proposed amendments to the EU ETS Directive for aviation activities, which entered into force on 5 June 2023 [2]. The main changes to the aviation ETS are applicable from 2024 onwards, and include the following:

- Applying EU ETS for flights within and between countries in the European Economic Area, as well as departing flights to Switzerland and to the United Kingdom, while applying CORSIA for flights to and from third countries.

- Applying EU ETS for flights between countries in the European Economic Area and the outermost regions, as well as between the outermost regions, unless they connect to the respective Member State's mainland. EU ETS also applies to flights from the outermost regions to Switzerland and the United Kingdom.

- Gradual phase-out of the free ETS allocation to airlines as follows: 25% in 2024; 50% in 2025; and

[34] The European Economic Area includes EU27, Norway, Iceland and Liechtenstein.

100% from 2026, meaning full auctioning of EU Allowances to the aviation sector from 2026. The free allocation for the years 2024 and 2025 is distributed according to the aircraft operators' share of verified emissions in the year 2023.

• Applying an annual linear reduction factor of 4.3% to the EU Allowances issued for aviation from 2024 onwards.

• Creation of a new incentive scheme for Sustainable Aviation Fuels (SAF). For the period from 2024 to 2030, a maximum of 20 million ETS allowances will be allocated to aircraft operators for the uplifting of SAF to cover part or all of the price difference between SAF and fossil kerosene, depending on the type of SAF used.

• Setting up a monitoring, reporting and verification system for non-CO_2 aviation effects[35]

• Assessment of CORSIA's environmental performance after the 2025 ICAO Assembly. The Commission will report in 2026 on the progress at ICAO negotiations every three years, accompanied by legislative proposals, where appropriate.

More detailed amendments to the ETS Directive are implemented though various delegated and implementing acts, which are referenced in the Directive itself.

Linking the EU ETS to other emissions trading systems is permitted provided that these systems are compatible, mandatory and have an absolute emission cap. An agreement to link the systems of the EU and Switzerland entered into force on 1 January 2020. Accordingly, flights from the EEA area to Switzerland are subject to the EU ETS, and flights from Switzerland to the EEA area fall under the Swiss ETS. Allowances from both systems can be used to compensate for emissions occurring in either system.

The Environmental Management Information Service (EMIS) of EUROCONTROL, which superseded the EU ETS Support Facility in 2023, continues to provide 28 States with access to EU ETS and ICAO CORSIA related data, as well as traffic and emissions data to over 400 aircraft operators.

Historic and forecasted aviation emissions under EU ETS

The initial total amount of aviation allowances within the EU ETS in 2012 was 95% of the average annual emissions between 2004 and 2006 of flights within the full ETS applicability scope (all flights departing from or arriving in the European Economic Area), representing 221.4 million tonnes (Mt) of CO_2 per year. The EUAAs issued for aviation activities in the ETS's third phase (2013-2020) was adjusted for the applicability scope. While aircraft operators may use EUAAs as well as EU Allowances (EUAs) from the stationary sectors, stationary installations are not permitted to use EUAAs. In addition, aircraft operators were entitled to use certain international credits (CERs) until 2020 up to a maximum of 1.5% of their verified emissions. In 2023, there were 254 aircraft operators reporting a total of 53 million tonnes (Mt) of CO_2 emissions under the EU ETS.

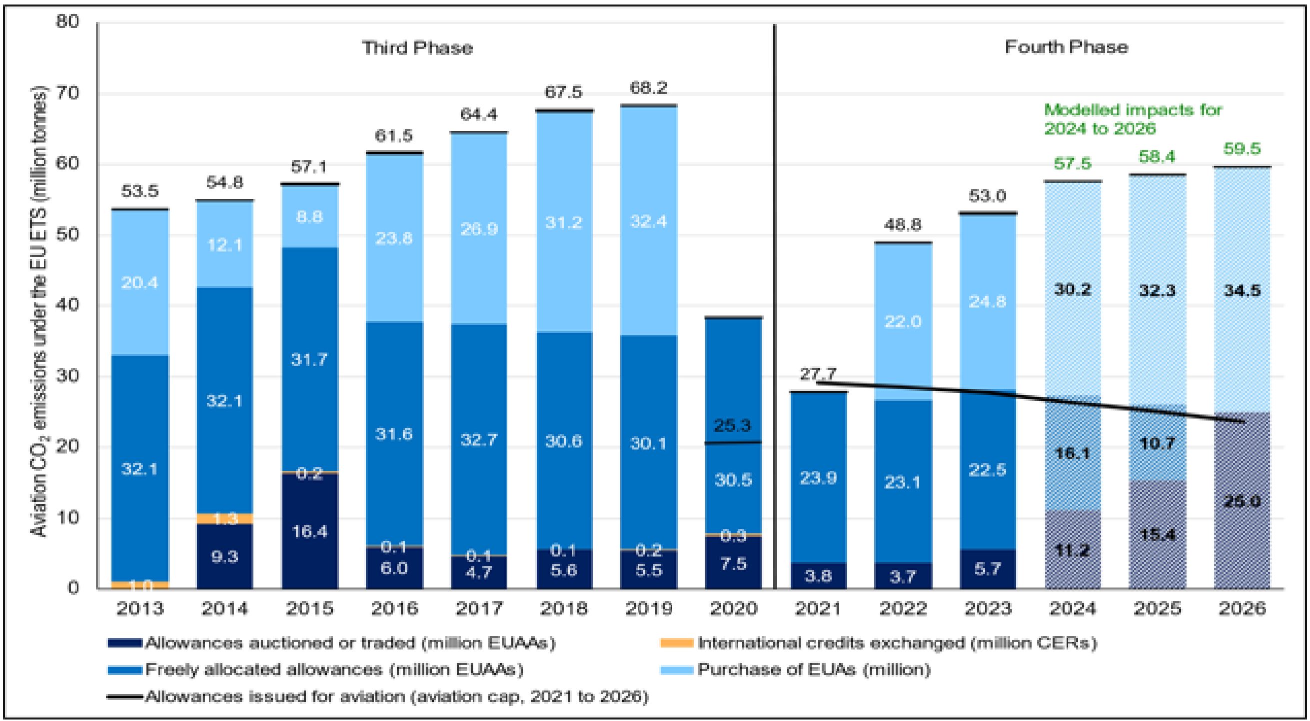
Aircraft operators are required to report verified emissions data from flights covered by the scheme on an annual basis. As is shown in Figure 4.1, total verified CO_2 emissions from aviation covered by the EU ETS increased from 53.5 Mt in 2013 to 68.2 Mt in 2019. This implies an average increase of CO_2 emissions of 4.15% per year. The impact of the COVID-19 pandemic on international aviation saw this figure fall to 25.3 Mt in 2020, representing a decrease of 63% from 2019 levels. From 2013 to 2020, the amount of annual EUAAs issued was around 38.3 Mt of which about 15% have been auctioned by the Member States, while 85% have been allocated for free. The purchase of EUAs by the aviation sector for exceeding the EUAAs issued went up from 20.4 Mt in 2013 to 32.4 Mt in 2019 contributing thereby to a reduction of around 155.6 Mt of CO_2 emissions from other sectors during 2013-2019. As a result of the COVID-19 pandemic, the verified emissions of 25.3Mt in 2020 were below the freely allocated allowances for the first time (see Figure 4.1).

Since 2021, a gradual recovery of aviation activities has been observed: total verified aviation CO_2 emissions covered by the EU ETS in 2021, 2022 and 2023 were 27.7Mt, 48.8Mt and 53.0Mt respectively. The free allowances allocated to the aviation sector were 23.9Mt in 2021, 23.1Mt in 2022 and 22.5Mt in 2023. Following the rebound of aviation sector's CO_2 emissions from the COVID-19 pandemic, the sector became a net purchaser of EUAs again in 2022 (22.0Mt) and in 2023 (24.8Mt). From 2021 until 2023, a linear reduction factor of 2.2% has been applied to the Allowances issued for aviation, and this factor will increase to 4.3% for the period of 2024-2027.

As also shown in Figure 4.1, the modelled CO_2 emissions under the aviation ETS are expected to grow to 59.5Mt in 2026. In line with the gradual phase out of the free allowances to the aviation sector, the annual amount of freely allocated EUAs for aviation is expected to reduce from 16.1 Mt in 2024 to 10.7Mt in 2025 and then become zero from 2026 onwards. Purchase of EUAs is expected to grow from 27.1Mt in 2024 to 28.7Mt in 2026. Emissions benefits from the claiming of Sustainable Aviation Fuels (SAF) could grow from 0.5Mt in 2024 to 1.7Mt in 2026, assuming a zero emissions factor of SAF as per the EU ETS Directive. Moreover, there could be a relative demand reduction within the aviation sector over the years 2024-2026 of 9.8Mt as a result of the carbon price incurred due to the EU ETS[36].

[36] Estimation from EASA AERO-MS model. See Appendix C for more details.

Figure 4.1 Aviation CO_2 emissions under the EU ETS in 2013-2023 and modelled impact of the revised ETS Directive for years 2024-2026, where 1 EUAA / EUA equals 1 tonne of CO_2 emissions[37]

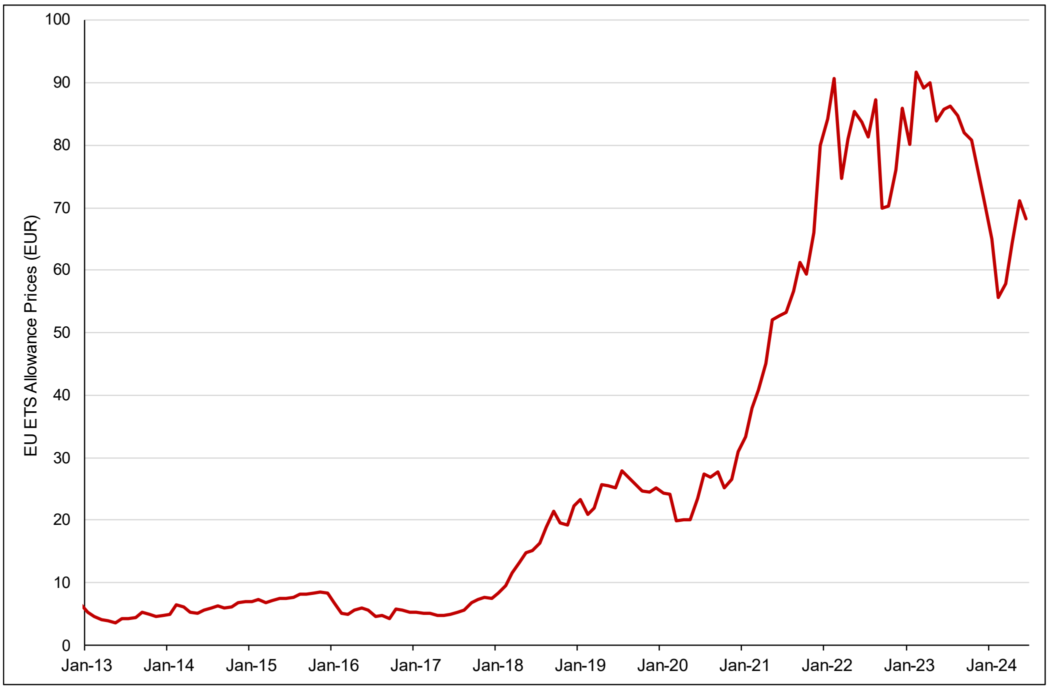


Note: Data in Figure 4.1 reflects the years in which the EUAAs were effectively released to the market. This applies especially for allowances attributable to years 2013, 2014 and 2015, which were all auctioned in 2015. The 2014 auctions of EUAAs relate to auctioning of EUAAs due to the postponement of 2012 auctions. Modelled data for years 2024-2026 from the updated AERO-MS model.

As shown in Figure 4.2, the annual average EU ETS carbon price varied between €4 and €30 per tonne of CO_2 during the 2013-2020 period. Consequently, total aircraft operator costs linked to purchasing EU Allowances (EUAs) have gone up from around €84 million in 2013 to around €955 million in 2019. Since 2021, the EUA price has increased significantly, reaching average annual EUA prices of more than €80 in 2022 and 2023, resulting in total aircraft operator cost of approximately €1.8 billion in 2022 and €2.1 billion in 2023. Peak EUA prices exceeding €90 per tonne of CO_2 were observed in early 2022 and again in 2023. For the period of 2024-2026, it is estimated that the ETS cost could represent 4-6% of airlines' total annual operating costs[38].

[37] In addition, the Swiss ETS is forecast to result in a purchase of ETS allowances by aviation sector as follows: 0.3 million in 2023; 0.4 million in 2024; 0.5 million in 2025 and 0.6 million in 2026.
[38] Estimation from EASA AERO-MS model.

Figure 4.2 EU ETS Allowance Prices (2013-2024)



From 2024 until 2030, airlines can apply for additional ETS allowances to cover part or all of the price differential between the use of fossil kerosene and SAF on their flights covered by the EU ETS. A maximum amount of 20 million allowances will be reserved for such a support mechanism, and airlines can apply for an allocation on an annual basis. The Commission will calculate the price differentials annually, taking into account information provided within the annual ReFuelEU Aviation report from EASA.

European Model for Impact Assessments of Market-based Measures

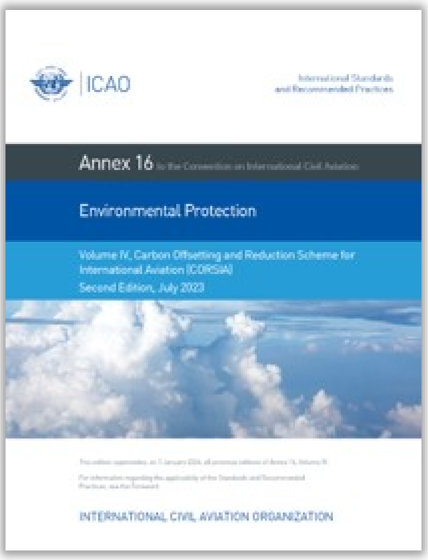
The EASA AERO Modelling System (AERO-MS) has been developed to assess the economic and environmental impacts of a wide range of policy options to reduce international and domestic aviation GHG emissions. These policies include taxes (e.g. fuel and ticket taxation), market-based measures (e.g. EU ETS, CORSIA), as well as the introduction of sustainable aviation fuels and air traffic management improvements. The model can provide insight into the effect of policy options on both the supply side and demand side of air travel due to higher prices, and the forecasted impact on emission reductions.

During the last 20 years, the AERO-MS has been a key part of more than 40 international studies where the model results have informed policy discussions and decisions. Beneficiaries of the AERO-MS include a wide range of organizations, including the European Commission, Member States, EASA, IATA, ICAO, aviation industry and NGOs. As a part of a project funded by the EU Horizon 2020 research programme, an update to AERO-MS was completed in 2024 to enhance its capabilities for future studies. This included a new base year of 2019 traffic and emissions, latest information on price elasticities, the addition of particulate matter emissions modelling and the inclusion of the impacts of SAF. Modelling results from AERO-MS have been used as input for various Figures included within this Chapter.

4.2 CARBON OFFSETTING AND REDUCTION SCHEME FOR INTERNATIONAL AVIATION (CORSIA)

Background

In 2016, the 39th ICAO General Assembly reconfirmed the 2013 aspirational objective of stabilising CO_2 emissions from international aviation at 2020 levels. In light of this, ICAO States adopted Resolution A39-3 which introduced a global market-based measure called the 'Carbon Offsetting and Reduction Scheme for International Aviation' (CORSIA). ICAO Assembly Resolutions are reassessed every three years, and the current Resolution A41-22 for CORSIA implementation was adopted by the 41st ICAO Assembly in 2022, following the outcome of the first CORSIA periodic review by the ICAO Council [3].



CORSIA is being implemented through the associated ICAO Standards and Recommended Practices (SARPs) contained in ICAO Annex 16, Volume IV, the 1st Edition of which became applicable on 1 January 2019. In March 2023, the 2nd Edition of Volume IV was approved by the Council and became applicable 1 January 2024. There were two main sources for the 2nd Edition updates: technical amendments arising from the 12th meeting of ICAO's Committee on Aviation Environmental Protection (CAEP) in February 2022, and consequential amendments to reflect the outcome of the 41 ICAO Assembly in October 2022.

12th ICAO CAEP Meeting

- Clarification on technical matters related to monitoring, reporting and verification provisions.
- Definition of an offsetting threshold of 3,000 tonnes of offsetting requirements per 3-year compliance cycle for aeroplane operators with low levels of international aviation activity.
- Clarification on the calculation of offsetting requirements for new aeroplane operators that do not qualify as new entrants.
- Alignment of verification-related contents with the latest applicable editions of International Organization for Standardization (ISO) documents referenced in Annex 16, Volume IV.

41st ICAO Assembly

- Use 2019 emissions as CORSIA's baseline emissions for the pilot phase years in 2021-2023; and 85% of 2019 emissions after the pilot phase in 2024-2035.
- Decision on the share of individual/sectoral growth factors: 100% sectoral growth factor until 2032; 85% sectoral / 15% individual growth factor in 2033-2035.
- Use of 2019 emissions for the determination of the new entrant operators threshold.

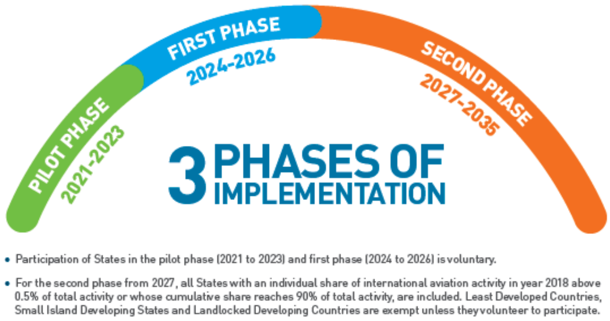
The SARPs are supported by guidance material included in the Environmental Technical Manual (Doc 9501), Volume IV and so called "Implementation Elements", which are directly referenced in the SARPs [4]. ICAO Member States are required to amend their national regulations in line with the amended SARPs, if necessary.

> **Europe's participation in CORSIA**
>
> In line with the 'Bratislava Declaration' signed on 3 September 2016, and following the adoption of the CORSIA SARPs by the ICAO Council, EU Member States and the other Member States of the European Civil Aviation Conference (ECAC) notified ICAO of their intention to voluntarily participate to CORSIA offsetting from the start of the pilot phase in 2021, provided that certain conditions were met, notably on the environmental integrity of the scheme and global participation. EU member states have implemented CORSIA's MRV provisions since 2019 and, as per the revised EU ETS Directive, are implementing CORSIA's offsetting requirements since 2021 for routes between the European Economic Area (EEA) and States that are participating in CORSIA offsetting, as well as for flights between two such States39. Implementation of CORSIA's monitoring, reporting and verification rules within the EU has been through the relevant ETS Regulations [5, 6, 7].

CORSIA scope and timeline

CORSIA operates on a route-based approach and applies to international flights, i.e. flights between two ICAO States. A route is covered by CORSIA offsetting requirements if both the State of departure and the State of destination are participating in the Scheme and is applicable to all aeroplane operators on the route (i.e. regardless of the administering State).

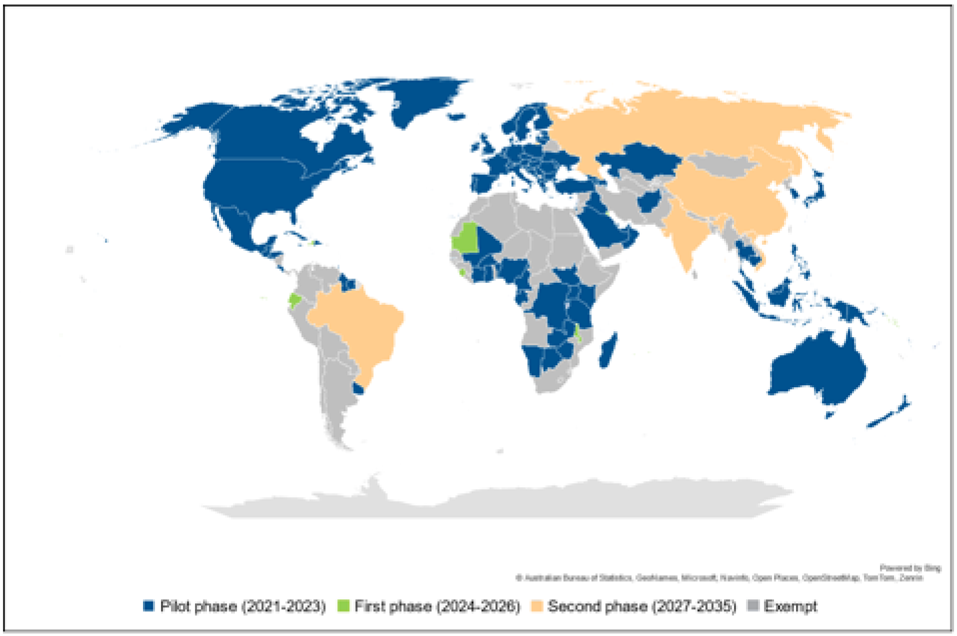
All aeroplane operators with international flights producing annual CO_2 emissions greater than 10, CO_2 emissions covered by CORSIA's offsetting requirements above 000 tonnes from aeroplanes with a maximum take-off mass greater than 5700 kg, are required to monitor, verify and report their CO_2 emissions on an annual basis from 2019. The CO_2 emissions reported for year 2019 represent the baseline for carbon neutral growth for CORSIA's pilot phase (2021-2023), while for the first and second phases in 2024-2035, the baseline is 85% of the CO_2 emissions reported for year 2019. The aviation sector is required to offset any international these baseline levels.



CORSIA includes three implementation phases. During the pilot and first phases, offsetting requirements will only be applicable to flights between States which have volunteered to participate in CORSIA offsetting. There has been a gradual increase of States volunteering to join CORSIA offsetting, rising from 88 States in 2021 to 129 in 2025 [8]. The second phase applies to all ICAO Contracting States, with certain exemptions.

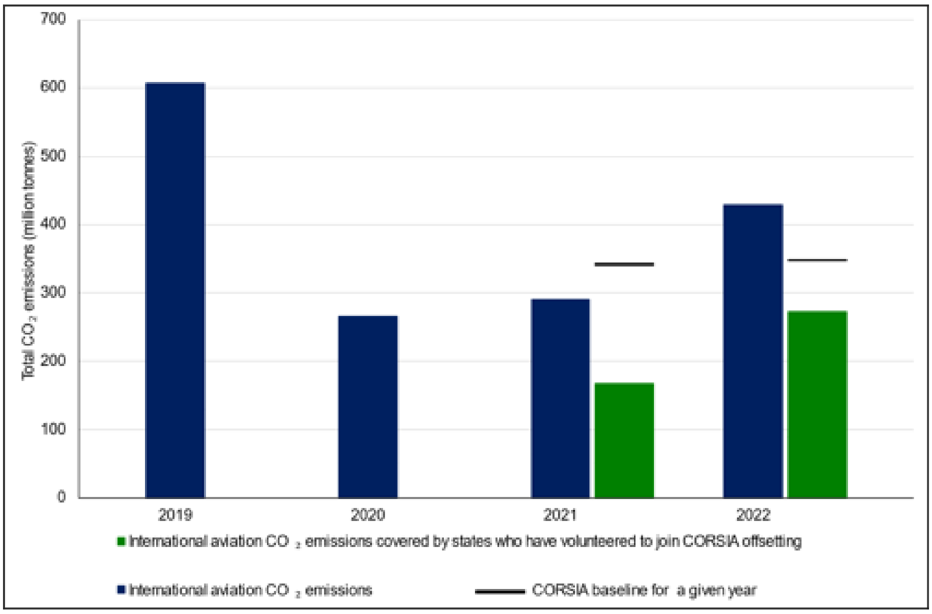
[39] As per the ETS Directive, EU ETS is being applied for flights within and between countries in the European Economic Area, as well as departing flights to Switzerland and to the United Kingdom.

Figure 4.3 ICAO **Member States participation in CORSIA offsetting in various phases**



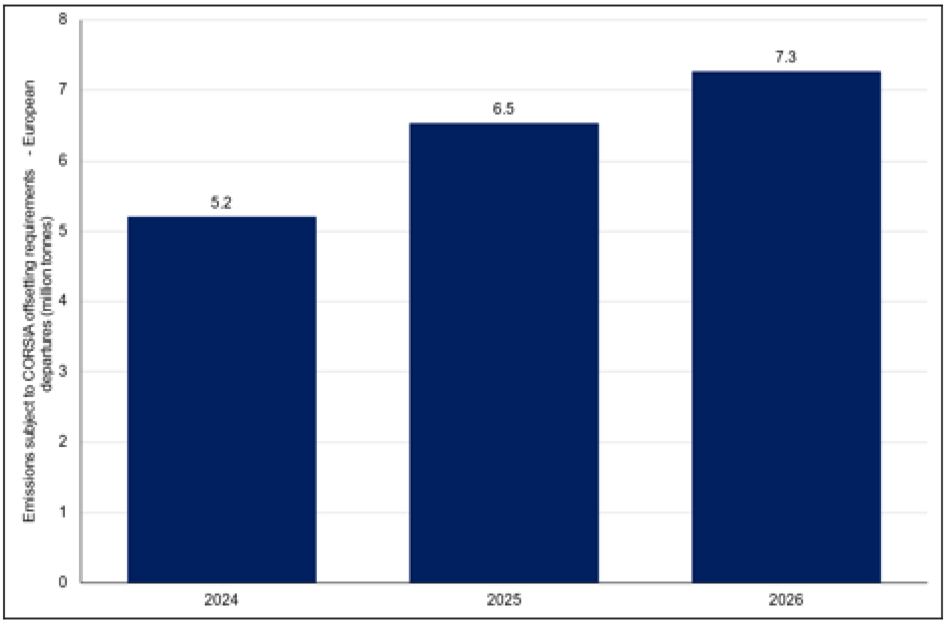
Due to the change in CORSIA baseline to 2019 emissions for years 2021-2023, and the fact that international aviation emissions covered by routes between two States that have volunteered to join CORSIA offsetting have not reached 2019 levels by 2023, there has not been any offsetting requirements to airlines from CORSIA during its pilot phase. Figure 4.4 illustrates the reported CO_2 emissions from all international flights (blue bars) and a subset of these emissions (green bars) between States that have volunteered to join CORSIA offsetting in respective years. For years 2021-2023, CORSIA's baseline emissions are the total CO_2 emissions covered by CORSIA offsetting in 2019. This baseline emissions will be re-calculated for every given year, based on the routes covered by CORSIA offsetting requirements in that given year.

Figure 4.4 International aviation CO_2 emissions reported through the CORSIA Central Registry



The revised EU ETS will be applied to flights within and between countries in the European Economic Area, as well as departing flights to Switzerland and to the United Kingdom, while applying CORSIA offsetting for flights to, from and between third countries that participate in CORSIA offsetting. It is estimated that the offsetting requirements for flights departing from Europe will increase from 5.2 tonnes in 2024 to 7.3 tonnes in 2026[40] (Figure 4.5).

Figure 4.5 Estimated CORSIA offsetting requirements for departing flights from Europe41



CORSIA in practice

International flights within the scope of CORSIA are attributed to an aeroplane operator, and each operator is attributed to an administrating State to which it must submit an Emissions Monitoring Plan. Since 1 January 2019, an aeroplane operator is required to report its annual CO_2 emissions to the State to which it has been attributed, irrespective of whether it has offsetting obligations. As of 1 January 2021, the State calculates annual offsetting requirements for each operator that has been attributed to it by multiplying the operator's CO_2 emissions covered by CORSIA offsetting obligations with a Growth Factor. For years 2021-2032, the Growth Factor represents the percentage growth of the aviation sector's international CO_2 emissions covered by CORSIA's offsetting requirements in a given year compared to the sector's baseline emissions. For the period of 2033-2035, the Growth Factor is calculated by using 85% of the sector's growth against the baseline and 15% of individual aeroplane operator's growth against the baseline.

At the end of each 3-year compliance period (2021-2023, 2024-2026, etc.), an aeroplane operator must meet its offsetting requirements by purchasing and cancelling certified CORSIA eligible emissions units. Each emissions unit represents a tonne of CO_2 avoided or reduced. In order to safeguard the environmental integrity of offset credits used under CORSIA, the emission units must comply with the Emission Unit Criteria approved by the ICAO Council. The price of a CORSIA eligible emissions unit has varied greatly depending on the type of the project (\$0.50 to \$45/tCO_2e during 2020-2021 with a weighted average of \$3.08/tCO_2eq in 2021) [9]. For the period 2024-2026, it is estimated that the cost of purchasing CORSIA offset credits could be limited at 0.07-0.15% of the total annual operating costs for airlines. Aeroplane operators can also reduce their offsetting

[40] Estimation by EASA AERO-MS model.
[41] Covers departing traffic for all airlines from EEA countries and Switzerland to third countries that participate in CORSIA offsetting, except for flights to the United Kingdom, which are covered by EU and CH ETS.

requirements by using CORSIA eligible fuels (CEF) that meet the CORSIA sustainability criteria, which includes at least 10% less CO_2e emissions on a life-cycle basis compared to a reference fossil fuel value of 89.1gCO_2e/MJ.

ICAO has established a Technical Advisory Body (TAB) to undertake the assessment of Emissions Unit Programmes against the approved Emissions Units Criteria, and to make annual recommendations on their use within CORSIA. To date, based on the TAB's recommendations, the ICAO Council has approved 11-emissions unit programmes to supply CORSIA Eligible Emissions Units for CORSIA's pilot phase in 2021-2023, and two programmes to supply Units for the first phase in 2024-2026 [10].

In addition to avoidance and reduction projects, removal projects that are designed to remove carbon from the atmosphere can include both natural (e.g., planting trees) and technological carbon removal processes (e.g. Direct Air Capture – DAC or Direct Air Carbon Capture and Storage – DACCS) and have a potential to produce high-quality carbon offsets in the future. Carbon capture and storage technologies can also potentially be utilized for the production of sustainable aviation fuels. The EU has put forward a carbon removal certification framework [11], which aims to scale up carbon removal activities by empowering businesses to show their action in this field. Such certified removals can potentially become eligible in schemes such as CORSIA or when offsetting internal aviation emissions.

In order to address concerns on double counting, rules for international carbon markets under Article 6 of the Paris Agreement were adopted at the UN COP26 meeting in 2021. These rules require a host country to authorize carbon credits for 'international mitigation purposes', such as CORSIA, and to ensure that these emission reductions are not used to achieve its National Determined Contribution (NDC) under the UNFCCC process. These rules are designed to guarantee that corresponding adjustments take place prior to these emission reductions being used to demonstrate compliance with CORSIA. First announcements of authorizations of carbon credits for CORSIA compliance purposes have been observed in early 2024 [12].

What are the differences and similarities between the EU ETS and CORSIA?

The EU ETS is a **cap-and-trade** system, which sets a limit on the number of emissions allowances issued, and thereby constrains the total amount of emissions of the sectors covered by the system. In the EU ETS, these comprise operators of stationary installations (e.g. heat, power, industry), maritime transport operators and aircraft operators. The total sum for aviation allowances in the EU ETS is 95% of the average emissions between 2004 and 2006, adjusted for the applicability scope and reduced by the linear reduction factor annually. The total number of emissions allowances is limited and reduced over time, thereby driving operators in need of additional allowances to buy these on the market from other sectors in the system – hence 'cap-and-trade'. This ensures that the objective of an **absolute decrease of the level of CO_2 emissions** is met at the system level. The revised EU ETS Directive is expected to lead to emission reductions of 61% in 2030 compared to 2005 levels for the sectors covered by the Directive. The supply and demand for allowances establishes their price under the ETS, and the higher the price, the higher the incentive to reduce emissions in order to avoid having to purchase more allowances. Aircraft operators can also use Sustainable Aviation Fuels to comply with their ETS obligations.

The ICAO CORSIA is an **offsetting** scheme with an objective of carbon neutral growth designed to ensure that CO_2 emissions from international aviation do not exceed 2019 levels in 2021-2023 and 85% of 2019 levels in 2024-2035. To that end, aeroplane operators will be required to purchase **offset credits** to compensate for emissions above the CORSIA baseline or use CORSIA Eligible Fuels. The observed spread of the cost of CORSIA eligible emission units has been high and dependent on the project category.

EU ETS allowances are not accepted under CORSIA, and international offset credits, including those deemed eligible under CORSIA, are not accepted under the EU ETS as of 1 January 2021.

Both the EU ETS and CORSIA include similar **Monitoring, Reporting and Verification (MRV) systems,** which are aimed to ensure that the CO_2 emissions information collected through the scheme is robust and reliable. The MRV system consists of three main components: first, an airline is required to draft an Emissions Monitoring Plan, which needs to be approved by a relevant Competent Authority. After the Plan has been approved, the airline will **monitor** its CO_2 emissions either through a fuel burn monitoring method or an estimation tool. The necessary CO_2 information will be compiled on an annual basis and **reported** from airlines to their Competent Authorities by using harmonised templates. A third-party **verification** of CO_2 emissions information ensures that the reported data is accurate and free of errors. A verifier must be independent from the airline, follow international standards in their work and be accredited to the task by a National Accreditation Body.

4.3 Sustainable Finance and Energy Taxation Initiatives

In addition to the EU ETS and CORSIA, there are recent regulatory developments in the area of sustainable finance and energy taxation that are relevant for the aviation sector, notably the introduction of aviation-related activities under the EU Taxonomy system, as well as proposal to introduce minimum rates of fuel taxation for intra-EU passenger flights.

EU Taxonomy

In order to direct investments towards sustainable products and activities, the EU has introduced a classification system, or "EU Taxonomy". This EU Taxonomy is expected to play a crucial role in scaling up sustainable investment and implementing the EU Green Deal by providing companies, investors and policymakers with definitions of which economic activities can be considered as environmentally sustainable. Under the Taxonomy Regulation [13], "Technical Screening Criteria (TSC)" have been developed for economic activities in various sectors. These TSC determine the conditions under which an economic activity qualifies as Taxonomy aligned and should be reviewed on a regular basis, and at least every 3 years.

On 9 December 2021, a first delegated act on sustainable activities for climate change mitigation and adaptation objectives of the EU Taxonomy ("Climate Delegated Act") was published in the Official Journal [14]. It included the activity on low carbon airport infrastructure as well as on manufacture of hydrogen and hydrogen-based synthetic fuels.

The Climate Delegated Act [15] was amended in 2023 to include the following additional aviation-related activities: manufacturing of aircraft, leasing of aircraft, passenger and freight air transport and air transport ground handling operations.

The new TSC focus on incentivising the development and market introduction of aircraft with zero direct (tailpipe) CO_2emissions, and best-in-class aircraft (See Figure 7.6 presenting a part of the Technical Screening Criteria for "best in class" aircraft). In addition, and as transitional activities, the TSC also incentivise the manufacturing and uptake of the latest generation aircraft that replace older, less fuel-efficient models without contributing to fleet expansion. The latest generation aircraft are identified by referring to a certain margin to the ICAO New Type Aeroplane CO_2 standard, several other requirements and 'do no significant harm' (DNSH) criteria, including on emissions and noise. In addition, the TSC also puts a strong emphasis on the replacement of fossil jet fuel with Sustainable Aviation Fuels (SAF) and the technical readiness of the aircraft fleet to operate with 100% SAF.

EU Energy Taxation Directive

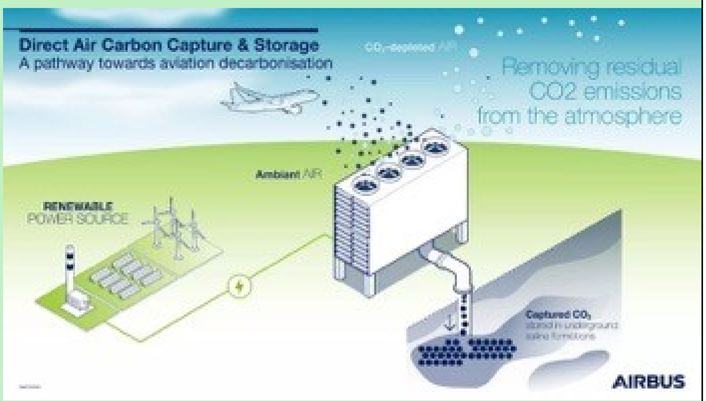
Aviation fuel, other than in private pleasure-flying, is currently exempted from taxation under the EU Energy Taxation Directive. EU Member States could tax fuel used for domestic flights or for intra-EU transport if agreed between the Member States concerned on a bilateral basis, although none currently do so. As part of the 'Fit for 55' Legislative Package, the European Commission has proposed to introduce minimum rates of taxation for intra-EU passenger flights that would encourage a switch to sustainable fuels as well as more fuel-efficient aircraft [16]. According to the proposal, the tax for aviation fuel would be introduced gradually over a period of 10 years before reaching the final minimum rate of €10.75/GJ (approximately €0.38 per litre). In comparison, sustainable aviation fuels would incur a zero-tax rate during this same period and after that benefit from a lower minimum tax rate. No agreement on a final Directive has been achieved to date.

Voluntary Offsetting

In recent years, some airlines have introduced voluntary offsetting initiatives aimed at compensating, partly or in full, those CO_2 emissions caused by their operations that are not mitigated by other measures. Such voluntary initiatives have the potential to contribute to a more sustainable aviation sector, assuming that investments are channelled to high quality offset credits that meet certain quality criteria, e.g. are additional[42]. However, there has been some criticism of the quality of offset credits in this unregulated voluntary market, as well as scepticism of such voluntary activity enhancing aviation sustainability [17, 18, 19].

STAKEHOLDER ACTIONS
Airbus Carbon Capture Offer (ACCO)

Airbus developed ACCO with the aim to bring to the aviation industry high-environmental integrity, scalable and affordable carbon dioxide removal credits. [21]. ACCO looks to support the management of the remaining and residual CO_2 emissions of aircraft with the latest carbon removal technologies.



As a first step, Airbus partnered with 1PointFive for exploring direct air carbon capture and storage solutions for the aviation industry. In particular, 1PointFive is developing a large-scale facility expected to capture 0.5 million tonnes of CO_2 per year starting in 2025. Airbus has committed to purchase 400,000 tonnes of CO_2 removals. This initiative aims to support efforts for decarbonising and mitigating Airbus' Scope 3 emissions from the use of its sold product, and also contributes to the larger efforts already underway across the aviation industry.

[42] "Additionality" means that that the carbon offset credits represent greenhouse gas emissions reductions or carbon sequestration or removals that exceed any greenhouse gas reduction or removals required by law, regulation, or legally binding mandate, and that exceed any greenhouse gas reductions or removals that would otherwise occur in a conservative, business-as-usual scenario. [20]

List of resources

[1] EC (2008), Directive 2008/101/EC of the European Parliament and of the Council of 19 November 2008 amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community.

[2] EU (2023), Directive (EU) 2023/958 of the European Parliament and of the Council of 10 May 2023 amending Directive 2003/87/EC as regards aviation's contribution to the Union's economy-wide emission reduction target and the appropriate implementation of a global market-based measure.

[3] ICAO (2022), Resolution A41-22: Consolidated statement of continuing ICAO policies and practices related to environmental protection — CORSIA.

[4] ICAO (2024), ICAO CORSIA Implementation Elements: CORSIA Implementation Elements (icao.int)

[5] EU (2024), Implementing Regulation (EU) 2018/2066 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC and amending Commission Regulation (EU) No 601/2012.

[6] EU (2018), Implementing Regulation (EU) 2018/2067 on the verification of data

and on the accreditation of verifiers pursuant to Directive 2003/87/EC.

[7] EU (2019), Commission Delegated Regulation (EU) 2019/1603 supplementing Directive 2003/87/EC of the European Parliament and of the Council as regards measures adopted by the International Civil Aviation Organisation for the monitoring, reporting and verification of aviation emissions for the purpose of implementing a global market-based measure.

[8] ICAO (2024), CORSIA States for Chapter 3 State Pairs.

[9] Ecosytem Marketplace (2024), CORSIA Carbon Market Data.

[10] ICAO (2024), CORSIA Eligible Emissions Units.

[11] EC (2022), Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a Union certification framework for carbon removals.

[12] Government of Guyana (2024), World's First Carbon Credits for Use in UN Airline Compliance Programme, CORSIA.

[13] EU (2020), Regulation (EU) 2020/852 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088.

[14] EU (2021), Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives.

[15] EU (2023), Delegated Regulation (EU) 2023/2485 of 27 June 2023 amending Delegated Regulation (EU) 2021/2139 establishing additional technical screening criteria for determining the conditions under which certain economic activities qualify as contributing substantially to climate change mitigation or climate change adaptation and for determining whether those activities cause no significant harm to any of the other environmental objectives.

[16] EC (2021), Proposal for a COUNCIL DIRECTIVE restructuring the Union framework for the taxation of energy products and electricity.

[17] Bloomberg (2024), Inside the Controversy That's Divided the Carbon Offsets Market - BNN Bloomberg.

[18] Washington Post (2023), Airlines want you to buy carbon offsets. Experts say they're a 'scam.' - The Washington Post.

[19] De Mello, Fabiana Peixoto (2024), Voluntary carbon offset programs in aviation: A systematic literature review, Transport Policy, Volume 147, Pages 158-168.

[20] ICAO (2019), CORSIA Emissions Unit Eligibility Criteria.

[21] Airbus (2024), Airbus Carbon Capture Offer.

5. ADDITIONAL MEASURES

- Significant airport initiatives are being taken forward to invest in onsite production of renewable energy to electrify ground support equipment, thereby mitigating noise and emissions.
- Airport infrastructure will need to be adapted to accommodate SAF and zero emissions aircraft (electric, hydrogen) to meet ReFuelEU Aviation requirements. Various research projects and funding mechanisms are leading the way.
- Some airports are supporting the uptake of SAF through investment in production, supply chain involvement, raising awareness, financial incentives and policy engagement.
- 132 airports in Europe have announced a net zero CO_2 emissions target by 2030 or earlier, and 13 airports have already achieved it.
- In 2023, a new Level 5 was added to the Airport Carbon Accreditation programme requiring 90% CO_2 emissions reductions in Scopes 1 and 2, a verified carbon footprint and a Stakeholder Partnership Plan underpinning the commitment of net zero CO_2 emissions in Scope 3.

5.1 Airport Measures

5.1.1 Aircraft Operations

Performance Based Navigation (PBN)

The use of Performance Based Navigation (PBN) enables an optimum aircraft flight path trajectory to mitigate environmental impacts, particularly in the vicinity of airports, without having to overfly ground-based navigation aids. Implementation of the PBN Regulation [15] has shown a positive trend since the last report. As of July 2024, 75% of instrument runways are now fully compliant with the requirements and the implementation of PBN has respectively started for 81% Standard Instrument Departures (SIDs) and 82% Standard Terminal Approach Routes (STAR) at these runways. Completion is due by 2030.

The implementation of the PBN Regulation is expected to result in a number of environmental benefits, although neither their evaluation nor their quantification is mandated. As such, it has proven challenging to identify relevant data for this report. Stakeholders responsible for putting in place the required PBN routes and procedures are encouraged to optimise airspace design and the potential environmental benefits, in particular for flight efficiency and route placement flexibility.

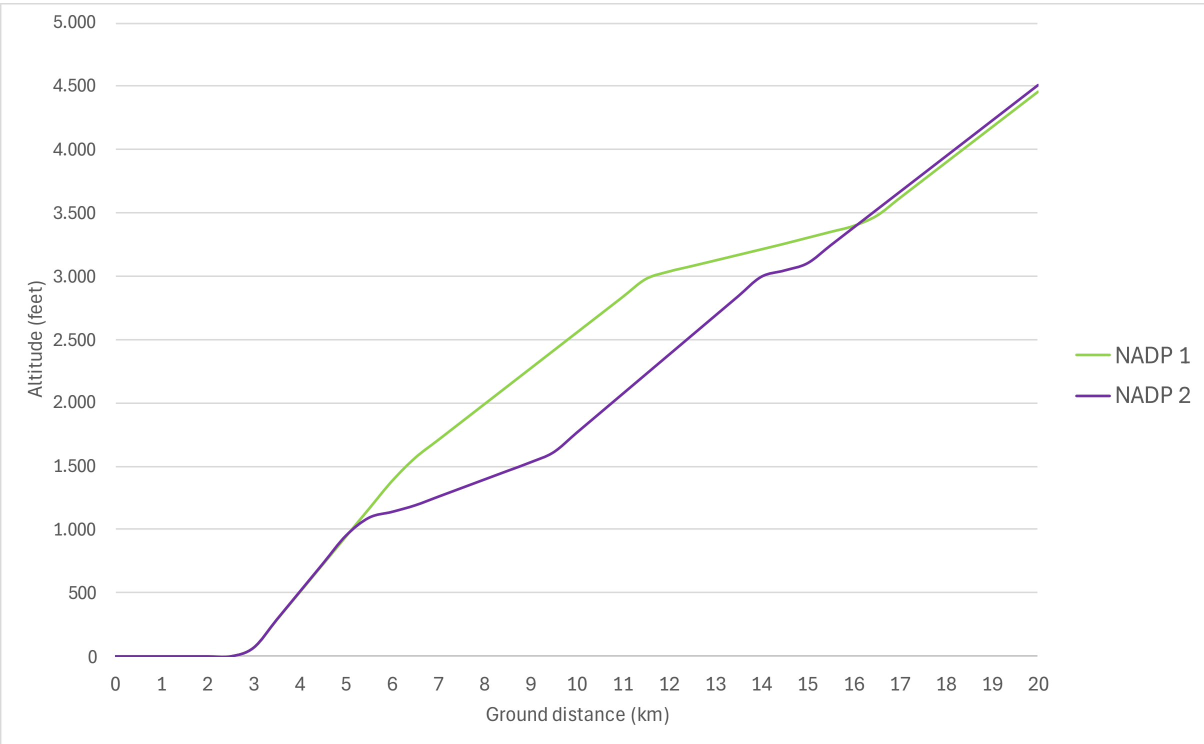
Green Operational Procedures

Building on the previous ALBATROSS research project [16], the goal of the SESAR project HERON launched in 2023 is to reduce the environmental impact from aviation through the deployment of already-mature solutions that range from more efficient aircraft operations to optimised management of air traffic during flights [17]. This includes the Green Apron Management demonstration, which uses sensors and artificial intelligence for more predictable and efficient aircraft handling during airport stopovers.

Noise Abatement Departure Procedures (NADPs)

NADPs aim to reduce the noise impact of departing aircraft by selecting the appropriate moment to clean the aircraft (i.e. retract flaps), which has an impact on the flown vertical profile. NADP1 results in noise reductions close to the airport, while NADP2 reduces noise further away and has lower fuel consumption (Figure 5.1). Depending on the operational context (aircraft type, take-off weight, weather, etc) and on the location of the noise sensitive areas, the best balance between noise and emission reductions needs to be determined.

Figure 5.1 Example of the difference between NADP 1 and 2 for a wide body aircraft with thrust reduction at 1,000ft.



A study performed by EUROCONTROL highlighted that in many cases a fixed NADP procedure for all aircraft types and runways is advised or mandated by the airport authorities, but that this is not always the optimal solution to balance noise and emission reductions. Noise sensitive areas vary from airport to airport, and from departure runway to runway. As such, airports should identify key noise sensitive areas in each Standard Instrument Departure procedure. By taking the local operational context into consideration and allowing the flight crew to determine the best NADP, additional noise or emission reductions could be achieved.

The study concluded that in some cases where NADP1 procedures are applied, using NADP2 procedures could reduce fuel burn by 50kg to 200kg while only marginally increasing noise by 1dB close to the airport.

Sustainable Taxiing

Trials linked to sustainable taxiing are ongoing at various airports (e.g. Amsterdam Schiphol, Eindhoven, Paris Charles-de-Gaulle and Brussels) through various SESAR research projects as well as national projects. To incentivise implementation and to synchronize developments, a EUROCONTROL / ACI-EUROPE Sustainable Taxiing Taskforce developed a Concept of Operations in 2024 [18].

The Concept of Operations (CONOPS) addresses the potential fuel burn reductions of several sustainable taxiing solutions, which could be up to 400kg CO_2 from a single aisle aircraft taxi-out phase. In addition, there are noise and air quality benefits as the aircraft engine start-up and shut-down procedures occur away from the gate area.

These benefits are mainly the result of operational improvements, such as single engine taxing, combining engine start-up while taxiing, or combining pushback and taxi clearances by air traffic control, thereby reducing total taxi and engine running times that still take into consideration engine thermal stabilization and some additional complexity in ground operations. Research is also looking into limiting Auxiliary Power Units (APU) use to outside certain temperature above a certain threshold. On-going trials are expected to further clarify how to integrate the different taxi operational solutions and quantify their benefits by end of 2025.

5.1.2 Airport Infrastructure

Various EU research projects, including TULIPS [19], OLGA [20] and STARGATE [21], are currently demonstrating innovative environmental solutions at airports, which can be replicated on a European scale.

Ground Support Equipment

Sustainable ground operations at airports have received growing attention in the last few years as a way to address concerns regarding health and working conditions of airport operational staff, as well as the impact on communities in the vicinity of airports. States are already in the process of adopting more stringent regulations to address these concerns resulting in airports looking to fully electrify their ground operations [22].

To advance carbon neutrality of ground operations, Skytanking and Brussels Airport have been developing electric hydrant fuel dispensers, which deliver aviation fuel from the underground hydrant system into the aircraft. After a successful test period in 2023 during which two diesel fuel dispensers were retrofitted to run on electricity, Skytanking commissioned two custom made fully electric hydrant fuel dispenser, which were delivered in 2024 leading to a significant reduction in noise and exhaust gases, which is important for both the local environment and for the ground handling staff. As part of the same research project, DHL Express has replaced a third of its ground handling fleet (tractors, container lifts, belly loaders and pushbacks) with fully electric equivalents.

In 2024, Frankfurt Airport commissioned an expansion to its vertical photovoltaic solar energy system beside Runway 18 West in order to supply renewable energy to power electrified ground support equipment [23]. This facility has provided such encouraging results that its gradually expanded from 8.4kW to 17.4MW, and is now considered the world’s largest facility of its kind at an airport. The airport is also using charging infrastructure bidirectionally, which means it's possible to turn electric vehicles into mobile power storage units [24].

Zero Emission Aircraft

The European Commission has established the Alliance for Zero Emission Aircraft (AZEA) to prepare the aviation ecosystem for the entry into service of hydrogen and electric aircraft (see Technology-Design chapter). This will require major investment in energy infrastructure is required to prepare for the introduction of zero-emission aircraft with electric and hydrogen propulsion. The large-scale introduction of zero-emission aircraft will be a crucial pillar in reaching net zero carbon emissions by 2050.

GOLIAT is an EU project that brings together all relevant aviation stakeholders to demonstrate small-scale liquid hydrogen aircraft ground operations at three European airports [25]. Launched in 2024, the group will support the aviation industry’s adoption of liquid hydrogen (LH2) transportation and energy storage solutions by:

- Developing and demonstrating LH2 refuelling technologies scaled-up for future large aircraft;
- Demonstrating small-scale LH2 aircraft ground operations at airports;
- Developing the standardisation and certification framework for future LH2 operations; and
- Assessing the sizing and economics of the hydrogen value chains for airports.

New airport pavement bearing strength calculation to optimise maintenance works

In order to ensure safe aircraft operations, airports need to continuously monitor the lifetime and life cycle of critical pavement infrastructure (runways, taxiways and aprons) based on the impact caused by different types of aircrafts with different weights, tyre geometry and tyre pressure. In 2024 EASA published guidance to European airports and competent authorities that changed the Aircraft Classification Rating - Pavement Classification Rating (ACR-PCR) methodology used to calculate pavement bearing strength [26]. These changes are expected to optimise the use of pavement, reduce maintenance needs and costs and also reduce greenhouse gas emissions through a well-managed and better targeted pavement life cycle management by airports.

Sustainable Aviation Fuels

The European policy framework for the deployment of SAF is ReFuelEU Aviation Regulation, which sets out a supply mandate for aviation fuel suppliers and an obligation on Union airports to facilitate this supply of aviation fuels containing the minimum shares of SAF to aircraft operators. European airports are also taking voluntary actions to support the uptake of SAF through various means (Table 5.1). A detailed overview of these types of SAF incentive initiatives by European airports has been compiled by ACI EUROPE [27].

Table 5.1 Overview of airport initiatives to support the uptake of SAF

Supply Chain Investment
• Support airlines on logistic issue to facilitate the delivery of SAF. • Engage in joint negotiations with SAF suppliers, carriers and other airports to develop SAF projects. • Invest in SAF production facilities.
Raise Awareness
• Inform passengers and corporations on opportunities to purchase SAF for their flights and/or support SAF projects to compensate for their CO_2 emissions.
Financial Incentives
• Provide airlines with SAF incentive programmes (e.g. cost sharing of SAF price premium, differentiated landing and take-off fees based on SAF use, free SAF storage).
Policy Engagement
• Engage with government and local stakeholders to support SAF development and financial incentives for airlines, but not through any kind of minimum shares of SAF other than those of ReFuelEU Aviation.

The EU ALIGHT research project, led by Copenhagen airport, is looking into how to address the barriers to the supply and handling of SAF at major airports by improving the logistics chain in the most efficient and cost-effective manner [28].

Greening Aviation Infrastructure

As the aviation sector evolves to address environmental challenges, this transition is being supported through Member State actions and EU support, notably the Trans-European Transport Network [29], the Alternative Fuels Infrastructure Regulation [30] and their 'financial arm' in the form of the Connecting Europe Facility [31].

Trans-European Transport Network (TEN-T)

The revision of the TEN-T Guidelines [32] introduces requirements on Member States that include the improvement of airport connections to the trans-European railway network, air traffic management infrastructure to enhance the performance and sustainability of the Single European Sky, alternative fuels infrastructure and pre-conditioned air supply to stationary aircraft.

Alternative Fuels Infrastructure Regulation (AFIR)

The AFIR introduces mandatory targets for Member States on the provision of electricity to stationary aircraft at TEN-T network airports and requires Member States to define national strategies on deployment of ground infrastructure for electric and hydrogen aircraft.

Connecting Europe Facility (CEF)

Under CEF Transport Alternative Fuel Infrastructure Facility, 20 projects representing 63 airports from across the EU were selected since 2021, with a total EU Grant support exceeding €160 million [33, 34]. The support has been directed to electricity and pre-conditioned air supply to stationary aircraft, electric charging of ground support equipment, electricity grid connections and green electricity generation.

5.2 Net Zero CO_2 Emissions

The ACI EUROPE Sustainability Strategy was launched in 2019 [35], which included the Net Zero Resolution that has been updated in 2024 [36]. 303 European airports have since committed to net zero[43] carbon emissions from airport operations within their control by 2050 and provided a roadmap detailing how this will be achieved [37].

This net zero commitment covers Scope 1 direct airport emissions and Scope 2 indirect emissions (e.g. consumption of purchased electricity, heat or steam). 132 airports have announced a net zero target by 2030 or earlier, and 13 airports have already achieved net zero. In 2022, guidance on reducing Scope 3 emissions from others operating at the airport which are the largest share of emissions (e.g. aircraft, surface access, staff travel) was published [38] and this was followed in 2023 with guidance on developing Net Zero carbon roadmaps [39].

STAKEHOLDER ACTIONS

Airport Carbon Accreditation Programme

The Airport Carbon Accreditation (ACA) programme [40] was launched in 2009 by the Airports Council International Europe and, as of June 2024, now includes 564 airports on a global basis. The ACA is a voluntary industry led initiative, overseen by an independent Administrator and Advisory Board, that provides a common framework for carbon management with the primary objective to encourage and enable airports to reduce their CO_2 emissions. All data submitted by airports is externally and independently verified. As of the latest 2022-2023 reporting period, there were **290 European airports** participating in the programme corresponding to 77.8% of European passenger traffic (Figure 5.2).

[43] Net zero carbon dioxide (CO_2) emissions are achieved when CO_2 emissions from human activities are balanced globally by CO_2 removals from human activities over a specified period. Net zero CO_2 emissions are also referred to as carbon neutrality.

Figure 5.2 – European airports participating in the ACA programme

The ACA programme was initially structured around four levels of certification (Level 1: Mapping, Level 2: Reduction, Level 3: Optimisation; Level 3+: Neutrality) with increasing scope and obligations for carbon emissions management (Scope 1: direct airport emissions, Scope 2: indirect emissions under airport control from consumption of purchased electricity, heat or steam and Scope 3: emissions by others operating at the airport such as aircraft, surface access, staff travel).

In 2020, Levels 4 (Transformation[44]) and 4+ (Transition[45]) have been added as interim steps towards the long-term goal of achieving net zero CO_2 emissions and to align it with the objectives of the Paris Agreement. Guidelines were also published to inform airports about offsetting options, requirements and recommendations, as well as dedicated guidance on the procurement of offsets.

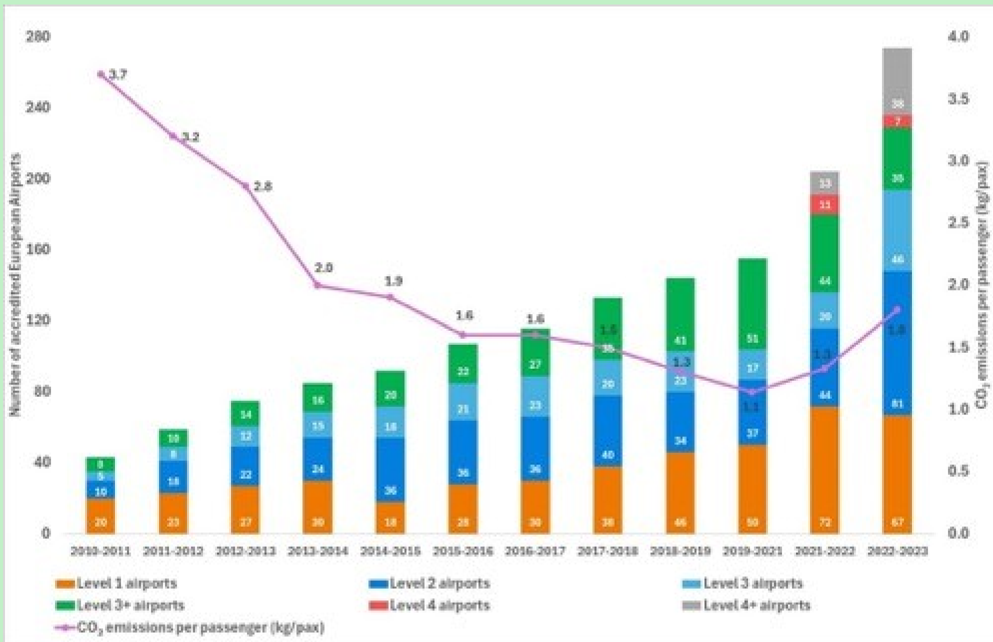
In 2023, a new Level 5 was added to the ACA programme. When applying for Level 5 airports are required to reach and maintain ≥ 90% absolute CO_2 emissions reductions in Scopes 1 and 2 in alignment with the ISO Net Zero Guidelines, as well as commit to achieving net zero CO_2 emissions in Scope 3 by 2050 or sooner. Any residual emissions need to be removed from the atmosphere through investment in credible carbon removal projects. To support airports in this endeavour, an update to the Airport Carbon Accreditation Offset Guidance Document [41] was published on carbon removal options and most effective removal strategies. Level 5 accredited airports need to outline detailed steps to achieve their emissions reduction targets, as part of their Carbon Management Plan.

Level 5 also requires airports to submit a verified carbon footprint for Scopes 1 and 2, and all relevant categories of Scope 3 as per the requirements of the GHG Protocol Guidance [42], notably covering all significant upstream and downstream activities from third parties, including airlines. Finally, airports must establish a Stakeholder Partnership Plan underpinning their commitment to net zero CO_2 emissions in Scope 3, by engaging with the entire airport ecosystem and actively driving third parties towards delivering emissions reductions with regular milestone to gauge progress.

[44] Definition of a long-term carbon management strategy oriented towards absolute emissions reductions and aligned with the objectives of the Paris Agreement. Demonstration of actively driving third parties towards delivering emissions reductions.
[45] All Levels 1 to 4 plus offsetting of the residual carbon emissions over which the airport has control.

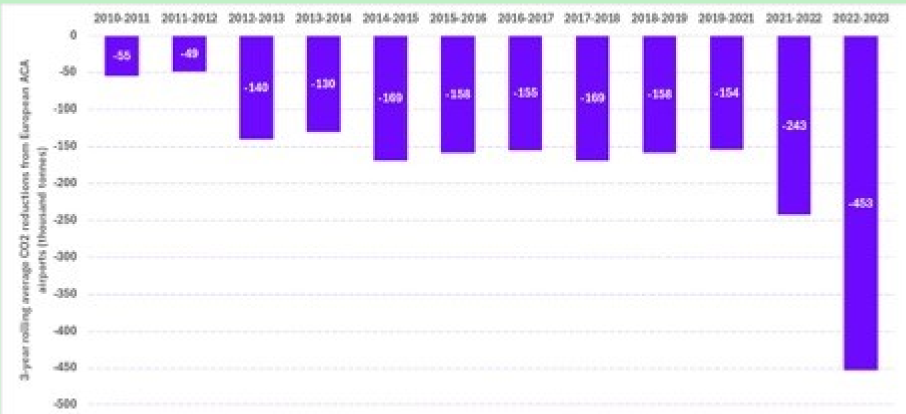
Ten airports were certified against Level 5 at launch, including 9 European airports (Amsterdam Schiphol, Eindhoven, Rotterdam-The Hague, Beja, Madeira, Ponta Delgada, Göteborg Landvetter, Malmö and Toulon-Hyères). Ivalo, Kittilä, Kuusamo and Rovaniemi airports were also subsequently accredited to Level 5 in 2024.

Figure 5.3 – Increasing number of accredited European airports and decreasing CO_2 emissions per passenger



The carbon emission per passenger travelling through European airports at all levels of Airport Carbon Accreditation has increased to **1.8 kg CO_2/passenger** (Figure 5.4). A total reduction in Scope 1 and 2 emissions compared to a three year rolling average[46] of **452,893 tonnes of CO_2** for all accredited airports in Europe was also reported (Figure 5.3). This represents about 20% reduction compared to the three-year rolling average.

Figure 5.4 – Scope 1 and 2 emissions reductions in airport CO_2 emission



Further developments in the ACA programme are envisaged in 2025 that will focus on the efforts of airport supply chains to reduce their CO_2 emissions.

[46] Emissions reductions have to be demonstrated against the average historical emissions of the three years before year 0. As year 0 changes every year upon an airport's renewal/upgrade, the three years selected for the average calculation do so as well. Consequently, airports have to show emissions reductions against a three-year rolling average.

STAKEHOLDER ACTIONS

Airport Council International Europe (ACI EUROPE)

ACI EUROPE represents over 500 airports in 55 countries, which accounts for over 90% of commercial air traffic in Europe. It works to promote professional excellence and best practice amongst its members, including in the area of environmental sustainability.

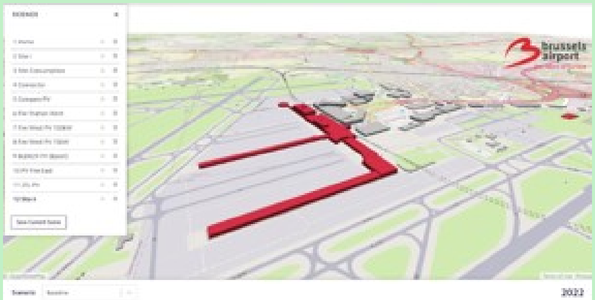
Digital Green Lane

The Digital Green Lane [43] was launched in 2023 and is a fully digital system for the delivery and collection of goods between freight forwarders and ground handlers, facilitated using cloud-based applications. This process offers numerous benefits, including shorter waiting times for the trucks that deliver and collect goods, a reduction in CO_2 emissions, increased transparency and less paper. The Digital Green Lane was further expanded by cargo community organisation Air Cargo Belgium and some 95% of all cargo in the Brussels Airport cargo zone is now processed via this system. A pilot programme incorporating this same system has also been launched at Athens airport.

Airport Regions Council (ARC)

ARC is an association of local and regional authorities hosting or adjacent to both major European hub airports and smaller airports. The organisation's expertise is at the intersection of airport operations and local/regional policies, and it supports maximising benefits and minimising environmental impact, ultimately striving to improve the well-being of residents in airport regions.

Digital Twin



Within the EU Horizon 2020 research project 'Stargate' [44], IES and Brussels Airport have developed a Digital Twin of the airport's 40 most energy-intensive buildings before modelling scenarios such as installing solar panels, electric vehicle chargers and replacing gas boilers with heat pumps to find the most effective routes to net zero carbon emissions by 2030. This marks a significant step up from the current use of digital twin technology, where it has most commonly been used to optimise commercial operations. Through rigorous modelling stages, it was verified that energy saving measures had the potential for up to 63% CO_2 savings against the 2019 baseline year. This approach will also be replicated at Athens, Budapest and Toulouse airports and promoted across ARC Members.

Non-Governmental Organisations (NGOs)

Environmental NGOs are actively involved in policy-making discussions to address the environmental impacts of aviation. They communicate civil society concerns and positions associated with noise, air pollution, climate change and social justice. They also contribute to raising awareness on aviation's environmental impact through transparency of data.

Tracking progress of business travel emissions savings

Travel Smart is a global campaign aiming at reducing corporate air travel emissions by 50% or more from 2019 levels by 2025, led by a coalition of NGOs in Europe, North America and Asia. The campaign ranks over 327 companies based on the sustainability of their business travel practices and holds them accountable through an Emissions Tracker [45]. This tool uses Carbon Disclosure Project [46] corporate emissions database and allows users to track the progress of a company's business air travel emissions reduction target.

The tracker shows through coloured bars whether companies have returned to levels of emissions above their targets or whether they have maintained reductions of -50% or more, thereby highlighting leaders and incentivising competition between companies. Through this Travel Smart campaign, various company best practices have highlighted that reducing flying is compatible with continued development of profitable business [47].

4. Section 2 – National actions in Norway

The actions described in this chapter are complimentary to the actions taken collectively in Europe described above in chapter 3 – Section 1, and several national initiatives are implementation of such actions. Both actions on CO2 emission reductions for domestic and international aviation are listed. Many of these actions listed are carried out by the private sector, as referred to below.

The following stakeholders have contributed to this section: Avinor, Widerøe, Norse, and Norwegian.

4.1 Aircraft related technology development and standards

There are several ongoing initiatives in Norway to reduce the emissions from air traffic, including new energy carriers and propulsion technologies.

Aircraft related technology development mainly follows three paths to reduce greenhouse gas emissions from aircraft: fully electric aircraft (battery electric and/or Hydrogen fuel cell), hybrid-electric aircraft, and aircraft that use hydrogen directly in custom gas turbines. Battery-electric operation is expected primarily for smaller aircraft and on shorter routes, while fuel cell and hybrid-electric solutions offer the potential for increased range and larger aircraft. Aircraft that combust hydrogen directly in adapted gas turbines will have longer range.

Norway is in a unique position to utilize electrified aircraft, thanks to its established market for smaller aircraft for short flights, considerable interest in the electrification of transport, and almost 100% renewable electricity production. Norwegian aviation operators' focus on the electrification of aviation has received considerable national and international attention. Several aircraft manufacturers and operators see Norway as a potential test area and early market for zero- and low-emission aircraft.

The National Aviation Strategy (Meld. St. 10 2022 – 2023 Sustainable and safe aviation) states that the Government's overall climate goal for domestic aviation is to accelerate the transition towards zero and low-emission aviation, so that the first commercial zero-emission aircraft are phased into Norway as soon as technology allows. CAA Norway's mandate is to facilitate sustainable aviation and safe integration of new technology. CAA Norway is taking an active role in supporting R&D activities nationally and internationally and is working closely with EASA through a dedicated Research Group. The CAA is also developing the comprehensive Regulatory Sandbox in collaboration with EASA. The sandbox will be designed to support different technological innovations and concepts and provide grounds for regulatory learning and to develop competences within the Authority itself.

The Government is furthermore prioritizing a new role within the CAA to be a focal point for the coordination and guidance for industry actors who wish to make use of the number of public support schemes available for research and innovation activities. In addition, the CAA is driving collaboration with authorities in other countries and other sectors to facilitate for faster and more efficient learning.

Avinor is, as the owner, operator and developer of a network of airports, the natural facilitator for the infrastructure at the airports. In 2023, Avinor established an energy transition programme that will contribute to comprehensive and uniform facilities for zero- and low-emission aircraft at the company's airports in line with market needs.

In 2023, Avinor updated a survey from 2020 on current and future electric power capacity at the company's airports. As a follow-up to the state aviation strategy, Avinor has responded to assignments on zero- and low-emission technology in aviation and the need for adaptations at airports in the preparatory work on the National Transport Plan 2025 – 2036.

According to Avinor, hydrogen as an energy carrier in aviation has received increased attention in recent years. Hydrogen can for example be produced by electrolysis or reforming natural gas. If the electricity used in the electrolysis comes from renewable energy, the production and combustion of hydrogen has no direct greenhouse gas emissions. Hydrogen is a useful energy carrier and can help reduce greenhouse gas emissions from air traffic in several ways: in connection with the production of biofuels (hydrogenation), as an input factor in the production of e-fuels, by direct combustion in adapted jet engines, in a system of fuel cells and electric motors. Furthermore, hydrogen may play an important role at airports in the future, for example in backup power applications, or as an energy carrier in heavy vehicles.

In 2023, Det Norske Veritas (DNV) – on behalf of Avinor – updated an overview of future hydrogen deliveries to Avinor's airports. The analysis work related to hydrogen will be continued and developed in 2024. Avinor participates in national and international projects, has contact with several airlines and aircraft manufacturers, and monitor the technological developments closely.

In 2021, Avinor and the Norwegian Air Sports Federation (NLF) received a Pipistrel Velis Electro, the world's first type-certified battery-electric aircraft. The fact that it is type certified by European aviation authorities means that it can, among other things, be used for pilot training. The aircraft is operated in collaboration between Avinor, NLF, SAS, Widerøe, Sundt Air and the climate foundation ZERO. The aircraft is used for demonstration flights and communications activities.

In the National Transport Plan 2025-2036 the Norwegian government prioritised NOK 1 billion to facilitate the transition to zero and low emission aviation. The government is hereby sending a powerful signal to the market about ambition and direction for development. This follow-up of the National Aviation Strategy demonstrates the political will over time for the restructuring of aviation. Resources are being prioritized to Avinor to provide infrastructure, and resources to CAA Norway will provide regulatory facilitation. Hence, Avinor and CAA Norway, are enabled to be drivers of transition. The establishment of Norway as a test arena is a key measure to achieve the government's goal of accelerating the introduction of new technology in Norwegian aviation. See chapter 2.13 and 4.6 for further information.

Environmental actions and policies of major airlines in Norway:

Norwegian

In 2022 Norwegian laid the foundation for a full fleet renewal by 2030 in the environmental sustainability strategy. Today Norwegian operates 66 Boeing 737-800NG and 22 Boeing 737Max and expect delivery for up to 14 MAX on lease in 2024. These aircraft are meant to replace 800NGs. The average age of Norwegian's fleet was 8 years and 3 months at the end of 2023.

In 2022, the company entered a landmark deal with Boeing to purchase 50 Boeing 737 MAX 8 aircraft with delivery from 2025 to 2028, with an option to purchase another 30. The new aircraft are predominately meant to replace previous generation aircraft. A new Boeing 737 MAX 8 has a lower fuel burn and reduces carbon emissions by at least 14% compared to the previous generation Boeing 737-800 NG. Norwegian expects a full fleet renewal to deliver 16-17% improvement to the company's carbon efficiency by 2030.

Another important part of the fleet renewal is to decrease local noise pollution. New aircraft are up to 60% quieter than older generations. Norwegian's operations follow all international environmental regulations. All Norwegian's aircraft meet ICAO Chapter 4 and Chapter 14 requirements for local noise pollution.

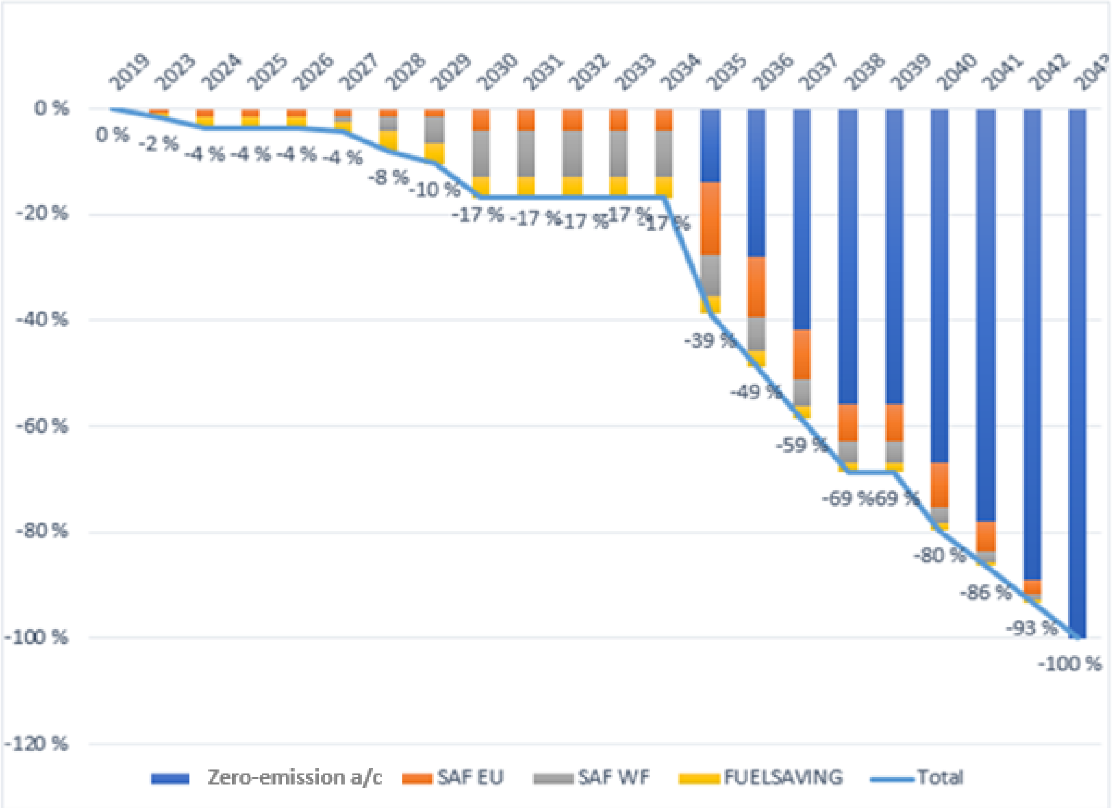
Laid down in the company's environmental sustainability strategy from 2022 the goal is to reduce CO2 emission per revenue passenger kilometre (RPK) to 53 grams CO2, compared to 2010. From 2010 until 2023 Norwegian reduced CO2 emissions per RPK from 97 grams to 75 grams.

<u>Widerøe</u>

Widerøe needs to renew an aging fleet, and the company serves short routes that can be well-suited for zero- and low-emission aircraft. Because of this, Widerøe can be viewed as an interesting partner for companies contributing to the development of tomorrow's regional aircraft. Widerøe closely follows developments through its subsidiary Widerøe Zero, which participates in several advisory boards with manufacturers to influence development. However, Widerøe is not an aircraft manufacturer, and the company must adapt to the developments that occur. The company is therefore prepared to adjust their plans along the way.

The company anticipates that their smallest aircraft (DH1 and DH3) will be replaced with zero-emission aircraft between 2035 and 2038. While their largest aircraft (DH4 and E2) is anticipated to be replaced between 2040 and 2043. Smaller zero- and low-emission aircraft may be phased in earlier, but these will have short ranges and fewer than 20 seats. These are well-suited for testing new technology but will constitute a marginal portion of Widerøe's fleet. Because of this they are not included in the company's emission reduction targets.

Widerøe has developed emission targets for the period 2023 – 2043, the base year is 2019. As shown in the graph below, emissions are to be reduced by17% by 2030, assuming the same production level. By 2043, the flights are to be emission-free.



Widerøe's emission targets for the period 2023 – 2043. The blue bar visualises use of zero-emissions aircraft. Source: Widerøe

The company acknowledges that there are still many challenges and uncertainties associated with the development of zero- and low-emission. Barriers include uncertainty in regard to when new technology will be mature and fully certified, and what operational characteristics the new aircraft will have in terms of range, runway length requirements, seating capacity etc.

Norse

Norse operates a modern fleet of Boeing 787 Dreamliners, designed to optimise fuel efficiency and minimize emissions. Norse estimates that their Boeing 787-9 aircraft, which is configured with 338 seats, boasts a fuel consumption per seat of 2.08 litres per 100 kilometres. This efficiency surpasses estimates for comparable aircraft (as illustrated in the table below), underscoring the company's dedication to reducing fuel costs and emissions while advancing their sustainability goals.

Aircraft	First flight	Seats	Sector	Fuel per seat
Norse Boeing 787-9	**2019**	**338**	**9,208 km**	**2.08 L/100km**
Boeing 787-10	2017	337	10,240 km	2.27 L/100km
Boeing 787-9 (standard)	2013	304	9,208 km	2.31 L/100km
Airbus A350-900	2013	315	9,208 km	2.39 L/100km
Boeing 777-9X	2020	395	13,300 km	2.42 L/100km
Airbus A330-900	2017	300	8,610 km	2.48 L/100km
Airbus A350-1000	2016	367	10,243 km	2.58 L/100km
Airbus A330-800	2017	248	8,610 km	2.75 L/100km
Boeing 787-8	2011	243	8,610 km	2.77 L/100km
Boeing 747-8	2011	467	11,000 km	2.82 L/100km
Boeing 777-300ER	2003	382	10,199 km	2.90 L/100km
Boeing 777-200ER	1996	301	11,000 km	3.08 L/100km
Airbus A330-300	1992	274	10,275 km	3.11 L/100km
Boeing 747-400	1988	487	10,147 km	3.16 L/100km
Airbus A380	2005	544	11,000 km	3.16 L/100km

[1] *Source: Calculated as the Boeing 787-9 (standard) consumption figure multiplied by 304 divided by 338*

[2] *Source: Various sources, all summarized at https://en.wikipedia.org/wiki/Fuel_economy_in_aircraft*

Norse is aware of their existing barriers regarding CO2 emissions reduction activities. The company has, since its first flight in 2022, focused on creating a financially sound airline. This has unfortunately left no resources for a sustainability office. Despite these limitations, members of the Norse team have taken ownership of sustainability topics within their domain. As the airline matures, Norse hope to support individual's awareness and knowledge, leading to a robust knowledge management system to be used throughout the company.

The main barrier Norse has faced in identifying and implementing sustainability measures is the lack of personnel with experience in and knowledge of sustainable aviation. While members of the Norse team have done a good job of quickly learning to ensure compliance, the company aspires to create a dedicated sustainability role.

4.2 Sustainable aviation fuels

The first flights using SAF in Norway were conducted by SAS and Norwegian in November 2014. In January 2016, Oslo Airport (owned and operated by Avinor) – in collaboration with AirBP, Neste, SkyNRG, Lufthansa Group, KLM and SAS – became the first international airport in the world to blend jet biofuel into the regular fuel supply system on the airport and to offer biofuel to all airlines refuelling there.

The Norwegian quota obligation (blending mandate) for advanced biojet fuels entered into force on 1 January 2020. It was the first enforced obligation of its kind for aviation in the world. 0,5 % of the sale of aviation fuels sold in Norway annually must be advanced jet biofuels. Advanced jet biofuels according to the European Union (EU) as well as the Norwegian definition, which include waste, forest residues, used cooking oil, animal fats etc. The mandate is imposed onto the fuel supplier, defines as the company responsible for paying excise duties on the fuel (e.g. CO2 tax). The Norwegian quota obligation is based on the mass balance principle – the obligation refers to the annual sale of fuel for aviation in Norway. This gives the suppliers the flexibility to choose when and where the obligation will be met. The quota obligation applies to both domestic and international aviation. Military flights are exempted. The Norwegian Environment Agency has evaluated the quota obligation, and the overall conclusion was that it has been working well.

From 1 January 2025 the SAF obligations according to EU Regulation 2023/2405 of the European Parliament and the Council of 18 October 2023, ReFuelEU Aviation takes effect. The Norwegian government has decided to keep the national mandate at 0,5% but is considering to harmonize the current mandate in line with ReFuelEU Aviation. EU Directive 2018/2001 has, as of the date of publication of this document, not been implemented into the EEA Agreement.

The following are examples of specific measures taken by the operators to support the transitioning to biofuels:

Norwegian

Norwegian's aircraft can fly on up to 50% certified sustainable aviation fuel today. The company actively engage with producers of SAF and will use its purchasing power to ramp up production of affordable fuels with high sustainability performance. In 2023, the company invested in a project to build an e-fuel plant, called Norsk e-Fuel. Norwegian is today co-owner in the project that will produce e-fuels from 2027/2028.

Norwegian acknowledges that Europe will have a shortage on SAF from 2030 (according to SkyNRG). Therefore, the company considers it as important to ramp up production in Europe to meet the future demand from airliners. Norwegian believes there are several opportunities to produce SAF in Norway, as the country has competitive prices on electricity, knowledge on heavy industry and an advantage on forest residues, among others. For industry to be able to invest in SAF Norwegian labels it as crucial to harmonize rules with the EU, create predictability for investors, and give new "green" industries access to feedstocks and support mechanisms.

According to Norwegian's environmental sustainability strategy the company has calculated that they will need to blend in up to 20% sustainable aviation fuel to meet the 2030-target. In 2023, Norwegian consumed 1,759 tonnes of SAF, compared to 1,777 tonnes in 2022. The share of SAF consumed as a share of total of JET A-1 uplifted was 0,3%, unchanged from 2022.

Widerøe

In 2023, Widerøe consumed 0,5% SAF of a total Jet A-1 uplifted in Norway, in compliance with the Government of Norway's blending mandate requirements.

Widerøe has introduced a technical solution offering their costumers an easy way to voluntary offset their emissions seamlessly in the booking process through the purchase of sustainable biofuel.

Norse

As part of Norse' sustainability strategy the company is committed to transpose to SAF as they become commercially viable. Norse actively advocate for legislative measures that incentivise climate action, including support for SAF.

4.2.1 SAF Roadmap

Avinor has been a major contributor to this subchapter.

This SAF Roadmap aims to describe the story of SAF use in Norway, including:

- who the key stakeholders in the development are,
- what has been done of knowledge development to understand both potential for production and what is needed to move developments forward,
- prospects for future production
- and current policies for use and production.

Early-stage developments

In the aviation sector in Scandinavia the airline SAS was probably the first to consider SAF as a technology for reducing carbon emissions. SAF was a topic in their annual report already in the year 2000.

The airport operator Avinor is working to reduce their own emissions from airport operations and from surface access to the airport. Avinor has also for more than 15 years in close cooperation with the airlines based in Norway (Norwegian, SAS and Widerøe), the Federation of Norwegian Aviation Industries and the Norwegian Confederation of Trade Unions (LO) taken a role to reduce aviation emissions. Since 2008 these organizations have published joint reports about aviation sustainability and the potential in new technologies. They have also cooperated on various industry initiatives over many years and worked to incentivize a green transition in the aviation industry.

Early uplift of SAF

In 2014 the first demo-flights in Norway with SAF took place, a cooperation project between Avinor, Norwegian, SAS and the non-governmental organization ZERO. A Norwegian flight from Bergen and a SAS flight from Trondheim both flew to Oslo with 49% SAF blend on the occasion of a climate conference.

In January 2016 Oslo Airport became the first international hub in the world to blend SAF into the fuel infrastructure (main fuel farm, hydrant and dispenser system) at the airport. A mass balance principle was applied; all airlines uplifting fuel at the airport got a share of SAF in their fuel mix when tanking there, but only airlines paying the premium for SAF were allowed to claim SAF usage in their communication and accounting. The project was initiated by AirBP and Lufthansa Group and carried out as a collaborative project with Avinor, SkyNRG, Neste, SAS and KLM.

The voluntary volume uplifted at Oslo Airport in 2016 was 1,25 million liters; a very small share of the total fuel consumption at the airport, but a large SAF volume that had to be sourced from different producers at the time. The project was expanded to the second largest airport (Bergen) in Norway the following year. SAF volumes were thus uplifted at Oslo airport in 2016 and at Oslo and Bergen airports in 2017 and 2018. However, the focus in Norway gradually moved from voluntary to mandatory uptake as the Norwegian government in 2018 announced a mandate for aviation to be effective from 2020.

In 2018 the Norwegian government announced the introduction of a national mandate from January 2020. Fuel suppliers for aviation must ensure that at least 0.5% by volume of the total amount of fuel sold per year consists of advanced biofuel. Advanced biofuel is defined as biofuel made from feedstock listed in Part A and Part B of Annex IX to the EU Renewable Energy Directive, Directive (EU) 2018/2001. For sustainability reasons, first generation biofuels such as feed-, food- and crop-based biofuels, which have limited scalability potential and raise sustainability concerns, are not included in the mandate. Synthetic fuels/e-fuels are also not included. In 2022 the mandate was fulfilled with 3,2 million liters of HEFA SAF made from animal fats not suitable as food and feed, originating from Europe.

All aviation fuel is covered by the mandate, except for fuel that is sold for flights carried out by military aircraft. The regulation allows for cooperation with other fuel suppliers, where fuel suppliers who trade more biofuel than they are obliged to can transfer excess volumes to other suppliers.

Voluntary uplift

Airlines like SAS and Widerøe have for some time already offered their passengers to pay the premium for SAF. The cost of this is quite substantial, compared to the total ticket price, and the experience so far has been that only a very small percentage have used the opportunity.

The airline Norwegian offers corporate customers to reduce their emissions from business travel through uplift of SAF. In August 2023 the airline Norwegian won a contract with the Norwegian Defense Logistics Organization for procurement of staff air travel services for the armed forces on scheduled civil commercial air services. Sustainability was emphasized when the Norwegian Defense invited airlines to bid, and the result was a contract with substantial voluntary uptake of SAF (more than 10% of the fuel consumption).

The voluntary uptake of SAF described in this section is volumes of SAF that are additional to the mandated volumes.

Knowledge base

In 2012 Avinor commissioned a comprehensive study on the topic of SAF. In 2021, the Norwegian aviation industry published a program for increased production and uptake of SAF, proposing both industry and government activities to reach the goal. In 2023 a study investigating the opportunities for SAF production from non-biological feedstocks (hydrogen, CO2, waste, plastics etc.) was published. Many of the mentioned reports are available in English at Avinor's website[47].

The prerequisites for production of SAF differ widely between different parts of the world. In order to establish and increase production in Norway it has been important to understand how SAF can be produced based on waste and residue feedstocks available locally. It has also been important to understand how SAF production can fit into the national industry structure.

Prospects for SAF production in Norway

Current SAF uplift in Norwegian aviation is based on imported SAF as there is no domestic production. As in other countries, the SAF currently used is produced from the HEFA pathway, based on used cooking oil and animal fats. However, supply of these feedstocks is limited, and the forecast is that production increases beyond 2030 primarily must come from other feedstocks. A major challenge is that new feed stocks rely on new and less mature production technologies.

There are several industry initiatives in Norway for production of SAF from feedstocks other than used cooking oil and animal fats, applying new pathways and production processes. There are three project development plans for production of e-fuels targeting the aviation sector, and there are also some initiatives on biobased SAF, although probably primarily planning to produce a biocrude (not ready SAF).

Funding is a challenge for the projects. None of the industry initiatives in Norway have yet taken a final investment decision. One of the reasons seems to be that costs of construction and other costs have increased since the pandemic. Some projects have received public funding, in particular from the European Innovation Fund and the national funding agency Enova.

In 2023 the airline Norwegian partnered up with one of the e-fuel-projects; Norsk e-Fuel; the airline has closed an offtake-agreement and also agreed to invest in the company.

In an industry context, SAF production could be an opportunity for value creation from several side streams and waste resources and an early market for hydrogen.

Policies; current and looking forward

The government has declared that the blending mandate is the main measure to increase the use of advanced jet biofuels. However, it has also stated that it will consider to harmonize the current national mandate in line with ReFuelEU Aviation, described in the ECAC/EU section of this document(chapter 3).

[47] https://avinor.no/konsern/klima/rapporter/rapporter

In 2023 the government submitted to parliament a new comprehensive aviation strategy, where environmental sustainability was one of the main four pillars. In the parliamentary adoption process, two decisions were made relevant for SAF:

- The Parliament asked the government to present a plan for how Norway can have a leading position in the production of sustainable fuels, so that Norway is well positioned through an industrial cluster, when the blending mandates are introduced in the EU.
- And the parliament asked the government to quickly present a plan to increase the production of advanced biofuels in Norway.

The Norwegian Ministry of Climate and Environment will follow-up on these decisions.

Short overview of status for SAF relevant projects in Norway
- e-fuels / e-SAF

Project name	Type of fuel / feedstocks	Planned start	Planned production volume	Location and partners	Status
Norsk E-fuel	RFNBO: green hydrogen and CO2	Production from 2027	30.000 ton from start. 150.000 ton from 2030 (3 plants)	Mosjøen from start. Hydrogen from Gen2Energy, CO2 transported in by rail. Also looking at other locations in Norway / the Nordics.	Securing sites Detailed FEED-study running (>100 mill NOK). Binding off-take for 10 years secured.
Nordic Electrofuels	RFNBO: green hydrogen and CO2 (and a fraction of RCF)	Production from 2027	8.000 ton from start (commercial pilot). Next step 40.000 ton. Full scale about 160.000 ton. 70% SAF; about 150.000 ton.	Herøya from start. CO2 from Eramet, will produce their own hydrogen. Has an additional portfolio of 6 projects in Norway in different stages, targeting 1 bill litres in Norway within 2036.	Plans FID early 2025. Detailed FEED-study finished (>100 mill). Binding offtake for 10 years with P2X-Europe.
SMA Minerals / Infinium	RFNBO; green hydrogen and CO2	Step 1 in 2027. Step 2 in 2030.	90.000 tons pr year om total.	Mo Industrial Park, Mo i Rana	FID for first stage chalk production expected in 2024. FID for efuels-production expected in 2025.

Short overview of status for SAF relevant projects in Norway
- side streams from forestry, municipal solid waste (MSW) etc.

Project name	Type of fuel / feedstocks	Planned start	Planned production volume	Location and partners	Status
Silva Green Fuel	A bio oil from sidestreams from forestry from which a large share can later be processed to SAF	Planned start 2028-2030. Potentially later expanding to multiple plants.	About 100 mill litres bio oil / plant. Working with plan that allows up to 50% of the oil to later be processed to SAF.	Tofte. Also working with other locations.	Demo plant built (around EUR 100 mill invested). Testing and further development of technology ongoing. FID expected in 2026.
Biozin	Production of bio-methanol based on forest residues and by-products from the sawmill industry	2030	100.000 ton methanol pr year. Methanol can later potentially de turned into SAF.	Åmli	Shell stopped development of their technology in 2023. During spring 2024 it was announced that Biozin and Bergene Holm started a cooperation with Equinor.
Biojet	Production of advanced biofuel, of which 75% will be SAF. Based on sidestreams from forestry / saw mill.	Production from 2028/2029	35.000 tons biofuel first year. 70.000 tons at full production (2031).	Ringerike. Site secured at Treklyngen. Contracts signed for feedstock. More plants outside Norway under consideration for later stage.	FEED-study planned started in 2025, following ongoing capital expansion (2024).
Equinor	MSW/RDF. Also looking into bio. Potentially also use of blue hydrogen to maximize carbon yield to SAF.	2031	About 100 mill litres	Mongstad	Expects FID in 2028.

4.3 Operational improvements

Avinor, the airlines and CAA Norway are continuously working on measures in the airspace that reduce aircraft fuel consumption and greenhouse gas emissions. Electronic aids for efficient air traffic management and information sharing (Collaborative Decision Management) are important tools and are constantly being developed. Norway is amongst the countries in Europe that has introduced Free Route Airspace. This is an approach to organising airspace that means airlines no longer follow predefined routes but can choose the most optimal route. This reduces both fuel consumption and greenhouse gas emissions.

Additionally, arrivals and departures are optimised and designed to enable continuous climbs and descents. Avinor is implementing curved approaches on all Avinor airports over the next few years (se chapter 4.6 for more information). This has the potential of limiting noise as well as a considerable reduction of distance flown and emission of CO2. This is especially true for Oslo Airport (OSL). This initiative is followed by actions to increase use of these procedures. One important action in progress is implementation of Required Navigation Performance (RNP), which will allow parallel curved approaches based on an extra safety net, in the form of a defined area between the parallel runways, where intrusion of an aircraft will trigger an alarm to the air traffic control officer (ATCO) on duty, such that corrective actions can be taken.

There are several operational improvements already implemented that have a positive effect on the climate:

- Continuous descend and continuous climb. According to EUROCONTROL statistics Norway is at the top in Europe and has been working diligently for many years, through campaigns, procedures, airspace design, work methodology and setting key performance indicators (KPIs).

- Cross border free route airspace. Everybody can fly direct, without detours, from A to B, in Norwegian airspace. Norway is best in Europe at horizontal efficiency enroute.
- Further, the implementation of space-based automatic dependent surveillance (ADS) in oceanic airspace has made it possible with considerably reduced spacing between aircraft at the same level in the airspace and consequently reducing the number of aircraft at suboptimal levels. More aircraft will be at their optimum level and therefore improving their fuel efficiency and reducing the emission of CO2.

Environmental actions and policies of major airlines in Norway:

Norwegian

Norwegian has in their environmental sustainability strategy calculated that more efficient operations could improve carbon efficiency by 3% by 2030. Operational efficiency includes how pilots fly. Norwegian is an industry leader in developing and implementing smart data-tools to improve fuel efficiency performance.

The SkyBreathe mobile application helps pilots to fly more fuel efficient, while the SkyBreathe aircraft performance monitor allows Norwegian to put the most efficient aircraft in operation at the most fuel consuming routes.

In 2022 and through 2023, Norwegian intensified fuel saving training among pilots to improve performance and increase scale. All pilots now receive scheduled training on an annual basis to stay updated on the latest fuel saving best practices. The training gives results. According to data provided through SkyBreathe, pilots were able to save 19,200 tonnes of fuel amounting to a total of 60,600 tonnes of CO2 in 2023. This is significant improvement from 2022, when pilots were able to save 17,000 tonnes of fuel and 53,000 tonnes of CO2.

Norwegian pilots also use a Cruise Profile Optimizer developed by AVTECH to make better route choices, helping pilots to calculate the most fuel-efficient altitude depending on the prevailing winds and aircraft performance.

Widerøe

Widerøe has defined direct emissions as CO2 emissions related to their flights (other emissions as well as scope 2 and 3 will be included in further reporting). Widerøe had an increase in total emissions by just under 2% in 2023 compared to the base year 2019. At the same time production increased by 7.5% measured in available seat kilometres. This means that the emissions per available seat kilometres have been reduced by 5.2%, and by 13.4% when measured per RPK.

The company’s increase in emissions is also related to operational expansion by offering transport by smaller aircraft on routes previously operated by operators with larger aircraft. Widerøe has also established some new direct routes so that customers can travel directly without stopovers (stopovers via a hub often result in a longer journey and therefor increased emissions).

Widerøe has previously introduced a system for dynamic flight planning, and this has already reduced the companies fuel consumption by approximately 10%. Moving forward, Widerøe is working on several new initiatives to achieve further reductions in fuel consumption and thus CO2 emissions. These are the most important measures:

- Widerøe is changing flight schedules so that less throttle is needed to meet arrival times for several routes. This can save up to 1.4 % in CO2 emissions from the DH8-400 fleet.
- Widerøe will upgrade the cockpits of their smallest aircraft with new navigation equipment. This enables the use of new curved approaches, which can save between 1-4 minutes of flight time with corresponding reductions in emissions.
- Optimization of speed/separation during approach on trunk routes.
- Widerøe will acquire Open Airlines' SkyBreathe and implement it during 2024. This system uses Big Data algorithms to analyse operational data from aircraft, including information about weather, aircraft type, weight, and traffic conditions. Based on this, the system provides insights and recommendations on how to operate the specific departure more fuel-efficiently.
- Widerøe is considering introducing a fuel-saving app so that each pilot can see the results of their own measures.

The fuel-saving initiatives aim to contribute to concrete annual reductions in CO2 emissions from Widerøe's flights compared to the 2019 baseline year, ref. graph in chapter 4.1.

Norse

In 2023 Norse migrated flight planning systems to FlightKeys to better balance cost and greenhouse gas (GhG) reduction with safety and network throughput. As a result, transatlantic flight time and subsequent CO2 and non-CO2 emissions have been reduced. Norse has also implemented optimal fuel consumption practices which has resulted in all pilots striving to reduce excess fuel consumption.

Additionally, FlightKeys are planning on integrating the Contrail Cirrus Prediction model (CoCiP) making contrail avoidance a feature available in the Flightkeys flight planning software. This will result in an estimated reduction of CO2 contrail warming by 72.95%.

4.4 Improvement of airport operations

Avinor must work with several identified measures until 2030 to reach targets for absolute emission reductions in line with SBTi for scope 1 and 2. Climate and energy measures, including a new energy solution for Svalbard Airport and a large-scale electrification of the vehicle fleet in the heavier segment, will result in a significant increase in investments. Avinor has more than 1300 vehicles. Of these, approximately 430 vehicles are in the passenger and van segment and about 750 large and heavy vehicles. Avinor's bus fleet of more than 20 buses became fully electric in 2023 when Avinor bought 13 used electric buses from Ruter. Enova support for charging infrastructure was also granted at the following airports: Oslo, Bergen, Stavanger and Trondheim. Avinor's first electric truck was ordered in 2023 and will be delivered in winter 2024. Furthermore, an electric 20-tonne wheel loader will be tested in 2024. A large proportion of Avinor's heavier vehicles are currently not possible to electrify, as there is no zero-emission technology available. Continued use and further phasing in of advanced biodiesel is essential if Avinor is to be able to reduce absolute emissions from its own operations towards 2030. In the coming years, it will be important for Avinor to monitor the technology development, be a driving force in introducing to zero-emission vehicles or biogas vehicles and enter collaborations with partners to test new concepts.

Svalbard Airport receives both electricity and district heating from the power plant in Longyearbyen. On October 19, 2023, this plant went from using coal to diesel as an energy source. Svalbard Airport has for several years investigated the possibility of establishing a biogas plant at the airport. By installing a container with two to three microgas turbines, Avinor can produce sufficient electrical energy to cover consumption at the airport in a climate-neutral way. The excess heat from the turbines and, if necessary, a gas-powered heating flask, will be used in connection with existing district heating plants and cover the heating needs. The plant has been designed in 2023 but is somewhat delayed and is expected to be in trial operation from 2025. In addition to efforts to reduce its own greenhouse gas emissions and its own energy consumption (scope 1 and 2), Avinor has for a long time also taken a leading role in efforts to reduce greenhouse gas emissions from air traffic (scope 3). Measures to improve airspace efficiency, work on SAF, and zero- and low-emission technologies for air traffic have been disclosed in Avinor's annual report for years.

4.5 Economic and marked-based measures

Norway has, since 2001, imposed a CO2 tax on civil domestic aviation, as one of few countries in the world. In 2025 this tax amounts to NOK 1.77 (EUR 0.15) per litre jet fuel (equivalent to NOK 694 pr ton CO2, or EUR 59 pr ton CO2) for emissions covered by the EU-ETS. For emissions not covered by the EU ETS, typically from small-scale passenger flights, the CO_2 tax amounts to NOK 3,58 (EUR 0,30) per litre jet fuel (equivalent to NOK 1 405 pr ton CO2, or EUR 119 pr ton CO2). International travel is exempt from CO2 tax.

Since 2012 civil aviation in the EU/EEA has been part of the EU’s emissions trading scheme. Available quotas are reduced every year in line with the strengthened ambition of 62% emissions reduction by 2030.

Norway is also one of the countries that have committed to participate in ICAOs Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) from its pilot phase in 2021. CORSIA addresses the increase in total CO2 emissions from international aviation and aims to stabilize net CO2 emissions at 2020 levels by requiring airlines to offset any emissions above this baseline. The airlines can achieve this by purchasing emissions unites from the carbon market, which represent reductions from other sectors.

In 2016, the Norwegian government introduced an air passenger duty. The air passenger duty is a fiscal tax with a potential environmental impact. The tax is levied per passenger on commercial air transport of passengers from Norwegian airports, except for flights from the Norwegian continental shelf and airports on Svalbard, Jan Mayen and Norwegian dependencies, also excepted from the tax children under two years old, transfer passengers, air crew on duty travel, and NATO forces. There are two rates, depending on the final destination: a low rate for journeys with a final destination in Europe (in 2025 this duty is NOK 60) and a high rate for journeys to other final destinations (in 2025 this duty is NOK 342).

From 2020 there has been a SAF mandate in Norway, at 0.5 % advanced biofuel. Aviation in Norway is also subject to a NOx tax.

Norse

Norse maintains updated Emission Monitoring Plans and surrenders emissions allowances per their audited reports accepted by the EU and UK Emissions Trading Schemes. In 2022 the company submitted Emissions Monitoring Plans for three compliance schemes, namely: ICAO CORSIA, EU ETS and the UK ETS. All three plans were approved by the regulators.

Subsequently, Norse prepared, independently verified and submitted the annual emissions reports covering all 2022 flights. A total of 4,237 EU ETS allowances and 3,618 UK ETS allowances were purchased and surrendered by the company in April 2023.

In 2024 a combined total of 2,457 UK ETS allowances and 2,933 EU ETS Allowances have been, or will be, purchased and surrendered by the companies Norwegian and UK AOCs.

5. Conclusion

This Action Plan provides an overview of the actions undertaken by Norway and the Norwegian aviation industry, also together with European partners, in contribution to the demanding work of reducing emissions and the development of a resource-efficient, competitive and sustainable multimodal transport system.

This action plan was finalised on 28 January 2025 and shall be considered as subject to update after that date.

APPENDIX A: Detailed results for ECAC scenarios from section A

1. BASELINE SCENARIO

a) Baseline forecast for international traffic departing from ECAC airports

Year	Passenger Traffic (IFR movement) (million)	Revenue Passenger Kilometres[48] RPK (billion)	All-Cargo Traffic (IFR movements) (million)	Freight Tonne Kilometres transported[49] FTKT (billion)	Total Revenue Tonne Kilometres[50] RTK (billion)
2010	4.71	1,140	0.198	41.6	155.6
2019	5.88	1,874	0.223	46.9	234.3
2023	5.38	1,793	0.234	49.2	228.5
2030	6.69	2,176	0.262	55.9	273.5
2040	7.69	2,588	0.306	69.0	327.8
2050	8.46	2,928	0.367	86.7	379.5
Note that the traffic scenario shown in the table is assumed for both the baseline and implemented measures scenarios.					

b) Fuel burn and CO_2 emissions forecast for the baseline scenario

Year	Fuel Consumption (10^9 kg)	CO_2 emissions (10^9 kg)	Fuel efficiency (kg/RPK)	Fuel efficiency (kg/RTK)
2010	38.08	120.34	0.0327	0.327
2019	53.30	168.42	0.0280	0.280
2023	48.41	152.96	0.0268	0.268

[48] Calculated on the basis of Great Circle Distance (GCD) between the airports of the available passenger reports (subset of the global traffic ; from 97% in 2010 up to 99% for the forecast years).

[49] Includes passenger and freight transport (on all-cargo and passenger flights).

[50] A value of 100 kg has been used as the average mass of a passenger incl. baggage (ref: ICAO).

2030	54.46	172.10	0.0250	0.250
2040	62.19	196.52	0.0240	0.240
2050	69.79	220.54	0.0238	0.238
For reasons of data availability, results shown in this table do not include cargo/freight traffic.				

c) *Average annual fuel efficiency improvement for the Baseline scenario*

Period	Average annual fuel efficiency improvement (%)
2010-2023	-1.50%
2023-2030	-1.01%
2030-2040	-0.40%
2040-2050	-0.08%

2. IMPLEMENTED MEASURES SCENARIO

2A) EFFECTS OF AIRCRAFT TECHNOLOGY IMPROVEMENTS AFTER 2023

d) Fuel consumption, CO_2, and CO_2 equivalent emissions of international passenger traffic departing from ECAC airports, with aircraft technology improvements after 2023 included. The well-to-wake emissions are determined by assuming 3.88 Kg of CO_2 equivalent emissions for 1 Kg of Jet-A fuel burn[51]:

Year	Fuel Consumption (10^9 kg)	CO_2 emissions (10^9 kg)	Well to Wake CO_2 equivalent emissions (10^9 kg)	Fuel efficiency (kg/RPK)	Fuel efficiency (kg/RTK)
2010	38.08	120.34	147.77	0.0334	0.334
2019	53.30	168.42	206.80	0.0284	0.284
2023	48.41	152.96	187.82	0.0270	0.270
2030	53.64	169.50	208.12	0.0246	0.246
2040	56.60	178.84	219.59	0.0218	0.218
2050	54.77	173.06	212.50	0.0187	0.187

[51] “Well-to-wake CO_2e emissions of fossil-based JET fuel are calculated by assuming an emission index of 3.88 kg CO_2e per kg fuel (see DIN e.V., "Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)", German version EN 16258:2012), which is in accordance with 89 g CO_2e per MJ suggested by ICAO CAEP AFTF.”

For reasons of data availability, results shown in this table do not include cargo/freight traffic.

e) Average annual fuel efficiency improvement for the Implemented Measures Scenario (new aircraft technology only)

Period	Average annual fuel efficiency improvement (%)
2010-2023	-1.50%
2023-2030	-1.22%
2030-2040	-1.19%
2040-2050	-1.55%

2B) EFFECTS OF AIRCRAFT TECHNOLOGY AND ATM IMPROVEMENTS AFTER 2023

f) Fuel consumption, CO_2 and CO_2 equivalent emissions of international passenger traffic departing from ECAC airports, with aircraft technology and ATM improvements after 2023. The well-to-wake CO_2 equivalent emissions are determined by assuming 3.88 Kg of CO_2 equivalent emissions for 1 Kg of Jet-A fuel burn:

Year	Fuel Consumption (10^9 kg)	CO_2 emissions (10^9 kg)	Well-to-Wake CO_2 equivalent emissions (10^9 kg)	Fuel efficiency (kg/RPK)	Fuel efficiency (kg/RTK)
2010	38.08	120.34	148.02	0.0327	0.327
2019	53.30	168.42	207.16	0.0280	0.280
2023	48.41	152.96	188.14	0.0268	0.268
2030	52.57	166.11	204.31	0.0241	0.241
2040	53.20	168.11	206.78	0.0205	0.205
2050	49.29	155.75	191.58	0.0168	0.168
For reasons of data availability, results shown in this table do not include cargo/freight traffic.					

g) Average annual fuel efficiency improvement for the Implemented Measures Scenario (new aircraft technology and ATM improvements)

Period	Average annual fuel efficiency improvement (%)
2010-2023	-1.50%
2023-2030	-1.51%
2030-2040	-1.60%
2040-2050	-1.98%

h) Equivalent CO_2e emissions forecasts for the scenarios described in this common section, assuming 3.88 Kg of CO_2 equivalent emissions for 1 Kg of Jet-A fuel burn:

Year	Well-to-wake CO_2e emissions (10^9 kg)			% improvement by Implemented Measures (full scope)
	Baseline Scenario	Implemented Measures Scenario		
		Aircraft techn. improvements only	Aircraft techn. and ATM improvements	
2010	147.77			
2019	206.80			
2023	187.82			
2030	211.32	208.12	203.95	-3%
2040	241.30	219.59	206.41	-14%
2050	270.79	212.49	191.24	-29%
For reasons of data availability, results shown in this table do not include cargo/freight traffic.				

2C) EFFECTS OF AIRCRAFT TECHNOLOGY, ATM IMPROVEMENTS AND SAF AFTER 2023 ON EU27+EFTA INTERNATIONAL DEPARTURES

The Net CO_2 emissions and expected benefits of SAF use are calculated where regional measures are taken (e.g. ReFuelEU Aviation) in the European scenario with measures.

i) Fuel consumption, CO_2, Net CO_2 emissions of international passenger traffic departing from EU27+EFTA airports, with aircraft technology and ATM improvements after 2023 The tank-to-wake Net CO_2 emissions are based on the use of Sustainable Aviation Fuels (ReFuelEU Aviation, 70% decarbonation factor for the synthetic aviation fuels, and 65% for aviation biofuels).

Year	Fuel Consumption (10^9 kg)	CO_2 emissions (10^9 kg)	Tank-to-Wake Net CO_2 emissions (10^9 kg)
2010	27.84	87.97	87.97
2019	38.19	120.69	120.69
2023	34.08	107.71	107.71
2030	36.97	116.84	112.21
2040	35.63	112.60	87.15
2050	32.80	103.63	54.67
For reasons of data availability, results shown in this table do not include cargo/freight traffic.			

APPENDIX B: Note on the methods to account for the CO_2 emissions attributed to international flights

a. Background

The present note addresses recommendations on the methodologies to account the CO_2 emissions, for the guidance on the development of the common European approach for ECAC States to follow, in view of the submission to ICAO of their updated State Action Plans for CO_2 Emissions Reduction (APER).

The ECAC APER guidance shall be established on the basis of the Fourth edition of the ICAO 9988 Guidance on the Development of States' Action Plans on CO_2 Emissions Reduction Activities document (advance unedited) to the extent possible. One of its objectives is to define a common approach for accounting CO_2 emissions of international flights: two different methods are proposed for CO_2 accounting, namely ICAO and IPCC. Because of their intrinsic definitions, it is expected that these two different approaches induce both accounting differences, and practical issues, and furthermore, two ways to target the CO_2 Emissions Reduction Activities, and to define the action plans, de facto.

At the 162nd ECAC DGCA meeting (DGCA/162), Directors General requested APER TG to continue its work on the common section on the basis of the use of the Intergovernmental Panel on Climate Change (IPCC) methodology, while encouraging ECAC Member States to comply to the extent possible with the ICAO Guidance for the national sections of their State action plans.

As the objective of the definition of the common section of the ECAC APER guidance consists into determining a common approach for all the foreseen activities, including CO_2 accounting and monitoring, the ECAC APER Task Group required to assess the details of each method and to propose recommendations in this present note.

b. Accounting methods

The ICAO Doc 9988 document 4th edition defines the two CO_2 accounting methods (§3.2. 2):

a) ICAO methodology: each State reports the CO_2 emissions from all international flights, which are operated only by aeroplane operators attributed to the State; the attribution of an aeroplane operator to a State shall be determined as per Annex 16, Volume IV, Part II, Chapter 1, 1.2;

b) IPCC methodology: each State reports the CO2 emissions from all international flights departing from all aerodromes located in the State or its territories. The international flights concern aircraft movements from a country to another country. Each method determines the country assignment of the movement.

Method	ICAO	IPCC
Definition	The ICAO methodology is based on the State of nationality of the airline, and defines an "international" flight as one undertaken to or from an airport located in a State other than the airline's home State, i.e. each State reports only on the international activity of its own commercial air-carriers.	The IPCC methodology defines international aviation as flights departing from one country and arriving in another, i.e. each State report to IPCCs in respect of all flights departing from their territory, irrespective of the nationality of the operator.
Use in projects	CORSIA/ETS (partially)	IPCC EAER UNFCCC