STATE ACTION PLAN OF THE REPUBLIC OF POLAND

FOR THE AVIATION CO_2 EMISSIONS REDUCTION

2025

Urząd Lotnictwa Cywilnego

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This State Action Plan (SAP) for Poland is composed of three sections. The first section is an introductory section that includes general information on the aviation sector in Poland. The second section is the common European section that presents the initiatives and measures taken collectively in the 44 States of the European Civil Aviation (ECAC) to reduce CO_2 emissions from the aviation system. This section was prepared by ECAC and EASA . The third section is the national section that includes additional information on the participation of Poland and Polish aviation industry in the EU aviation research and development programs towards the carbon neutral civil aviation, including complementary measures. The input to this section was jointly prepared by the CAA and national aviation industry stakeholders. All national initiatives are contributions to the European measures, so the quantification is already included in Section II of the State Action Plan.

LIST OF ACRONYMS AND SYMBOLS

AAT - Aircraft Assignment Tool

ACARE – Advisory Council for Research and Innovation in Europe

ACA – Airport Carbon Accreditation

ACI – Airports Council International

AIRE – The Atlantic Interoperability Initiative to Reduce Emissions

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

ATM – Air Traffic Management

CAEP – Committee on Aviation Environmental Protection

CNG – Carbon neutral growth

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

ICAO – International Civil Aviation Organisation

IFR – Instrumental Flight Rules

IPCC – Intergovernmental Panel on Climate Change

IPR – Intellectual Property Right

JU – Joint Undertaking

LTAG – Long-Term Aspirational goal for international aviation

MBM – Market-based Measure

MT – Million tonnes

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

RED – Renewable Energy Directive

RPK – Revenue Passenger Kilometre

RTK – Revenue Tonne Kilometre

RTD – Research and Technological Development

SAF – Sustainable Aviation Fuels

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

SECTION I

Introduction to the State Action Plan

1. COMMON INTRODUCTORY SECTION FOR EUROPEAN STATE ACTION PLANS

The International Civil Aviation Organization (ICAO) Contracting State **Poland** is a member of the European Union and 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.

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.

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.

Poland, 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.

Poland recognises the value of each State preparing and submitting to ICAO an updated State Action Plan for CO_2 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.

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

Poland 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 CO_2 emissions is necessary, and that this should include:

- emission reductions at source, including European support to CAEP work in this matter (standard setting process);
- research and development on emission reductions technologies, including public-private partnerships;

[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.

- 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;
- 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
- 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.

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 the first section of this Action Plan, where the involvement of **Poland** is described, as well as that of other stakeholders.

In **Poland** a number of actions are undertaken at the national level, including those by stakeholders. These national actions are reported in the second section of this Plan.

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 POLAND

2.1 GENERAL OVERVIEW

Poland is located in the central Europe and is the sixth-largest country in Europe. The total area is 322 577 km^2. Poland has a population of 36.6 million inhabitants. Poland's GDP per capita of €30 100 ranks below the EU average (€37 600). It accounts for 4.4% of the EU's total GDP.

The institutions mainly involved in aviation sustainability and environmental protection in Poland are the Ministry of Infrastructure, the Ministry of Climate and Environment, the National Centre for Emissions Management, the Energy Regulatory Office and the Civil Aviation Authority (CAA).

Established on 3rd July 2002 by the Aviation Law Act, the President (Director General of Civil Aviation) supervises the civil aviation in Poland. The tasks and competences of the Civil Aviation Authority include, among others, granting authorizations to air carriers and aircraft users, issuing approvals and decisions in the scope of civil aviation, certification of airports and landing fields, maintaining a register of aircraft. With the headquarters in Warsaw, the structure of the CAA consists of departments and offices as well as delegations located throughout Poland, that together supervise:

- air transport market,
- airport infrastructure,
- technology and equipment,
- air navigation,
- flight safety,
- training and licensing of aviation personnel,
- passenger rights,
- security in civil aviation,
- unmanned aircrafts,
- flight operations and transport of dangerous goods.

The CAA headquarters are in Warsaw. The CAA cooperates with international organizations, including the International Civil Aviation Organization (ICAO), the European Civil Aviation Conference (ECAC), the European Union Aviation Safety Agency (EASA) and EUROCONTROL.

The mission of the CAA is to act for the safety and sustainable development of civil aviation in Poland. The CAA is also a competent authority for Union airports and aircraft operators being in scope of the ReFuelEU Aviation Regulation[2]

[2] ReFuelEU Aviation promotes the increased use of sustainable aviation fuels (SAF) as the single most powerful

2.2 AIRPORTS AND AIRCRAFT OPERATORS

In Poland there are 15 international airports open to commercial traffic. Among them, in 2025 8 Polish airports (EPGD, EPKT, EPKK, EPWA, EPPO, EPRZ, EPMO, EPWR)[3] have meet the criteria of the definition of the union airport being in scope of the ReFuelEU Aviation Regulation while 2 Polish airports (EPWA and EPGD) are accredited airports at Level 1 of ACI Airport Carbon Accreditation (ACA) programme.

No.	ICAO Code	Airport Name
1	EPGD	Gdańsk-Lech Wałęsa
2	EPKT	Katowice-Pyrzowice
3	EPKK	Kraków-Balice
4	EPWA	Warszawa-Chopina
5	EPPO	Poznań-Ławica
6	EPRZ	Rzeszów-Jasionka
7	EPMO	Warszawa-Modlin
8	EPWR	Wrocław-Strachowice

In April 2025, 32 Polish aircraft operators had a valid Air Operator Certificate (AOC), issued by the CAA in accordance with the Regulation (EU) 965/2012, operating aircrafts with more than 19 seats capacity or full cargo. Among them, 11 Polish aircraft operators have met the criteria of the definition of the aircraft operator being in scope of the ReFuelEU Regulation[4].

No.	CRCO Identification number	Operator Name
1	42288	AMC AVIATION SP. Z O.O.
2	47914	BARTOLINI AIR REGIONAL SP. Z.O.O.
3	36143	ENTER AIR SP. Z O.O.
4	31322	JET STORY SP. Z.O.O.
5	1763	POLSKIE LINIE LOTNICZE LOT S. A.
6	45504	RYANAIR SUN S. A

tool to decrease aviation CO_2 emissions. The measure is part of the Fit for 55 package to meet the emissions reduction target of 55% by 2030. It sets requirements for aviation fuel suppliers to gradually increase the share of SAF blended into the conventional aviation fuel supplied at EU airports. According to this regulation the gradually increasing shares of SAF have to be supplied at Union airports, starting from 1 January 2025 with a minimum share of 2% of SAF.

[3] According to the ReFuelEU Aviation Regulation 'Union airport' means an 'airport' as where passenger traffic was higher than 800 000 passengers or where the freight traffic was higher than 100 000 tonnes in the previous reporting period, and which is not situated in an outermost region, as listed in Article 349 TFEU.

[4] According to the ReFuelEU Aviation Regulation 'aircraft operator' means a person that operated at least 500 commercial passenger air transport flights, or 52 commercial all-cargo air transport flights departing from Union airports in the previous reporting period or, where it is not possible for that person to be identified, the owner of the aircraft.

7	28197	SKYTAXI SP. Z O.O.
8	40572	SMART JET SP. Z O.O.
9	38446	SMARTWINGS POLAND SP. Z O.O.
10	33010	SPRINTAIR CARGO SP. Z O.O.
11	30192	SPRINTAIR S.A.

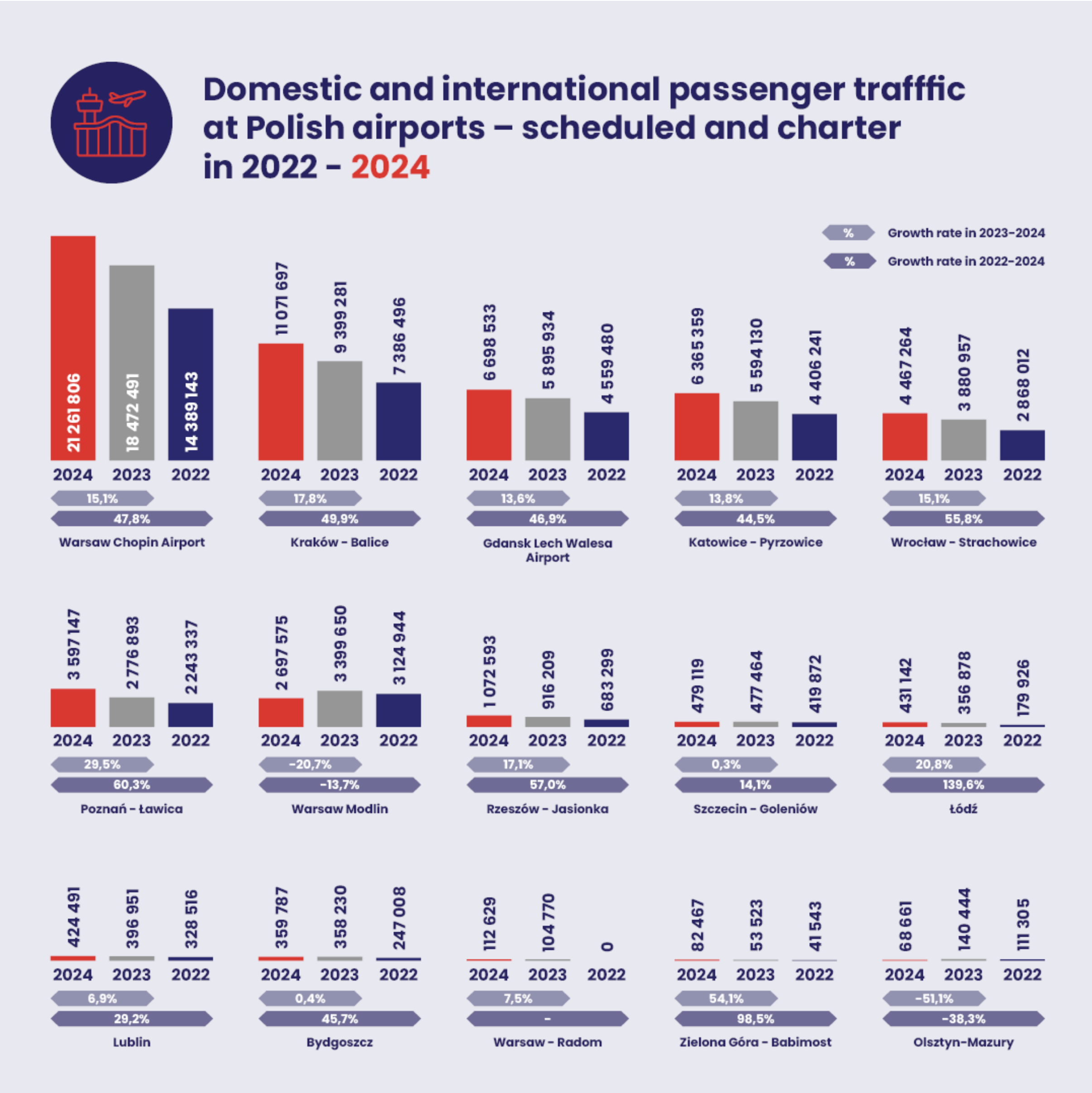
Poland is fully integrated in the European aviation market. According to EU Regulations, any operator from any EU/EFTA Member State has full right to operate domestic and intra EU/EFTA flights, regardless of the country that issued the AOC. Extra-European air transport is regulated by bilateral agreements, both traditional (Poland/Third Countries) and European ones, on the basis of the EU External Aviation Policy. Some of them allow the open-skies template and provide for an exchange of fifth freedom traffic rights. Therefore, traffic share of the major airlines operating in Poland, sorted by the total number of passengers transported in 2024, is described in point 2.1.

Poland is also a part of EU Emissions Trading System (EU ETS) and ICAO Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

2.3 AIR TRAFFIC DATA

In 2024, airports in Poland served **59.2 million passengers**, that is 7 million (13.3%) more than in 2023 and 10.2 million (20.8%) more than in 2019. Carriers performed **426.9 thousand passenger air operations** in 2024 – 12.4% more than in 2023 and 6.6% more than in 2019.

2024 was a record year for many Polish airports. Chopin Airport in Warsaw served more than 20 million passengers for the first time in its history, reaching almost 21.3 million. John Paul II International Airport Kraków-Balice exceeded the threshold of 10 million passengers with a result of 11.1 million, while Rzeszów-Jasionka Airport exceeded 1 million passengers in civilian traffic with a result of almost 1.1 million at the end of the year.



International transport

International transport at Polish airports in 2024 increased by 14.8% compared to 2023. This is a result of 5.9 percentage points higher than the airports associated in the ACI Europe organization. In the entire international traffic, Polish airports served 55.6 million passengers. The number of passenger operations increased by 14.6% and amounted to 374.2 thousand. As part of international scheduled transport, Polish airports served 46.4 million passengers in 2024 - 5.1 million more than in 2023. As part of charter transport, 9.2 million passengers were transported - 2.1 million more than in the previous year.

The largest number of passengers in international traffic in 2024 was carried by Ryanair (17.4 million), Wizz Air (11.5 million) and PLL LOT (9 million). The largest increases in international traffic were recorded by Ryanair (+1.7 million passengers), Wizz Air (+933.2 thousand) and Enter Air (+761.8 thousand).

Domestic transport

Domestic transport decreased by 5.1% compared to 2023. As a result, Polish airports achieved a result that was 7.6 percentage points worse than airports associated with ACI Europe. The largest number of domestic passengers was carried by PLL LOT. The national carrier achieved a quantitative increase of 82.4 thousand passengers in 2024 (+2.6%) compared to 2023.

Regular scheduled transport

In scheduled international and domestic traffic, airports served 50 million passengers in 2024 (+10.8% to 2023). The largest number of people travelled to Great Britain (7.8 million passengers), Italy (5 million) and Spain (4.3 million). The largest increases compared to 2023 were recorded in Spain (+1.3 million passengers), Italy (+1.1 million) and Denmark (+473 thousand).

International scheduled operations at Polish airports – passenger traffic by destination country in 2023 - 2024

■ 2024 ■ 2023 % - market share

		2024	%	2023	%
1	United Kingdom	7 756 344	16,71%	7 733 609	18,71%
2	Italy	5 035 994	10,85%	3 899 614	9,43%
↑3	Spain	4 300 810	9,27%	2 974 401	7,20%
↓4	Germany	4 153 355	8,95%	3 854 454	9,32%
5	Norway	2 456 895	5,29%	2 364 566	5,72%
6	Netherlands	2 022 604	4,36%	1 757 418	4,25%
7	France	1 871 740	4,03%	1 708 780	4,13%
↑8	Denmark	1 467 024	3,16%	994 061	2,40%
↓9	Sweden	1 328 471	2,86%	1 432 355	3,47%
↓10	Greece	1 277 197	2,75%	1 111 503	2,69%
↓11	Ireland	1 036 090	2,23%	1 033 523	2,50%
↑12	Türkiye	978 031	2,11%	749 013	1,81%
↑13	UAE	787 080	1,70%	624 095	1,51%
14	Belgium	777 518	1,68%	655 214	1,59%
↓15	United States	773 216	1,67%	779 630	1,89%
↑16	Cyprus	732 963	1,58%	595 347	1,44%
↑17	Portugal	674 118	1,45%	570 898	1,38%
18	Switzerland	641 839	1,38%	584 334	1,41%
↑19	Croatia	630 088	1,36%	515 133	1,25%
↓20	Austria	579 257	1,25%	635 395	1,54%
↑21	Malta	578 822	1,25%	377 923	0,91%
↑22	Finland	512 119	1,10%	405 619	0,98%
23	Bulgaria	391 751	0,84%	448 584	1,09%
↑24	Hungary	384 171	0,83%	382 604	0,93%
↑25	Czechia	358 309	0,77%	303 561	0,73%
	Other countries	4 909 985	10,58%	4 844 719	11,72%
	Total	46 415 791		41 336 353	

The largest number of passengers in regular traffic in 2024 was handled by Chopin Airport in Warsaw (19 million, +2.3 million passengers by 2023), followed by John Paul II International Airport Kraków-Balice (10.8 million, +1.6 million) and Gdańsk Lech Wałęsa Airport (6.1 million, +598.8 thousand).

Among the carriers, the largest number of passengers in international scheduled traffic in 2024 was served by Ryanair (17 million, +1.9 million passengers to 2023), Wizz Air (11.5 million, +935.2 thousand) and PLL LOT (7.7 million, +468.6 thousand).

International scheduled operations at Polish airports – passenger traffic by carriers in 2023 - 2024

No.	Carrier	2024 passengers	2024 %	No.	2023 passengers	2023 %
1	Ryanair	16 969 606	36,56%	1	15 118 018	36,57%
2	Wizz Air	11 451 720	24,67%	2	10 516 530	25,44%
3	LOT Polish Airlines	7 746 148	16,69%	3	7 277 503	17,61%
4	Lufthansa	2 107 827	4,54%	4	1 817 616	4,40%
5	Enter Air	1 226 842	2,64%	5	1 041 026	2,52%
6	KLM Royal Dutch Airlines	1 041 305	2,24%	6	793 255	1,92%
7	Norwegian Air Shuttle	659 783	1,42%	7	626 000	1,51%
8	EasyJet	555 010	1,20%	8	482 498	1,17%
↑ 9	Finnair	362 986	0,78%	15	240 786	0,58%
↑ 10	Swiss International Air Lines	357 980	0,77%	12	306 323	0,74%
↓ 11	British Airways	353 744	0,76%	9	347 667	0,84%
↓ 12	Austrian Airlines	330 932	0,71%	10	322 802	0,78%
13	SAS	312 818	0,67%	13	250 770	0,61%
↑ 14	Flydubai	301 942	0,65%	16	225 154	0,54%
↓ 15	Air France	299 932	0,65%	11	319 256	0,77%
↑ 16	Turkish Airlines	276 462	0,60%	18	183 167	0,44%
17	Qatar Airways	266 026	0,57%	17	208 910	0,51%
↓ 18	Emirates	232 903	0,50%	14	241 227	0,58%
19	Jet2.com	204 792	0,44%	19	171 871	0,42%
20	Air Dolomiti	187 967	0,40%	20	163 637	0,40%
↑ 21	EL AL Israel Airlines	159 217	0,34%	33	7 913	0,02%
22	SunExpress	136 215	0,29%	22	123 445	0,30%
↓ 23	Aegean Airlines	132 436	0,29%	21	146 417	0,35%
↑ 24	Brussels Airlines	113 925	0,25%	25	50 709	0,12%
↓ 25	TAP Portugal	111 503	0,24%	23	104 706	0,25%
	Other carriers	515 770	1,11%		249 147	0,60%

	2024	2023
Polish carriers – passengers	8 979 544	8 320 670
Polish carriers – %	19,35%	20,13%
Low-cost carriers – passengers	30 369 734	27 278 531
Low-cost carriers – %	65,43%	65,99%
Total	46 415 791	41 336 353

% - market share

Charter transport

In 2024, Polish airports served almost 9.2 million charter passengers in international charter traffic (+29.4% to 2023). The largest number of people traveled to Turkey (2.8 million passengers, +501.6 to 2023), Greece (1.6 million, +271 thousand) and Egypt (1.6 million, +529.4 thousand).

International charter operations at Polish airports – passenger traffic by destination country in 2023 - 2024

■ 2024 ■ 2023 % - market share

Rank	Country	2024	%	2023	%
1	Türkiye	2 811 290	30,68%	2 309 739	32,62%
2	Greece	1 620 831	17,69%	1 349 874	19,06%
3	Egypt	1 566 097	17,09%	1 036 661	14,64%
4	Spain	802 955	8,76%	643 790	9,09%
5	Tunisia	559 275	6,10%	354 189	5,00%
6	Bulgaria	304 032	3,32%	322 924	4,56%
7	Albania	202 534	2,21%	154 774	2,19%
8	Cyprus	146 986	1,60%	126 012	1,78%
↑9	Italy	113 760	1,24%	79 512	1,12%
↓10	Portugal	104 953	1,15%	81 435	1,15%
↑11	United Kingdom	99 435	1,09%	18 090	0,26%
12	Austria	97 355	1,06%	53 806	0,76%
↑13	Thailand	64 563	0,70%	44 814	0,63%
↓14	Dominican Republic	57 811	0,63%	59 833	0,85%
15	Belgium	54 929	0,60%	42 248	0,60%
↑16	Morocco	46 378	0,51%	17 010	0,24%
↓17	Montenegro	44 508	0,49%	36 090	0,51%
↑18	United States	43 500	0,47%	17 016	0,24%
↓19	Tanzania	41 301	0,45%	48 193	0,68%
↑20	Kenya	33 168	0,36%	17 908	0,25%
↓21	Israel	33 168	0,36%	20 413	0,29%
↑22	UAE	30 976	0,34%	15 989	0,23%
↓23	Viet Nam	26 764	0,29%	17 846	0,25%
↓24	Mexico	25 327	0,28%	29 944	0,42%
25	Cabo Verde	23 916	0,26%	16 705	0,24%
	Other countries	206 765	2,26%	165 702	2,34%
	Total	9 162 577		7 080 517	

The largest number of passengers in international charter traffic in 2024 were served by Katowice Airport in Pyrzowice (3.2 million, +592.2 thousand passengers by 2023), Chopin Airport in Warsaw (2.3 million, +493.6 thousand) and Poznań-Ławica Airport (1.1 million, +235.2 thousand).

Among carriers, the largest number of passengers in international charter traffic in 2024 were served by Enter Air (2.6 million +576 thousand passengers by 2023), Buzz (1.3 million, +7.1 thousand) and PLL LOT (1.3 million, +208.4 thousand).

International charter operations at Polish airports – passenger traffic by carriers in 2023 - 2024

No.	Carrier	2024 passengers	2024 market share	No. (2023)	2023 passengers	2023 market share
1	Enter Air	2 623 771	28,64%	1	2 047 759	28,92%
2	Buzz	1 343 502	14,66%	2	1 336 408	18,87%
3	LOT Polish Airlines	1 279 440	13,96%	3	1 071 015	15,13%
4	Smartwings	766 686	8,37%	4	621 479	8,78%
5	Mavi Gök Airlines	452 623	4,94%	5	263 869	3,73%
6	Ryanair	414 075	4,52%	6	243 601	3,44%
↑ 7	Electra Airways	383 091	4,18%	9	174 260	2,46%
8	Skyline Express Airline	307 034	3,35%	8	178 860	2,53%
↑ 9	SkyUp Airlines	289 003	3,15%	14	75 022	1,06%
↓ 10	Pegasus Airlines	287 117	3,13%	7	205 695	2,91%
11	Nouvelair Tunisie	179 461	1,96%	11	145 668	2,06%
12	Sky Express	123 275	1,35%	12	115 217	1,63%
↓ 13	FlyEgypt	101 893	1,11%	10	154 551	2,18%
↓ 14	Corendon Airlines	97 428	1,06%	13	79 177	1,12%
15	FreeBird Airlines	74 358	0,81%	15	71 686	1,01%
↑ 16	Air Cairo	50 762	0,55%	26	9 333	0,13%
↑ 17	Nesma	34 698	0,38%	20	18 191	0,26%
18	Fly Lili	32 342	0,35%	-	-	-
↑ 19	Plus Ultra Lineas Aereas	24 852	0,27%	22	12 321	0,17%
20	Sky Vision Airlines	19 061	0,21%	-	-	-
↑ 21	Aegean Airlines	18 729	0,20%	30	6 338	0,09%
↑ 22	Omni Air International	18 086	0,20%	23	12 083	0,17%
↑ 23	AirExplore	17 314	0,19%	44	895	0,01%
↑ 24	Israir	13 915	0,15%	34	3 731	0,05%
↑ 25	Air Albania	13 178	0,14%	96	86	0,00%
	Other carriers	196 883	2,15%		233 272	3,29%

Polish carriers

6 005 581 (2024)
5 080 963 (2023)

65,54% (2024)
71,76% (2023)

Total

9 162 577 (2024)
7 080 517 (2023)

% - market share

Cargo transport

In the transport of goods by air, there was a decrease in the amount of cargo by 0.8% compared to 2023. In 2024, 196 thousand tons of air cargo were transported and 8.6 thousand air cargo operations were handled (-5.4% to 2023).

SECTION II

Measures taken collectively in Europe

3. EUROPEAN SECTION: 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.

3.1 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.

3.2 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.

3.3 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.

3.4 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)[5] 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.

3.5 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-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.

[5] 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.

4. ECAC BASELINE SCENARIO AND ESTIMATED BENEFITS OF IMPLEMENTED MEASURES

4.1 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).

4.1.1 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[6] 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[7] (published in 2024 by EUROCONTROL). Historical data for the year 2010 and 2019 are also shown later for reference.

	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	32 HST/29 NT city-pairs faster implementation	31 HST/29 NT city-pairs	26 HST city-pairs later implementation.

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

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

(new & improved connections)			
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)

Table 1. Summary characteristics of EUROCONTROL scenarios

4.1.2 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[8] (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;

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

- 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.

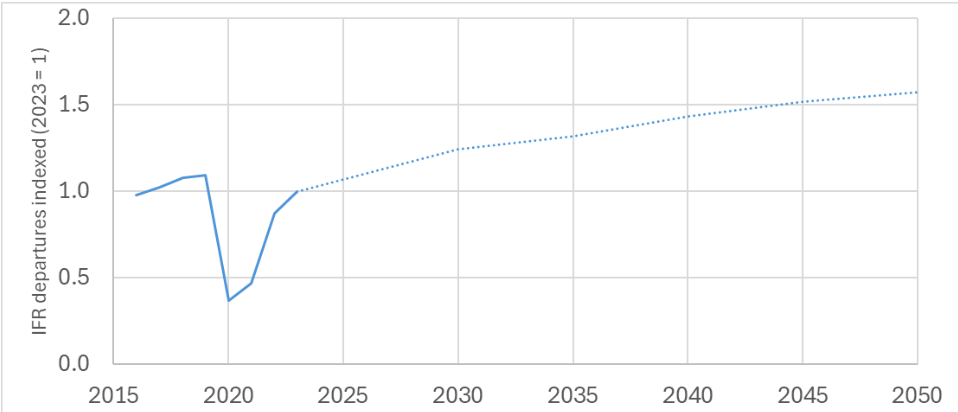


Figure 1. Updated EUROCONTROL 'Base' scenario of the passenger flight forecast for ECAC international departures from 2024 to 2050.

4.1.3 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[9] 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[10]). 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[11] 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

[9] 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.

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

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

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[12].

The following tables and figures show the results for this baseline scenario, which is intended to serve as a reference case by approximating fuel consumption and CO_2 emissions of European aviation in the absence of mitigation actions.

Year	Passenger Traffic (IFR movement) (million)	Revenue Passenger Kilometres[13] RPK (billion)	All-Cargo Traffic (IFR movements) (million)	Freight Tonne Kilometres transported[14] FTKT (billion)	Total Revenue Tonne Kilometres[15] 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 2. Baseline forecast for international traffic departing from ECAC airports

[12] 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.

[13] 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)

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

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

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.				

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

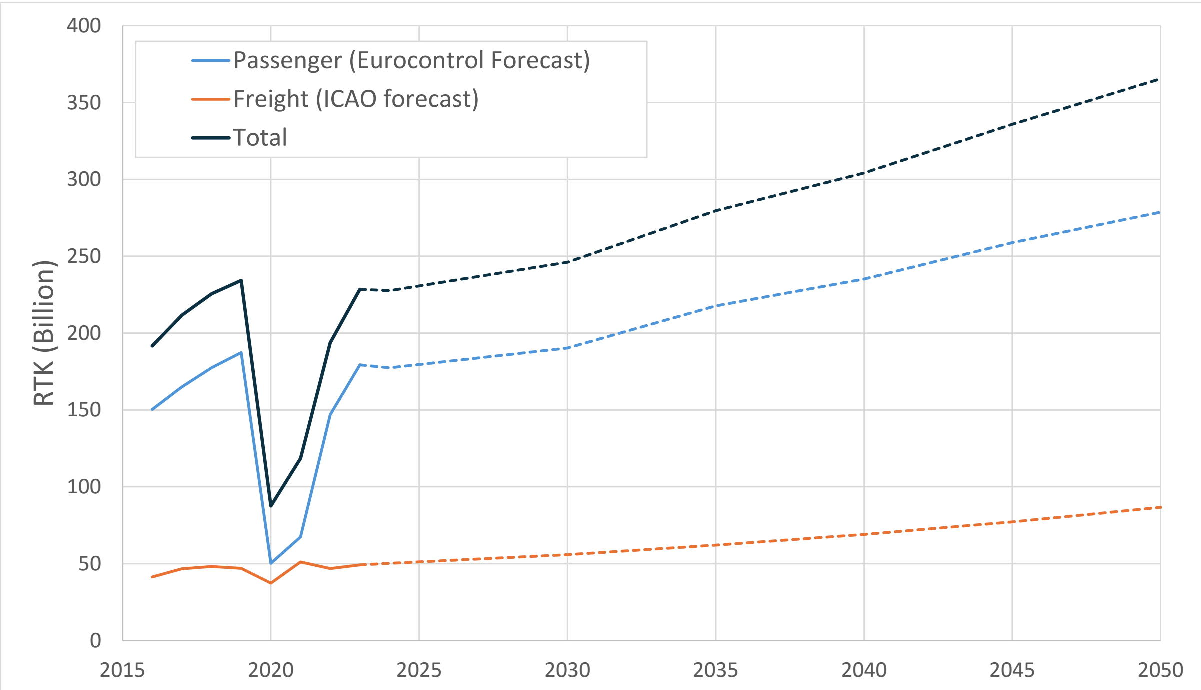


Figure 2. Forecasted traffic until 2050 (assumed both for the baseline and implemented measures scenarios)

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).

4.2 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[16] (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[17] 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[18], 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

16 https://www.easa.europa.eu/domains/environment/impact-assessment-tools

17 See SESAR Exploratory Research projects - https://www.sesarju.eu/exploratoryresearch.

18 https://www.acare4europe.org/sria/flightpath-2050-goals/protecting-environment-and-energy-supply-0

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.

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**[19].

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

Table 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).

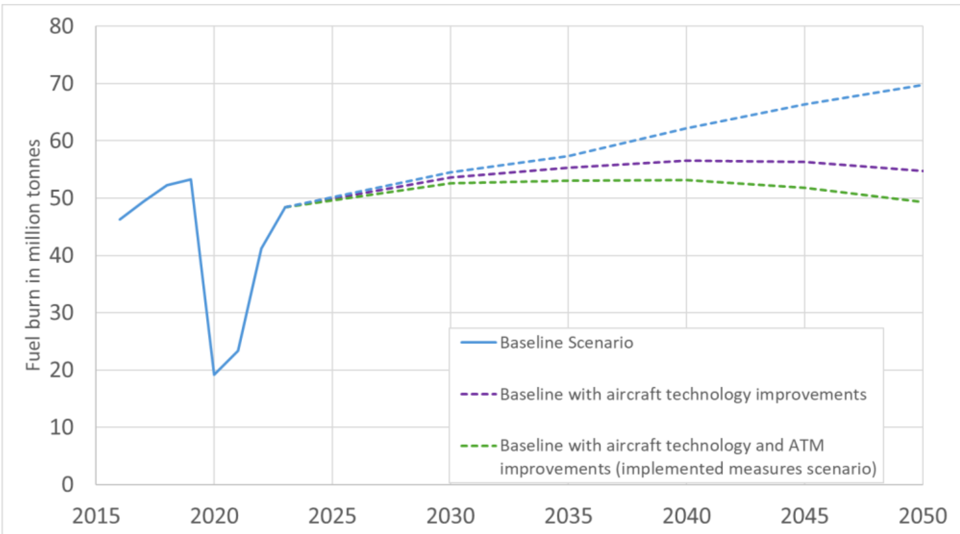


Figure 3. Fuel consumption forecast for the baseline and implemented measures scenarios (international passenger flights departing from ECAC airports).

[19] 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).

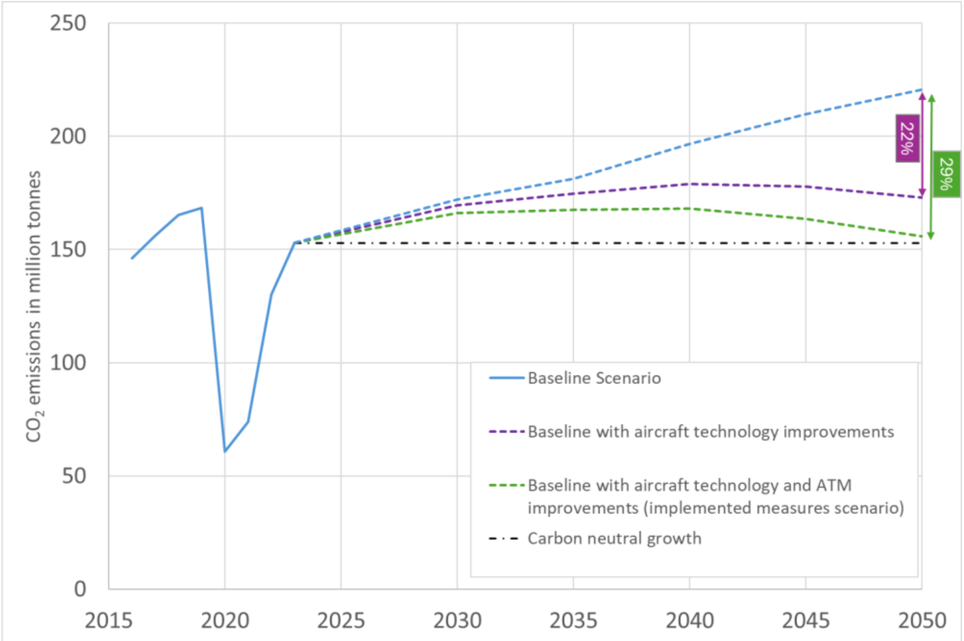


Figure 4. CO_2 emissions forecast for the baseline and implemented measures scenarios

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.

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.				

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

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.

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

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

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.

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.				

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

The following 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.

4.3 APPENDIX: DETAILED RESULTS FOR ECAC SCENARIOS

4.3.1 BASELINE SCENARIO

Baseline forecast for international traffic departing from ECAC airports:

Year	Passenger Traffic (IFR movement) (million)	Revenue Passenger Kilometres20 RPK (billion)	All-Cargo Traffic (IFR movements) (million)	Freight Tonne Kilometres transported21 FTKT (billion)	Total Revenue Tonne Kilometres[22] 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.					

Fuel burn and CO2 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
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.				

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%

[20] 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).

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

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

4.3.2 IMPLEMENTED MEASURES SCENARIO

4.3.2.1 EFFECTS OF AIRCRAFT TECHNOLOGY IMPROVEMENTS AFTER 2023

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[23]:

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

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%

4.3.2.2 EFFECTS OF AIRCRAFT TECHNOLOGY AND IMPROVEMENTS AFTER 2023

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

[23] "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."

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.					

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%

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.				

4.3.2.3 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.

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.			

5. ACTIONS TAKEN COLLECTIVELY IN EUROPE

5.1 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[24] 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).

5.1.1 AIRCRAFT ENVIRONMENTAL STANDARDS

5.1.1.1 AIRCRAFT CO_2 EMISSIONS

Since 1 January 2020, new aircraft types have to comply with a new type CO_2 standard[25], 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, and so the availability of certified CO_2 data remains limited[26]. 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.

[24] 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.
[25] 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.
[26] EASA (2025), EASA Aeroplane CO_2 Emissions Database.

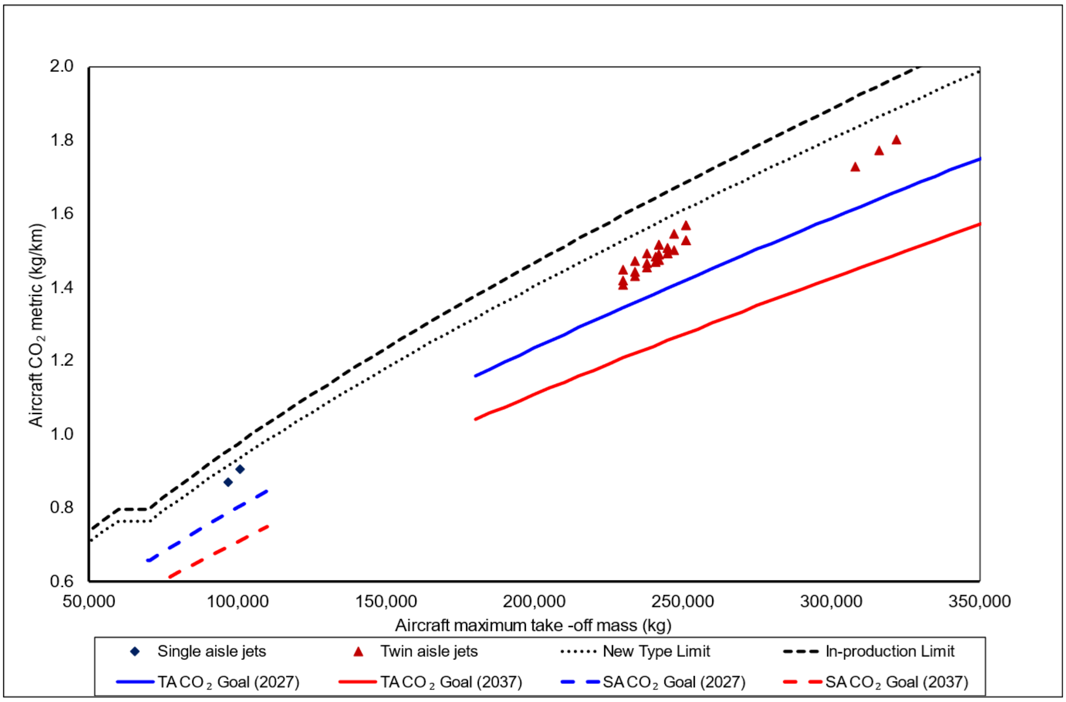


Figure 5.1 Certified aircraft CO_2 emissions performance

5.1.1.2 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[27].

5.1.2 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.

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

5.1.2.1 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[28], 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[29], 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.

5.1.2.2 EASA INNOVATIVE AIR MOBILITY HUB

The EASA Innovative Air Mobility (IAM) Hub[30] 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.

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

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

30 EASA (2025), Environmental Footprint Aviation Study for Drones & eVTOLs.

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[31].

5.1.2.3 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.

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

5.1.2.4 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. 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[32], 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[33].

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[34]. 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[35]. 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[36] 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.

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[32] AZEA (2023), Current aviation regulatory landscape for aircraft powered by hydrogen or electric propulsion.
[33] EASA (2025), Innovation Services.
[34] AZEA (2023), Current Standardisation Landscape.
[35] AZEA (2024), Concept of Operation for the Introduction of Electric, Hybrid-electric and Hydrogen powered Zero Emission Aircraft.
[36] AZEA (2024), Flying on electricity and hydrogen in Europe.

	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

Figure 1.2 ATAG indicative overview of where low- and zero-carbon energy could be deployed in commercial aviation alongside that of SAF[37]

5.1.3 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[38], and noise, specifically the impact of the sonic boom generated when flying at supersonic speed.

5.1.4 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[39]. 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.

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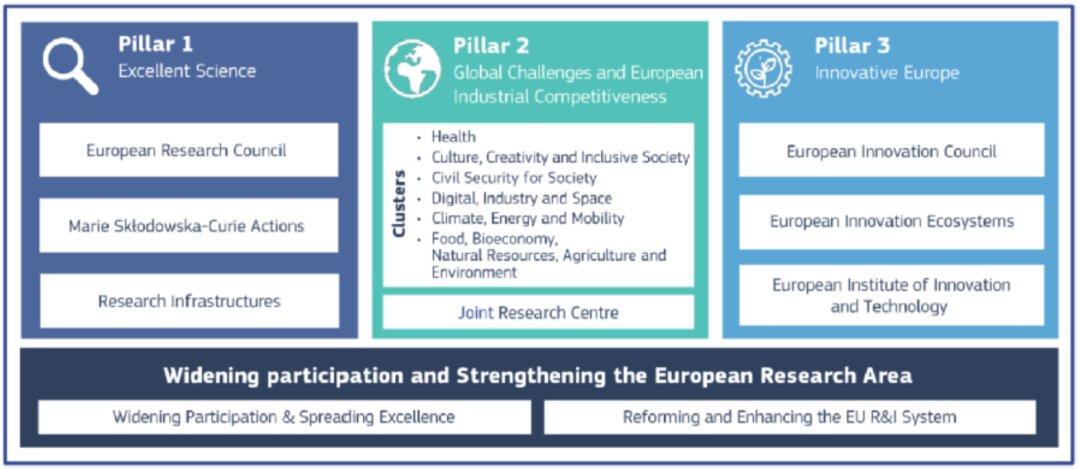
[37] ATAG (2021), Waypoint 2050 Second Edition.
[38] ICCT (2022), Environmental limits on supersonic aircraft in 2035.
[39] EASA (2025), General Aviation Flightpath 2030+.

5.1.5 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[40]. 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

[40] EU (2025), Horizon Europe.

One such Horizon Europe project is HESTIA[41] that focuses on increasing the scientific knowledge of the hydrogen-air combustion of future hydrogen-fuelled aero-engines. Another example is BeCoM[42] 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[43].

5.1.5.1 CLEAN SKY (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[44]. 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[45] and the results are summarised in Table 5.1.

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.

[41] EU (2025), HESTIA Horizon Europe project.
[42] EU (2025), BeCoM Horizon Europe project.
[43] EU (2025), EU Research Projects.
[44] Clean Sky 2 (2014), Council Regulation (EU) No 558/2014 of 6 May 2014 establishing the Clean Sky 2 Joint Undertaking.
[45] Clean Sky 2 (2024), Technology Evaluator.

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)**

Table 5.1 Final Clean Sky 2 Technology Evaluator Assessment Results

5.1.5.2 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[46]. 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 5.2[47].

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

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

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).

Table 5.2 Clean Aviation Targets

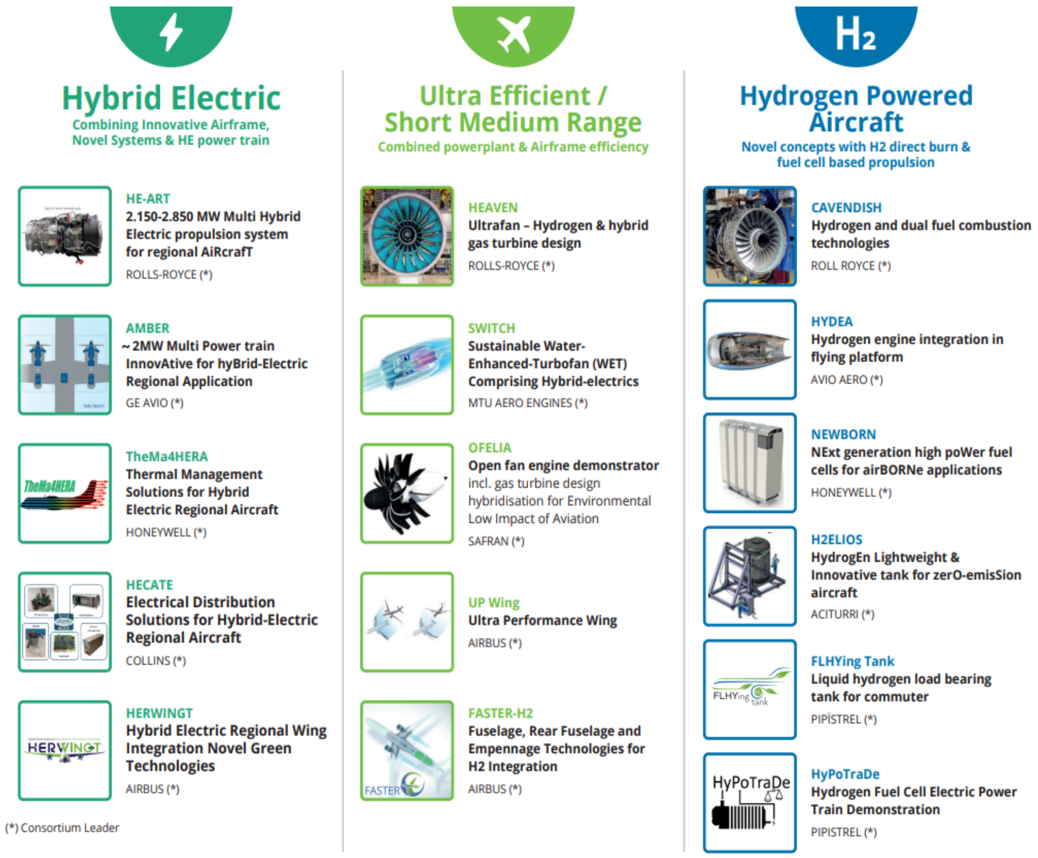


Figure 1.3 Initial projects launched in 2023 to deliver important technology bricks in all three areas

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.

5.2 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 have 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.

5.2.1 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[48], 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.

5.2.2 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 5.3). For instance, aviation biofuels mean biofuels as defined in the Renewable Energy Directive (RED)[49] 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.

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

[48] European Commission (2023), Regulation (EU) 2023/2405 of the European Parliament and of the Council of 18 October 2023 on ensuring a level playing field for sustainable air transport (ReFuelEU Aviation)

[49] EU (2018),Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (Text with EEA relevance.).

		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)

Table 5.3 ReFuelEU Aviation aviation fuel categories

5.2.2.1 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[50,51]. 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[52], 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. In addition, three pathways for the co-processing of renewable feedstocks in petroleum refineries are qualified with a feedstock blending limit of up to 24%.

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[50] ASTM (2021) D1655, 2021, Standard Specification for Aviation Turbine Fuels. DOI: 10.1520/D1655-21C.
[51] Ministry of Defence (2024), DefStan 91-091 Issue 17
[52] ASTM (2021), D7566, 2021, Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons. DOI: 10.1520/D7566-21.

In order to be included in ASTM D7566, novel SAF production pathways need to go through a qualification process specified in ASTM D4054[53]. 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 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.

Production pathway	Feedstocks[54]	Certification name	Maximum SAF share
Biomass Gasification + Fischer-Tropsch (Gas+FT)	Energy crops, lignocellulosic biomass, solid waste	FT-SPK[55]	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[56]	10%[57]
Biomass Gasification + FT with Aromatics	Energy crops, lignocellulosic biomass, solid waste	FT-SPK/A[58]	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[59]	50%
HEFA from algae	Microalgae oils	HC-HEFA-SPK[60]	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%

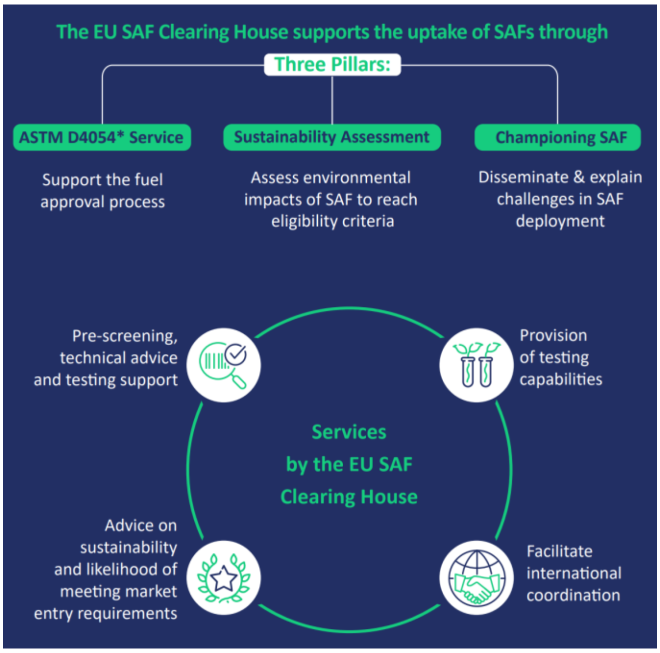
Table 5.4 Drop-in SAF qualified production pathways

[53] ASTM (2021), ASTM D4054, 2021, Standard Practice for Evaluation of New Aviation Turbine Fuels and Fuel Additives. DOI: 10.1520/D4054-21A.
[54] The listed feedstocks are technologically feasible for the specific production pathway, but not necessarily applicable under certain regulations (e.g. ReFuelEU Aviation).
[55] FT-SPK: Fischer-Tropsch synthesised paraffinic kerosene.
[56] HFS-SIP: hydroprocessed fermented sugars to synthetic iso-paraffins.
[57] TRL 7-8 for conventional sugar feedstock; TRL 5 for lignocellulosic sugar feedstock.
[58] FT-SPK/A: Fischer-Tropsch synthesised paraffinic kerosene with Aromatics.
[59] CH-SK: catalytic hydrothermolysis synthesised kerosene.
[60] HC-HEFA-SPK: Synthesised paraffinic kerosene from hydrocarbon-hydroprocessed esters and fatty acids.

5.2.2.2 EU SAF CLEARING HOUSE

The EU SAF Clearing House[61], 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).

5.2.2.3 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

[61] European Union (2024), EU SAF Clearing House

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.

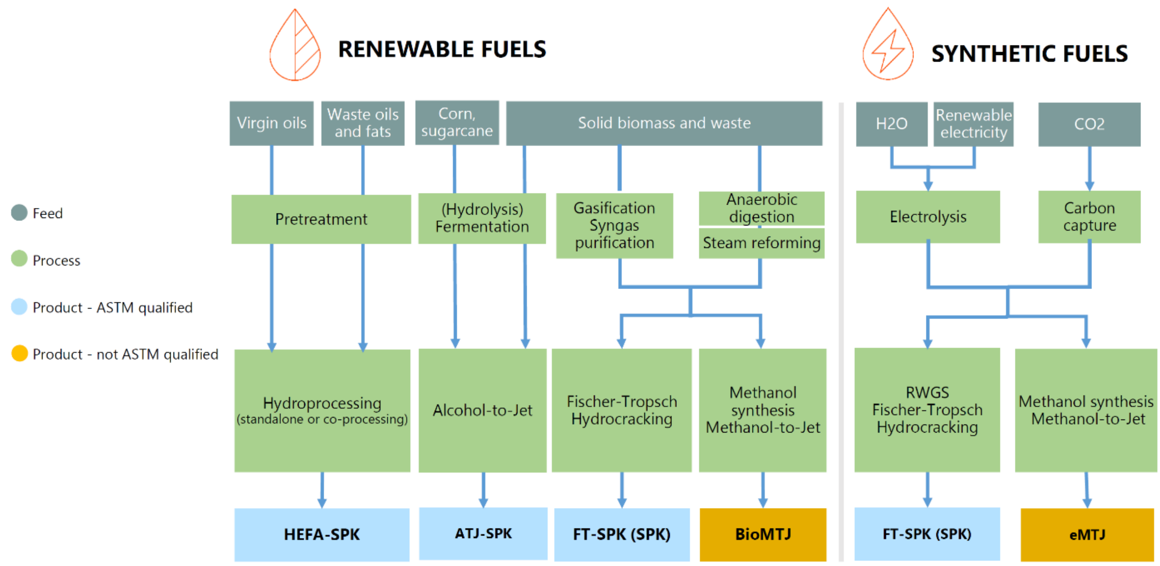


Figure 5.4 Main SAF production pathways with similar building blocks[62] [8]

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[63] 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.

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

[62] Renewable and Low-Carbon Fuels Value Chain Industrial Alliance (2024)
[63] Technology Readiness Level.

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.

5.2.3 HOW SUSTAINABLE ARE SAF

5.2.3.1 SUSTAINABILITY CRITERIA

Table 5.5 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)[64].

[64] ICAO (2021), CORSIA Sustainability Criteria for CORSIA Eligible Fuels.

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[65] 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.

Table 5.5 SAF sustainability criteria

[65] EU (2018), Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action.

5.2.3.2 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 5.5), but given historic concerns surrounding biofuel sustainability, it is encouraged to calculate actual life cycle emission values rather than applying a default value.

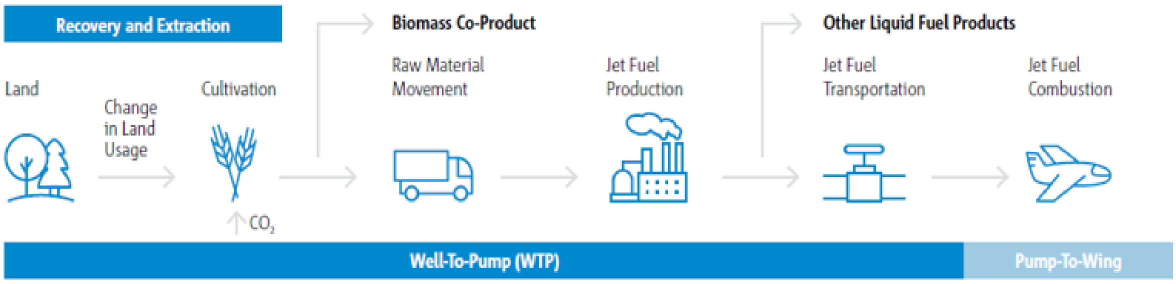


Figure 5.5 Components of typical well-to-wing LCA for biofuel-based jet fuel

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[66]. 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 5.6 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.

5.2.3.3 SAF AND NON-CO2 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.

[66] European Court of Auditors (2023), The EU’s support for sustainable biofuels in transport. An unclear road ahead.

Some types of SAF have the potential to offer significant non-CO_2 emissions reductions[67,68].

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[69] and RAPTOR[70] have shown that the use of certain types of SAF could have positive impacts on local air quality[71] 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)[72].

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[73].

[67] Teoh, Roger et al (2022), Targeted Use of Sustainable Aviation Fuel to Maximize Climate Benefits

[68] Märkl, Raphael Satoru et all (2024), Powering aircraft with 100 % sustainable aviation fuel reduces ice crystals in contrails

[69] AVIATOR Project (2024), Assessing aViation emission Impact on local Air quality at airports: TOwards Regulation.

[70] RAPTOR (2024), Research of Aviation PM Technologies, modelling and Regulation

[71] Lukas Durdina, Benjamin T. Brem, Miriam Elser, David Schönenberger, Frithjof Siegerist, and Julien G. Anet (2021), Reduction of Nonvolatile Particulate Matter Emissions of a Commercial Turbofan Engine at the Ground Level from the Use of a Sustainable Aviation Fuel Blend.

[72] Voigt, C. et all (2021), Cleaner burning aviation fuels can reduce contrail cloudiness | Communications Earth & Environment (nature.com)

[73] Euractiv (2024), European ECLIF3 flight test study shows significant contrail reduction with 100% SAF

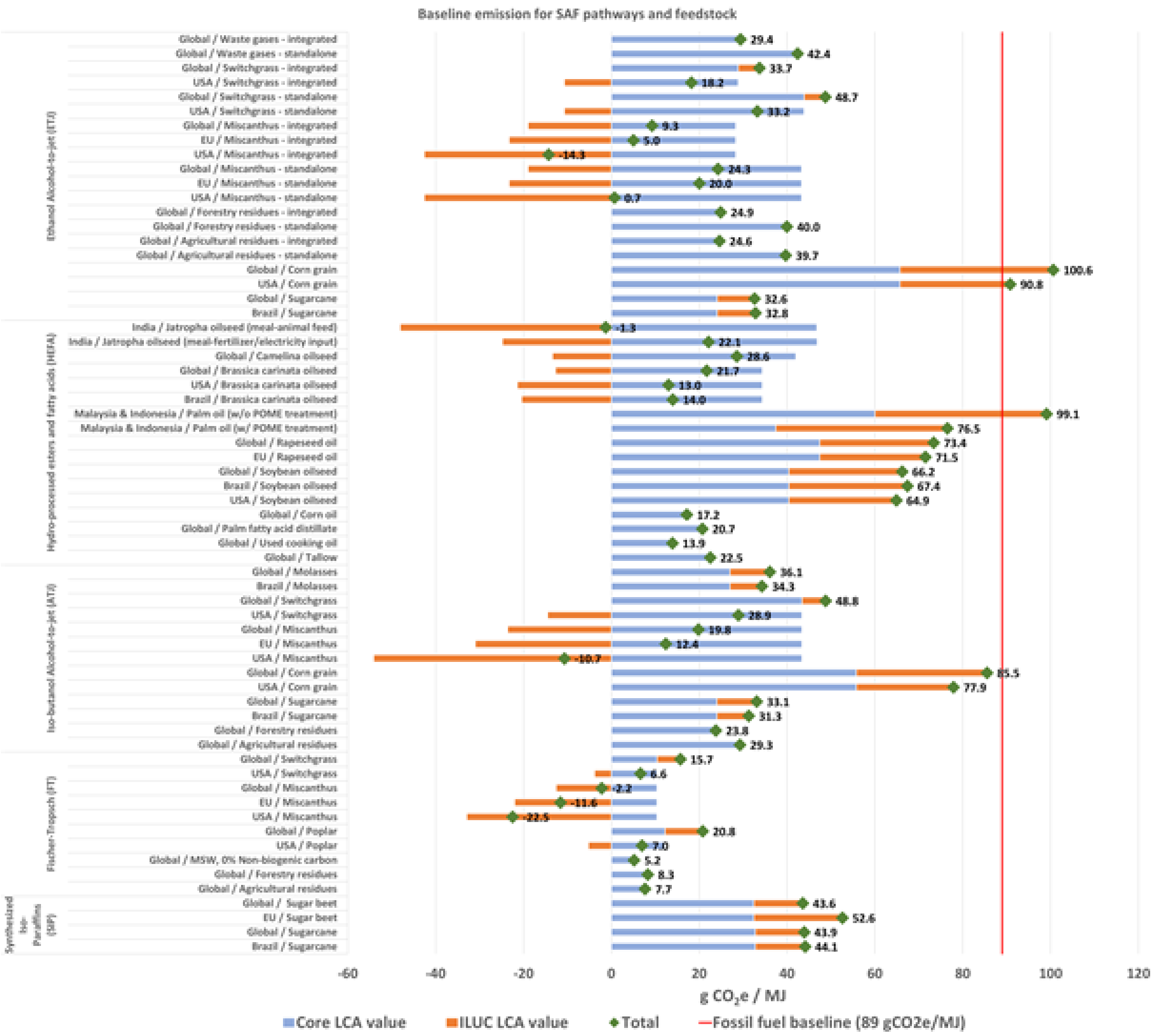


Figure 5.6 LCA emissions for CORSIA eligible SAF pathways and feedstock compared to CORSIA fossil fuel reference value (89 g CO_2e/MJ)[74,75]

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

[74] ICAO (2021), CORSIA Supporting Document "CORSIA Eligible Fuels - Life Cycle Assessment Methodology" (Version 3 – March 2021).

[75] 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.

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 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[76, 77]. 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[78].

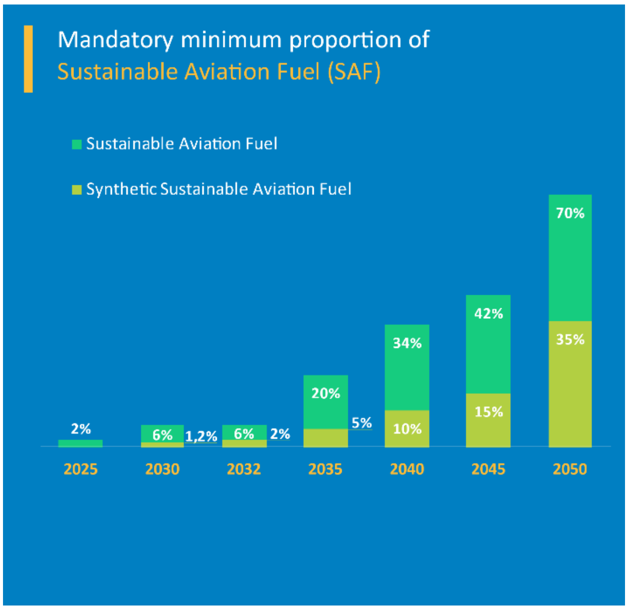
76 Euractiv (2024), Biofuel certification schemes slammed for failing to halt fraud

77 Argus (2024), Norway says Esso misclassified animal fat biofuels

78 ISCC (2023), Biodiesel and EU Imports from China

5.2.4 SAF POLICY ACTIONS

5.2.4.1 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. 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[79] identifies and assesses 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)[80].

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

[79] Report from the Commission to the European Parliament and the Council: The ReFuelEU Aviation SAF Flexibility Mechanism, COM/2025/59 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2025%3A59%3AFIN)

[80] EUROCONTROL (2024), Use of sustainable aviation fuels in European States (ECAC) and airports

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.
- EU-funded international cooperation SAF projects with partner States in Africa, Asia, Latin America and the Caribbean. This includes a €4 million ACT-SAF project to conduct feasibility studies and capacity building activities.
- Designation of SAF as a 2024 Global Gateway Flagship initiative, supporting the development, production and use of SAF by de-risking SAF investments outside Europe via different types of funding.
- International cooperation at ICAO level, including the EU's role in the negotiations to reach an agreement at CAAF/3 in November 2023.

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[81]. 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

[81] ICAO (2023), ICAO Global Framework for SAF, LCAF and other Aviation Cleaner Energies

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.

5.2.4.2 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[82]. 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[83].

5.2.5 SAF MARKET

Global SAF production represented only 0.53% of jet fuel use in 2024, up from 0.2% in 2023[84,85,86]. 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.

5.2.5.1 CURRENT AND FUTURE SAF PRODUCTION CAPACITY

According to information collated with the support of ReFuelEU Aviation Member State Network (Figure 5.7), 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'.

[82] ECAC Guidance on Sustainable Aviation Fuels (SAF) (2023), European Civil Aviation Conference
[83] Department for Transport (2024), Aviation fuel plan
[84] Simple Flying (2024), IATA Says SAF Production Will Reach 0.53% of Aviation 2024 Fuel Usage
[85] EUROCONTROL (2024), Use of sustainable aviation fuels in European States (ECAC) and airports
[86] Transport and Environment (2024),How is e-kerosene developing in Europe?

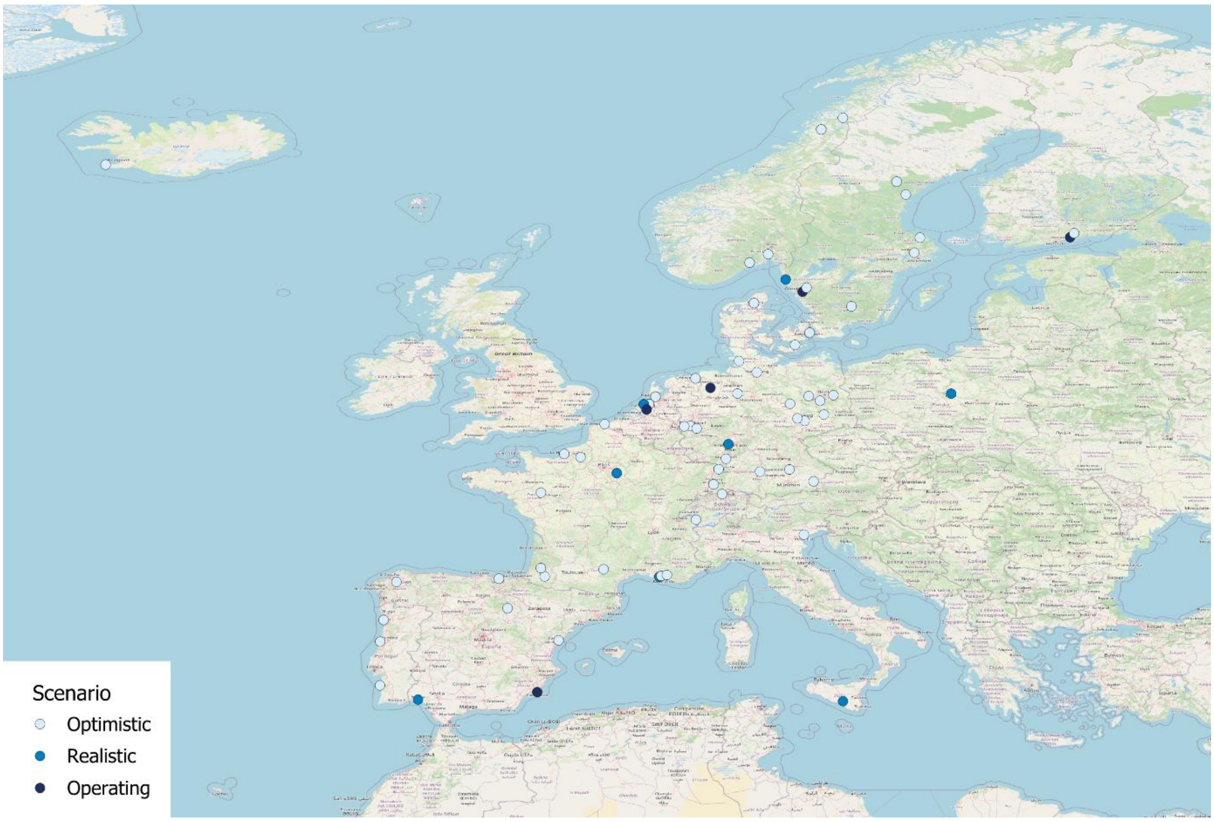


Figure 5.7 Projected EU SAF facilities in 2030 under the Optimistic scenario

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[87] 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[88]. 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 5.8 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.

[87] SkyNRG (2024), Sustainable Aviation Fuel Market Outlook – June 2024 Update
[88] International Energy Agency (2023), Renewables 2023 Analysis and forecast to 2028

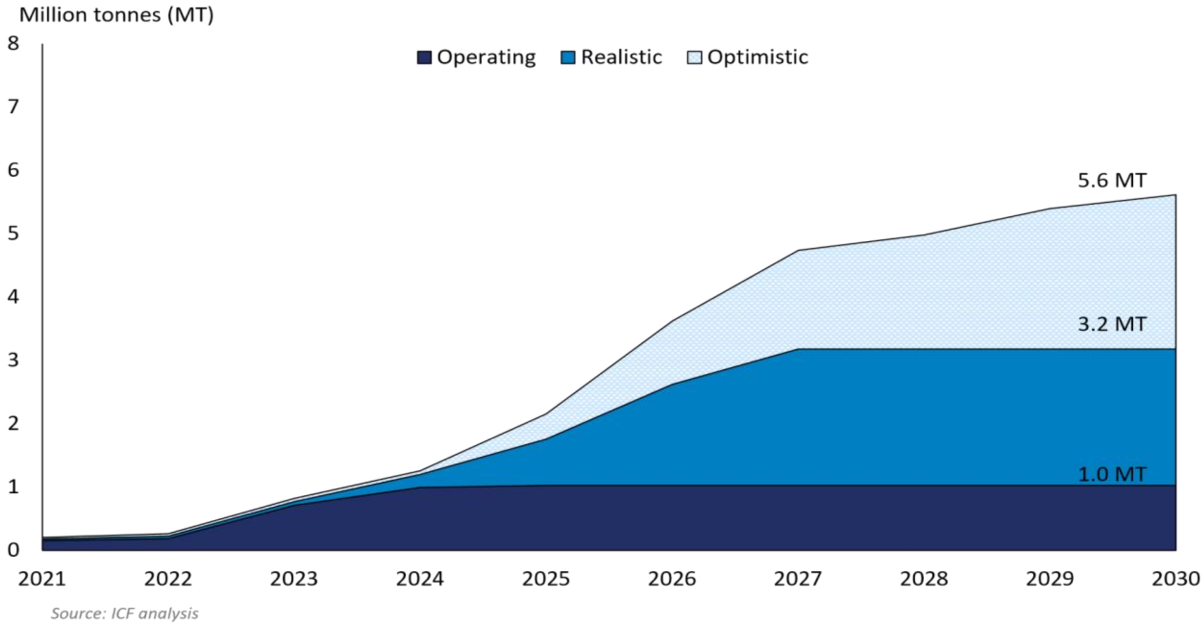


Figure 5.8 Projected EU SAF capacity in 2030 by scenario

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[89]. Overall, renewable energy passed 30% of the total global energy supply for the first time in 2023[90]. 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.

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[91] 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.

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 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[92].

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89 The Economist (2024), The exponential growth of solar power will change the world
90 The Guardian (2024), Renewable energy passes 30% of world's electricity supply
91 Assuming 0.3 – 0.5 Mt average SAF output per year per facility.
92 ICF (2021), Fueling Net Zero – How the aviation industry can deploy sufficient sustainable aviation fuel to meet climate ambitions. An ICF Report for ATAG Waypoint 2050

5.2.5.2 CO2 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. The second, more ambitious scenario assumes 80% and 90% emission reductions respectively for the two SAF types.

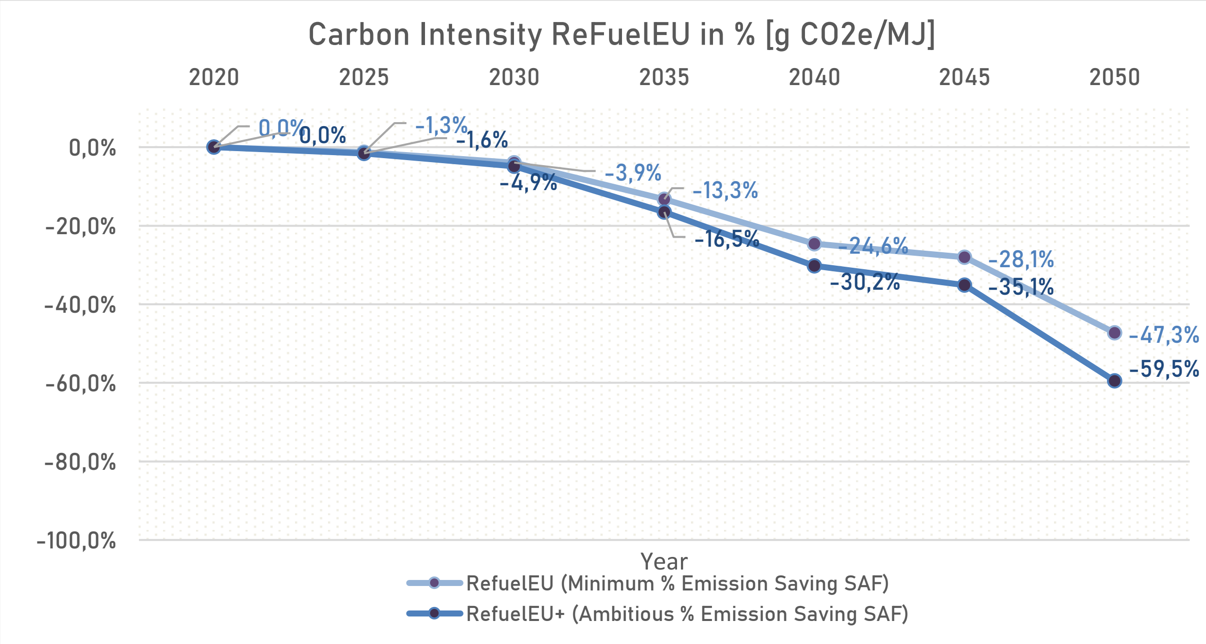

Figure 5.9 % CO_2eq emissions reductions from the uptake of SAF under ReFuelEU Aviation scenarios

5.2.5.3 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[93,94,95]. 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 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.

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93 IATA (2024), Unveiling the biggest airline costs

94 Price Reporting Agencies (PRA) used as data source: S&P Global Commodity Insights (Platts), Argus Media and General Index.

95 With the density of kerosene of around 0.8 g/cm3, this results in a price of around 1.02€/l.

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 5.10 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[96,97].

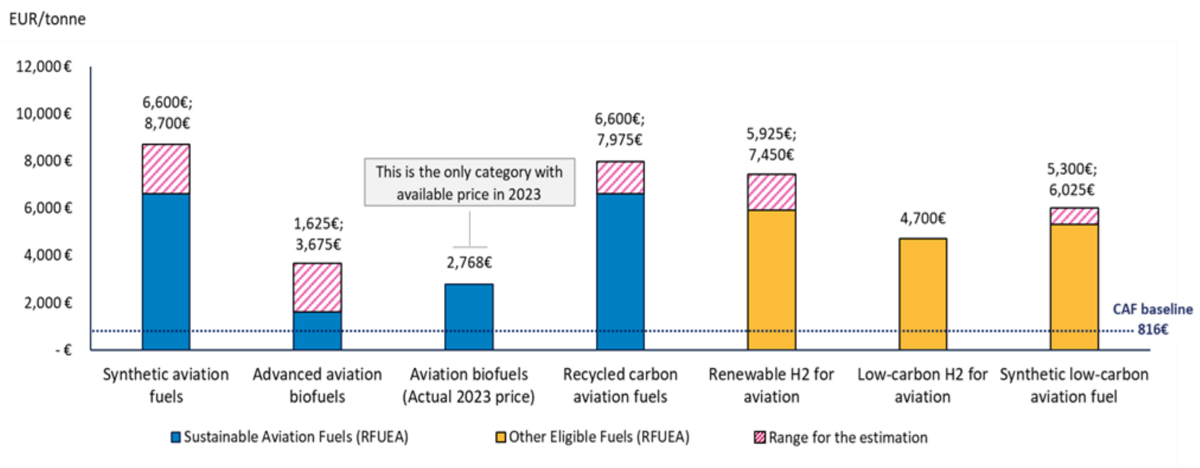
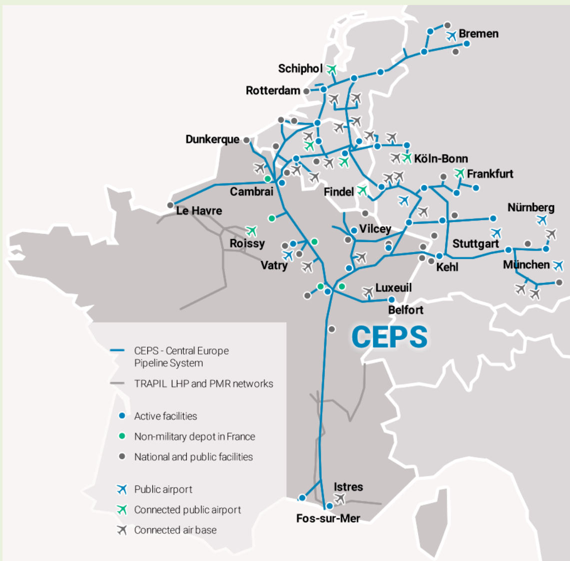


Figure 5.10 Estimated prices and production costs in 2023 for ReFuelEU Aviation eligible fuels

STAKEHOLDER ACTIONS

Central Europe Pipeline System: First delivery of SAF

The Central Europe Pipeline System (CEPS)[98] [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

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96 EASA (2024), ReFuelEU Aviation Market Report
97 Politico (2024), Franco-German energy cash splash strains EU single market
98 CIM&CCMP (2024), The CEPS network

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[99]

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[100]

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[101]

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[102]

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

[99] Neste (2022), Delivering CORSIA certified SAF to airlines
[100] Neste (2022), First flight in history with 100% sustainable aviation fuel on a regional commercial aircraft
[101] SkyNRG (2024), SkyNRG launches Project Runway with Microsoft as a founding member
[102] INERATEC (2023), Groundbreaking for e-fuel production plant in Frankfurt

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[103]

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.

[103] The Guardian (2023), First transatlantic flight using 100% sustainable jet fuel takes off

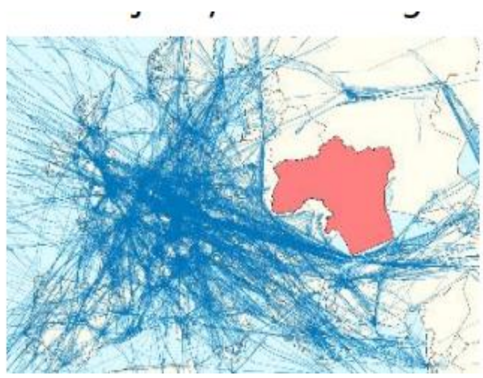
5.3 AIR TRAFFIC MANAGEMENT AND OPERATIONAL IMPROVEMENTS

- 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.

5.3.1 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)[104] 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

[104] EC (2004), Regulation (EC) No 549/2004 laying down the framework for the creation of the Single European Sky; R**egulation (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).

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[105], 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)[106], 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[107] 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.

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[105] SESAR (2020), European ATM Master Plan

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

[107] 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.

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.

5.3.2 SES ENVIRONMENTAL PERFORMANCE AND TARGETS

5.3.2.1 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[108] 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.

5.3.2.2 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 5.11). 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).

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

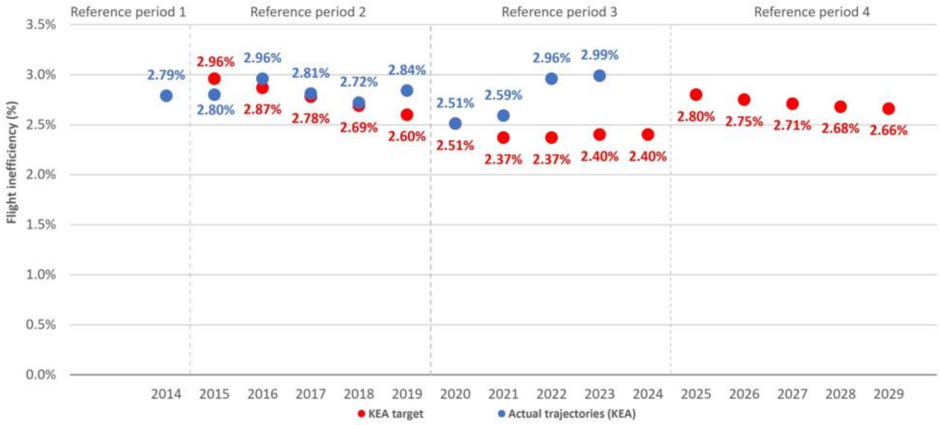

Figure 5.11 KEA horizontal en-route flight inefficiency and targets for 2014 to 2029

5.3.2.3 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)[109] and the shortest constrained trajectory (KES/SCR)[110]. As with all other indicators, KEP and KES/SCR (Figure 5.12) 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.

[109] 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.
[110] 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.

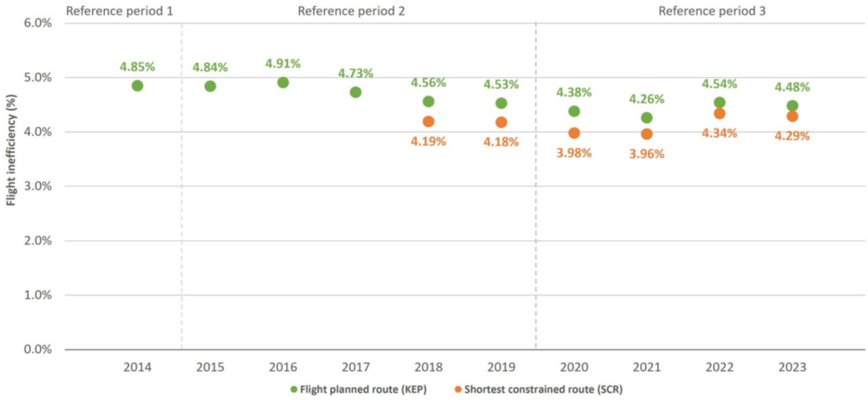

Figure 5.12 KEP horizontal en-route flight inefficiency and KES/SCR for 2014 to 2023

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 5.13) 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 5.13 illustrates that there is a limited capacity to accommodate CDOs during busier periods.

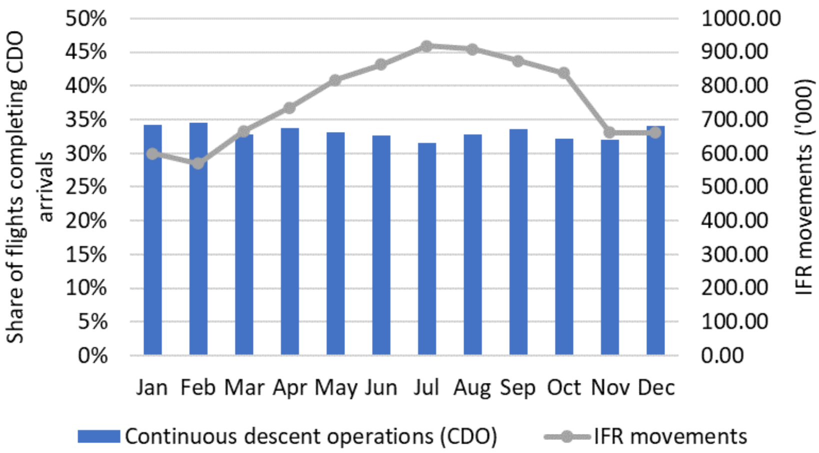

Figure 5.13 CDO vertical flight efficiency indicator for 2023

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.

5.3.2.4 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 5.14) 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.

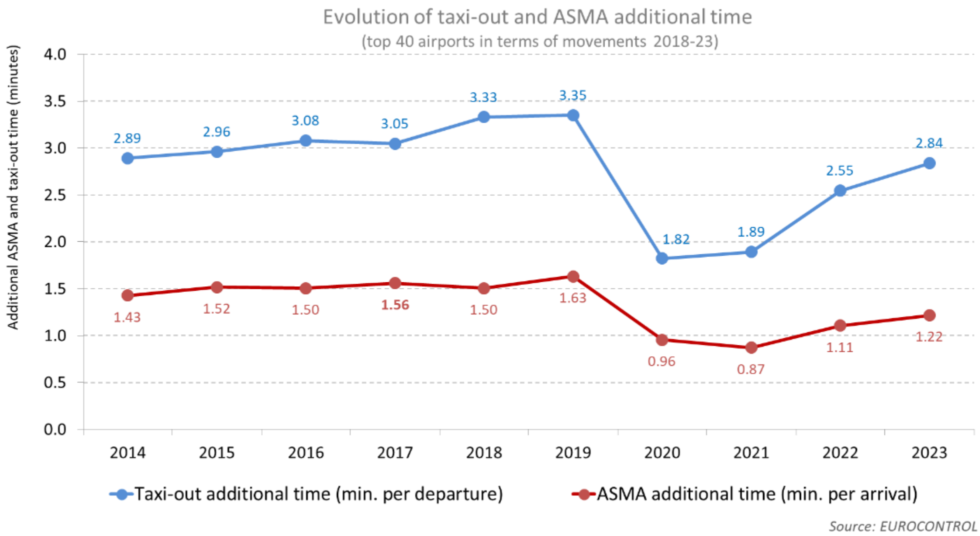

Figure 5.14 Average additional ASMA and taxi-out times for the busiest EU27+EFTA 40 airports in terms of flight movements

Significant variations exist between the top 40 busiest EU27+EFTA airports in terms of additional ASMA time (Figure 5.15).

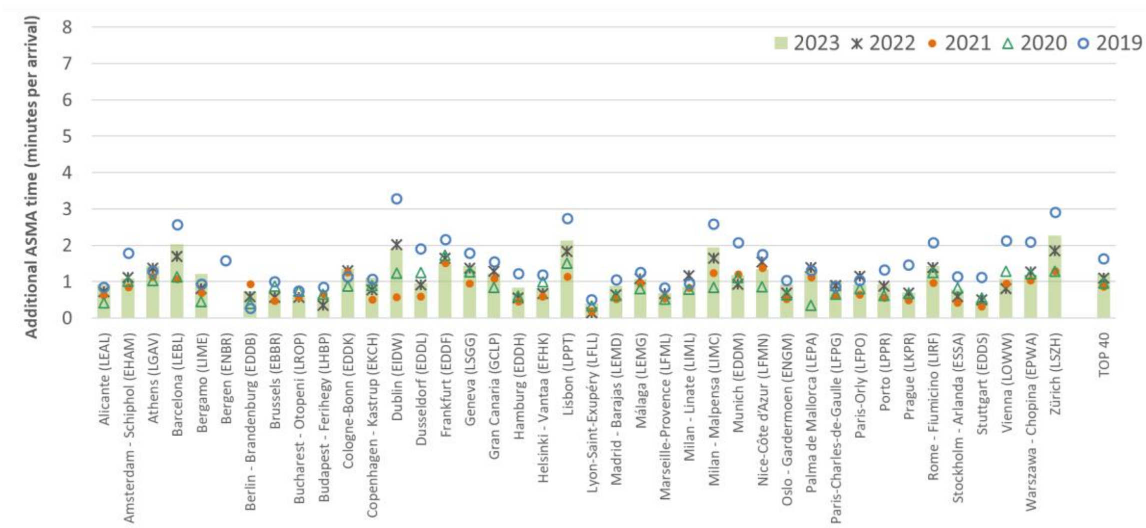

Figure 5.15 ATM related inefficiencies on the arrival flow (AMSA) at the 40 busiest EU27+EFTA airports (2019-2023)

5.3.2.5 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[111] 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[112].

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[113]. 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

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[111] 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

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

[113] 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

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.

5.3.2.6 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.

5.3.3 OPERATIONAL PERFORMANCE INDICATORS

5.3.3.1 TOTAL GATE TO GATE CO2 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 5.16 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.

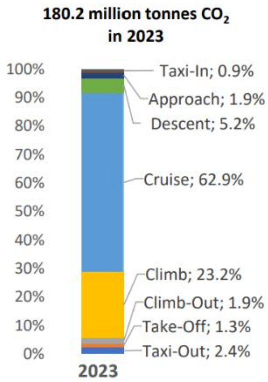


Figure 5.16 Total CO_2 emissions by flight phase within the EUROCONTROL area during 2023

5.3.3.2 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[114]. Figure 5.17 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.

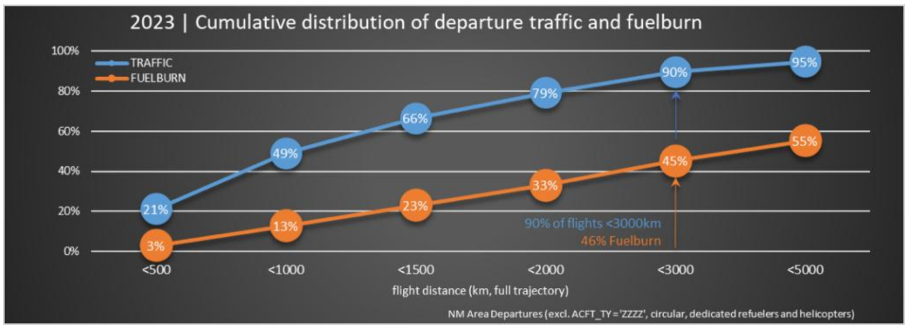


Figure 5.17 Cumulative distribution of departure and fuel burn in 2023

5.3.3.3 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[115]. 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.

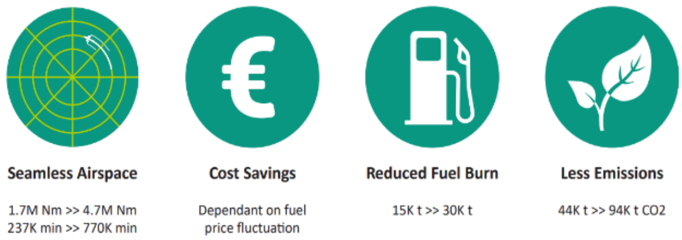
In line with the European ATM Master Plan and EC Regulation No. 2021/116, FRA implementation with cross-border dimension and connectivity to Terminal Manoeuvring Areas (TMA) should be completed

[114] EUROCONTROL (2024), CO_2MPASS Interactive Dashboard
[115] EUROCONTROL (2022), Free route airspace

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.

5.3.4 SESAR: TOWARDS THE DIGITAL EUROPEAN SKY

5.3.4.1 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[116].

The current SESAR 3 Joint Undertaking[117] 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

[116] SESAR (2021), SESAR Solutions Catalogue
[117] EU (2021), SESAR Single Basic Act

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[118].

- **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[119]. This leads to long thrust descent, which is inefficient even if it does not include intermediate level-offs (Figure 5.18). 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.

- **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[120,121]. 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[122]. 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).

[118] SESAR (2020), Albatross Project
[119] SESAR Optimised Profile Descents Demonstration Report.
[120] SESAR (2021), SESAR Solutions Catalogue charting progress towards the Digital European Sky
[121] SESAR (2020), Albatross Project
[122] SESAR (2024), Dynamic Route Availability Document (RAD)

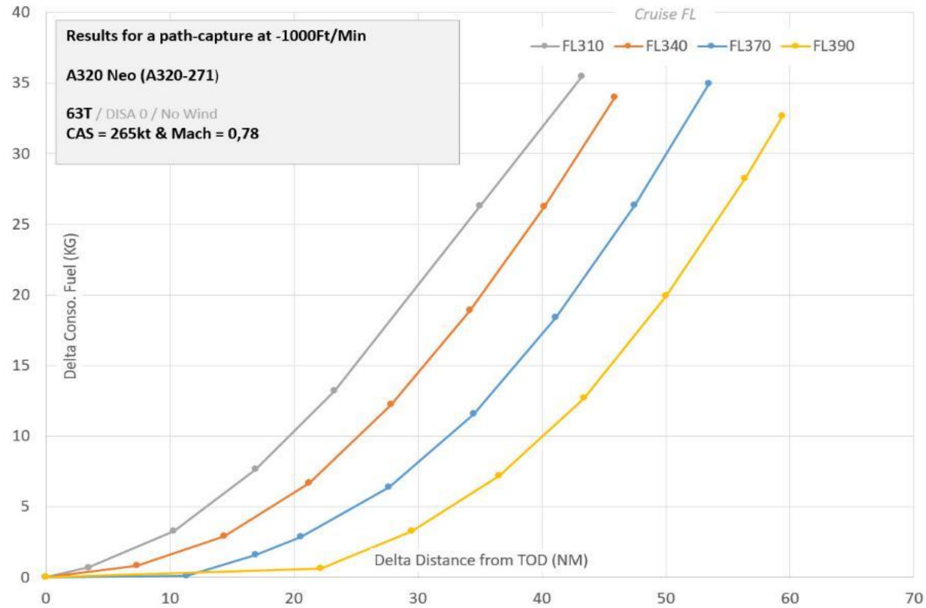


Figure 5.18 Increased fuel consumption as a function of the distance before the optimum Top of Descent that the descent phase is started, without intermediate level-offs (e.g. when a descent from cruise at FL370 is started 50nmi early, the additional fuel burn is 30 kg).

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)[123].

5.3.4.1.1. 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.

[123] SESAR (2024), Airport Operations Plan (AOP)

5.3.4.2 SESAR DEPLOYMENT

sesar DEPLOYMENT MANAGER

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 5.19) aiming to reduce inefficiencies and thus generate fuel and CO_2 savings in different phases of the flight, especially cruise. The SESAR Deployment Programme[124] 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[125] 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.

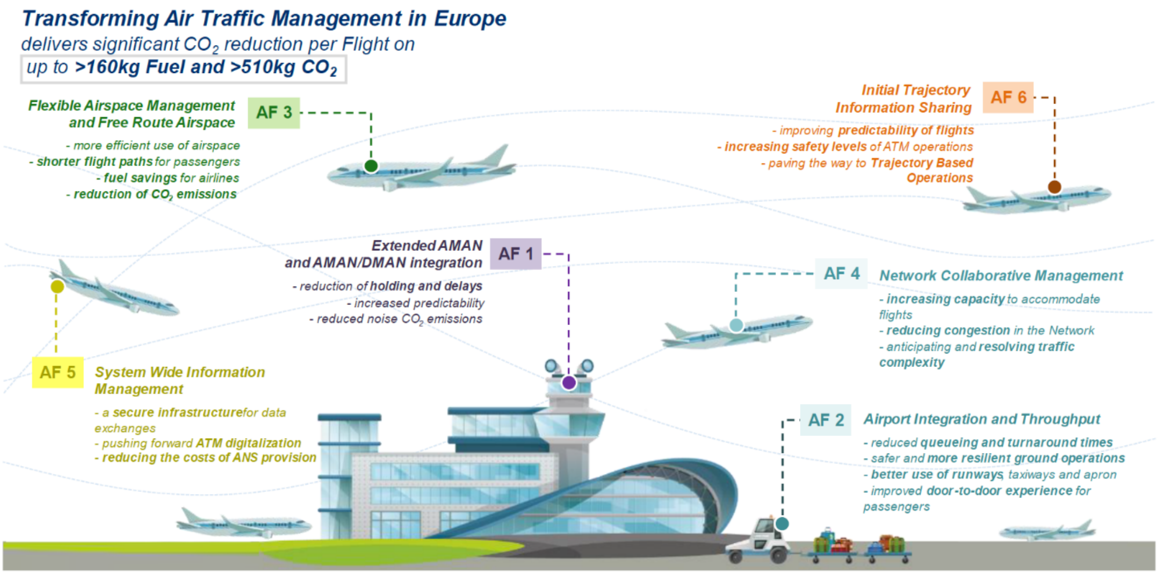


Figure 5.19 Overview of Common Projects 1 (CP1) ATM Functionalities

Table 5.6 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.

[124] SESAR (2022), SESAR Deployment Programme 2022
[125] SESAR (2025), SESAR Deployment Manager

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

Table 5.6 *CO_2 savings per Common Project 1 ATM Functionality*

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 5.7). Furthermore, the BCR and CO_2 savings are expected to increase overtime as CP1 AF are fully implemented (Table 5.8).

	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 5.7 Benefit-Cost Ratio and CO_2 savings from CP1 AF implementation

	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

Table 5.8 Savings in fuel and CO_2 emissions per flight in 2023 and the forecast out to 2040

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.

5.4 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.

5.4.1 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.

5.4.1.1 AVIATION AND EU ETS

The EU decided to include aviation activities within the EU ETS in 2008[126], 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)127. 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[128] [2]. The main changes to the aviation ETS are applicable from 2024 onwards, and include the following:

[126] 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

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

[128] 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

- 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 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[129]
- 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.

5.4.1.2 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 5.20).

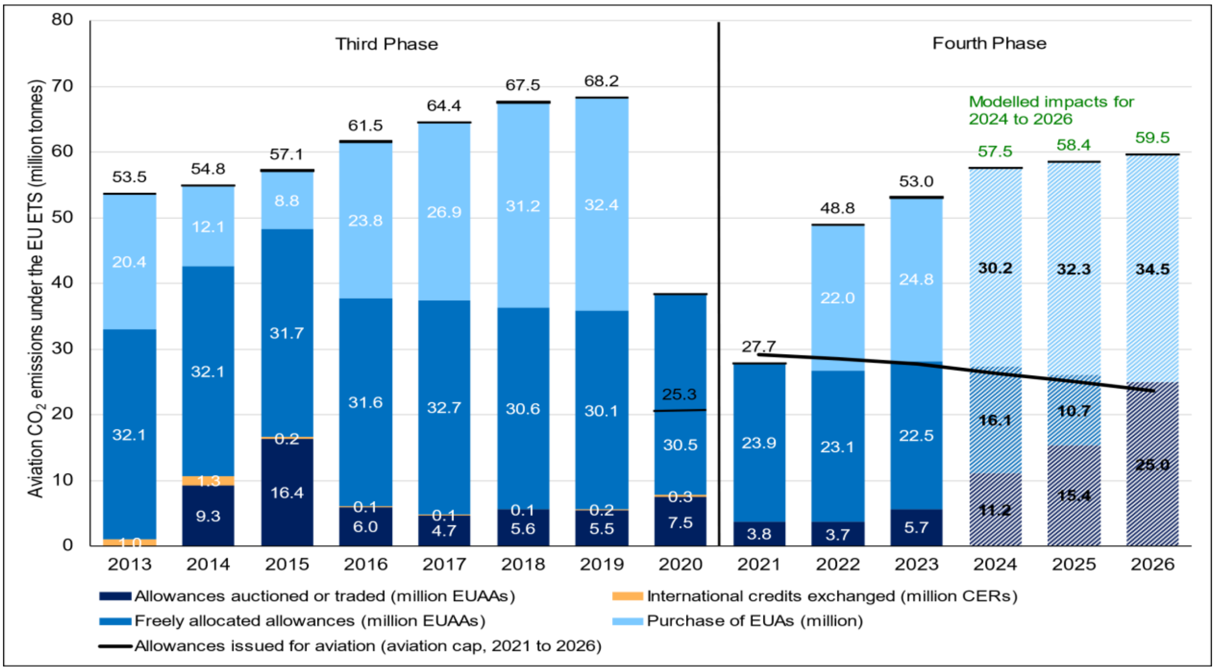


Figure 5.20. Aviation CO_2 emissions under the EU ETS in 2013-2023 and modelled impact of the revised ETS Directive for years 2024-2026, where 1 EUAA / EUA equals 1 tonne of CO_2 emissions[130]

Note: Data in Figure 5.20 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.

[130] 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.

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 5.20, 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[131].

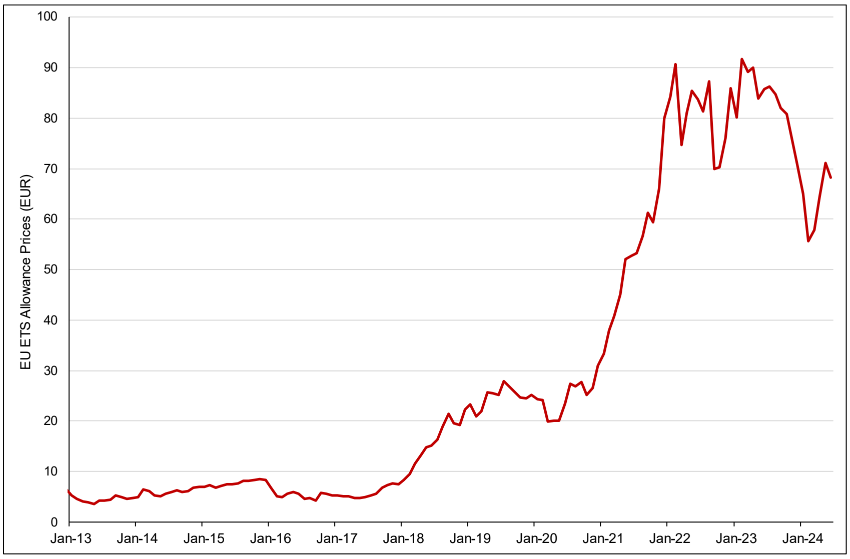


Figure 4.2 EU ETS Allowance Prices (2013-2024)

As shown in Figure 5.21, 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[132].

From 2024 until 2030, airlines can apply for additional ETS allowances to cover part or all of the price

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

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.

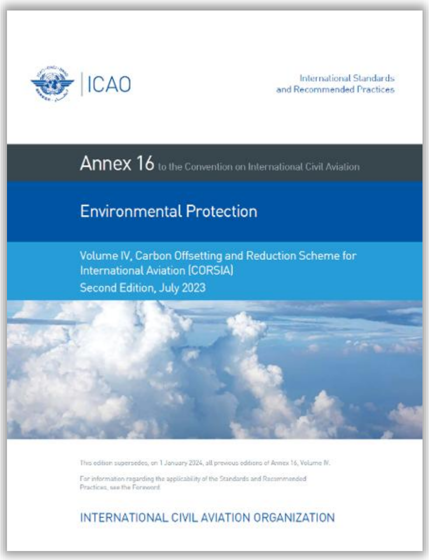
5.4.2 CARBON OFFSETTING AND REDUCTION SCHEME FOR INTERNATIONAL AVIATION (CORSIA)

5.4.2.1 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[133].

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.



5.4.2.2 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.

5.4.2.3 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[134] [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

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

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

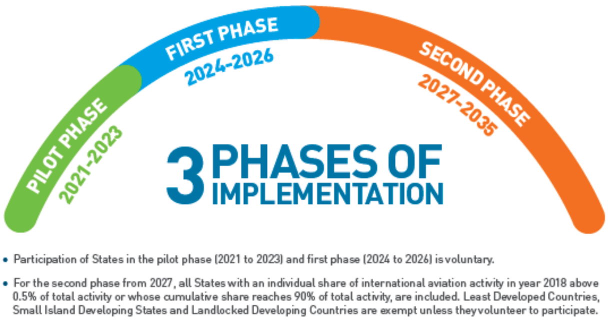
European Civil Aviation Conference (ECAC) notified ICAO of their intention to voluntarily participate to CORSIA offsetting from the start of the pilot phase in 2021, provided that certain conditions were met, notably on the environmental integrity of the scheme and global participation. EU member states 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 States135. Implementation of CORSIA's monitoring, reporting and verification rules within the EU has been through the relevant ETS Regulations[136,137,138].

5.4.2.4 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[139]. The second phase applies to all ICAO Contracting States, with certain exemptions.



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[135] 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.

[136] 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

[137] EU (2018), Implementing Regulation (EU) 2018/2067 on the verification of data and on the accreditation of verifiers pursuant to Directive 2003/87/EC

[138] 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

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

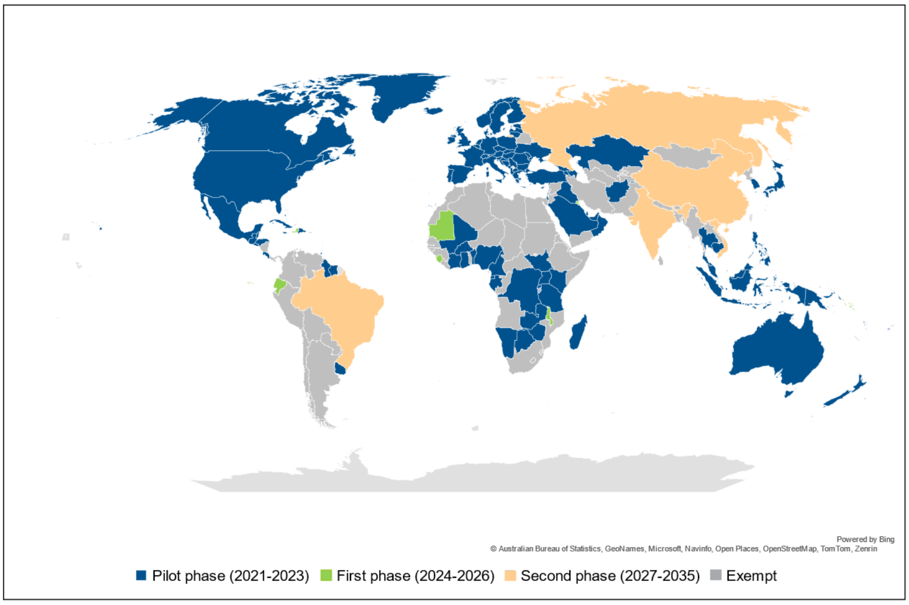

Figure 5.23 ICAO Member States participation in CORSIA offsetting in various phases

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.

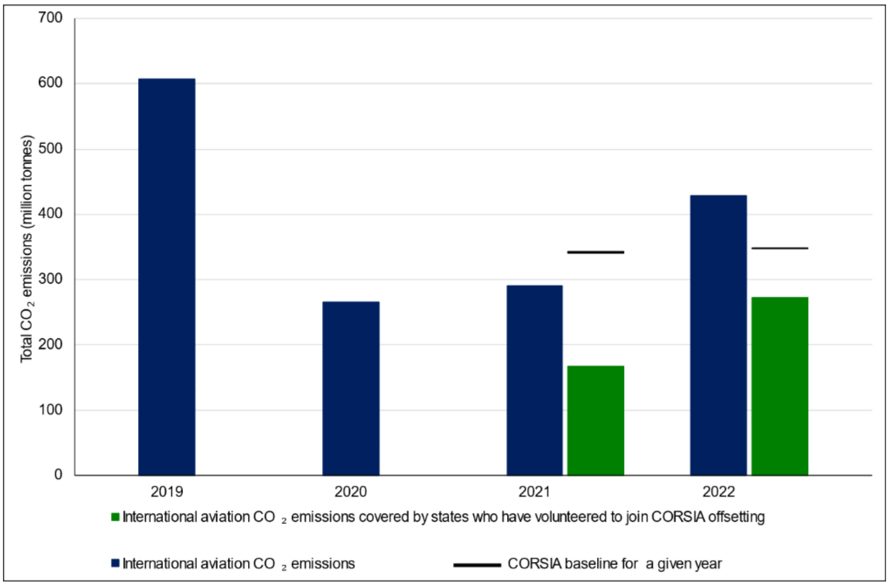

Figure 5.23 International aviation CO_2 emissions reported through the CORSIA Central Registry

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[140] (Figure 5.24).

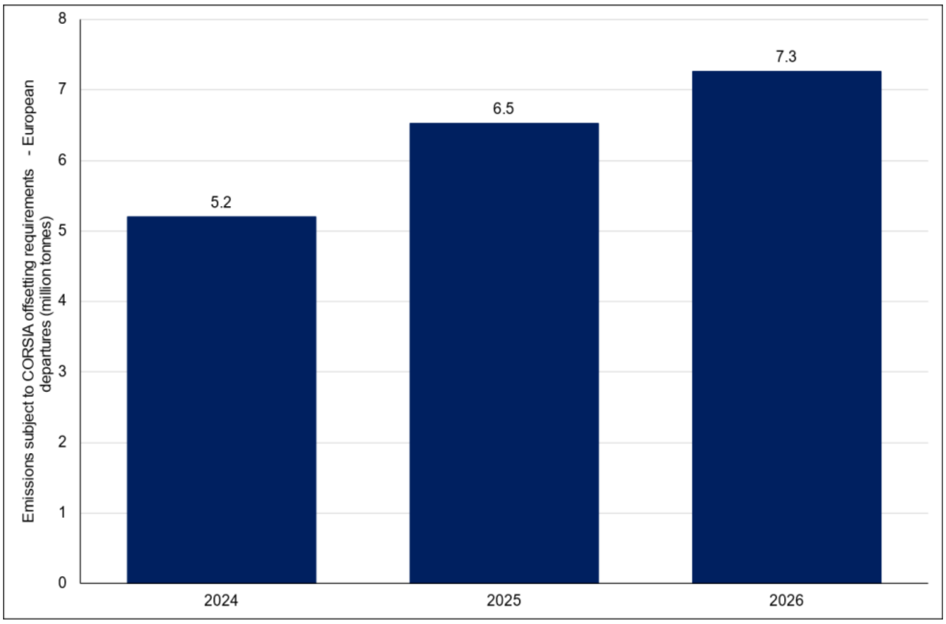

Figure 5.24 Estimated CORSIA offsetting requirements for departing flights from Europe[141]

5.4.2.5 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

[140] Estimation by EASA AERO-MS model.
[141] 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.

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)[142]. 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 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[143].

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[144], 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[145].

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**

[142] Ecosytem Marketplace (2024), CORSIA Carbon Market Data
[143] ICAO (2024), CORSIA Eligible Emissions Units
[144] EC (2022), Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a Union certification framework for carbon removals
[145] Government of Guyana (2024), World's First Carbon Credits for Use in UN Airline Compliance Programme, CORSIA

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.

5.4.3 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.

5.4.3.1 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[146]. 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[147] 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. 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.

5.4.3.2 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[148]. 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.

5.4.3.3 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[149]. However, there has been some criticism of the quality of offset

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[146] 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

[147] 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

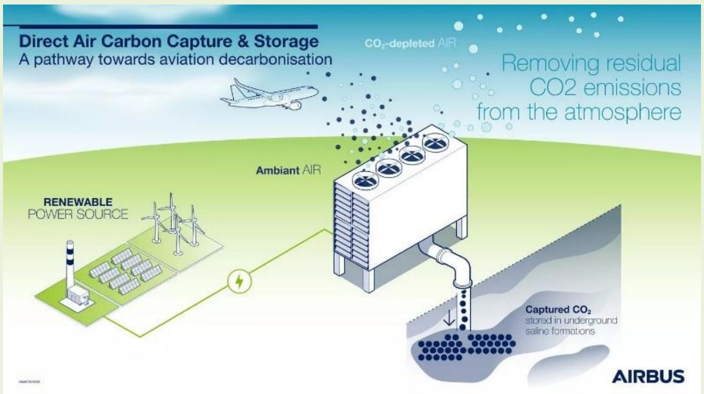
[148] EC (2021), Proposal for a COUNCIL DIRECTIVE restructuring the Union framework for the taxation of energy products and electricity

[149] "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,

credits in this unregulated voluntary market, as well as scepticism of such voluntary activity enhancing aviation sustainability[150,151,152].

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.

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.

150 Bloomberg (2024), Inside the Controversy That's Divided the Carbon Offsets Market - BNN Bloomberg

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

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

5.5 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.
- Global environmental challenges require global cooperation to achieve agreed future goals.
- International Cooperation is a key element to reach the global objective of net-zero CO_2 emissions by 2050 including the aim to achieve a 5% reduction of CO_2 emissions from the use of Sustainable Aviation Fuels (SAF), Low Carbon Aviation Fuels and other aviation cleaner energies by 2030.
- Since 2022, EU entities (e.g. States, Institutions and Stakeholders) have committed more than €20M to support environmental protection initiatives in civil aviation across Africa, Asia, Latin America and the Caribbean.
- Collaboration with Partner States has contributed to the sound implementation of CORSIA-Monitoring Reporting and Verification in more than 100 States and facilitated new States joining its voluntary pilot and first phases.

- Technical support contributed to the development of a first or updated State Action Plan for CO_2 emissions reduction within 18 States, and to an enhanced understanding of SAF and the associated opportunities worldwide.
- Future efforts with Partner States in Africa, Asia, Latin America and the Caribbean are expected to focus on the implementation of CORSIA offsetting and building capacity to increase SAF production.
- SAF, which has the biggest potential to significantly reduce the carbon footprint of air transport in the short- and long-term, are also an opportunity for States to develop their green economy and to boost job creation. Hence, initiatives like the EU Global Gateway are providing financial support (initially on feasibility studies) to help realise viable SAF production projects in Partner States.
- Awareness, coordination, and collaboration in International Cooperation initiatives among supporting partners are essential factors to maximise the value of the resources provided to Partner States.
- The Aviation Environmental Protection Coordination Group (AEPCG) provides a forum to facilitate this coordination of European action with Partner States.

5.5.1 AIRPORT MEASURES

5.5.1.1 AICRAFT OPERATIONS

5.5.1.1.1 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[153] 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.

[153] EU (2018), Regulation 2018/1048 laying down airspace usage requirements and operating procedures concerning performance based navigation

5.5.1.1.2 Green Operational Procedures

Building on the previous ALBATROSS research project[154], 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[155]. This includes the Green Apron Management demonstration, which uses sensors and artificial intelligence for more predictable and efficient aircraft handling during airport stopovers.

5.5.1.1.3 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 5.25). 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.

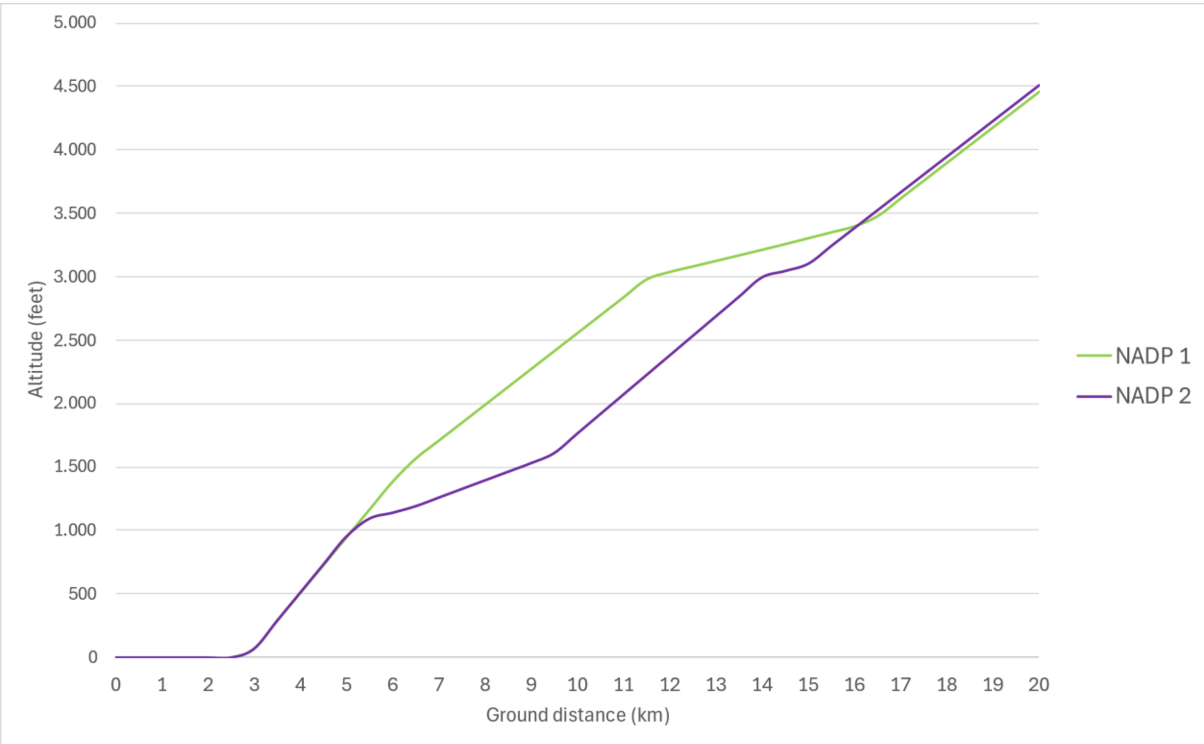


Figure 5.25 Example of the difference between NADP 1 and 2 for a wide body aircraft with thrust reduction at 1,000ft.

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

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[154] SESAR (2021), ALBATROSS research project
[155] SESAR (2023), HERON research project

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.

5.5.1.1.4 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[156].

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.

5.5.1.2 AIRPORT INFRASTRUCTURE

Various EU research projects, including TULIPS[157], OLGA[158] and STARGATE[159], are currently demonstrating innovative environmental solutions at airports, which can be replicated on a European scale.

5.5.1.2.1 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

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[156] EUROCONTROL (2024), Sustainable Taxiing Operations – Concept of Operations and Industry Guidance
[157] EU (2025), TULIPS Horizon 2020 research project
[158] EU (2025), OLGA Horizon 2020 research project
[159] EU (2025), STARGATE Horizon 2020 research project

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[160].

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[161]. 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[162] .

5.5.1.2.2 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.

[160] Schiphol (2024), Emissions Free by 2030
[161] Fraport (2024), Frankfurt Airport Vertical Photovoltaic System
[162] Fraport (2024), Frankfurt Airport Using Charging Infrastructure Bidirectionally

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[163] [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.

5.5.1.2.3 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[164]. 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.

5.5.1.2.4 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 5.9). A detailed overview of these types of SAF incentive initiatives by European airports has been compiled by ACI EUROPE[165].

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.

[163] EU (2024), GOLIAT (Ground Operations of LIquid hydrogen AircrafT) research project
[164] EASA (2024), Guidance for the implementation of the new Aircraft Classification Rating (ACR) – Pavement Classification Rating (PCR) method for the EASA Member States
[165] ACI-E (2024), European airports' initiatives to incentivise SAF

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.

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

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[166].

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[167] and their 'financial arm' in the form of the Connecting Europe Facility[168].

Trans-European Transport Network (TEN-T)

The revision of the TEN-T Guidelines[169] 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[170,171]. 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.

[166] EU (2025), ALIGHT Horizon 2020 research project
[167] EU (2023), Alternative Fuels Infrastructure Regulation
[168] EU (2025), Connecting Europe Facility
[169] EU (2024), Regulation (EU) 2024/1679 of 13 June 2024 on Union guidelines for the development of the trans-European transport network, amending Regulations (EU) 2021/1153 and (EU) No 913/2010 and repealing Regulation (EU) No 1315/2013
[170] EC (2023), Transport infrastructure: over EUR 352 million of EU funding to boost greener mobility
[171] EU (2024), CEF Transport Alternative Fuels Infrastructure Facility (AFIF) call for proposal

5.5.2 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[172]. 303 European airports have since committed to net zero[173] carbon emissions from airport operations within their control by 2050 and provided a roadmap detailing how this will be achieved[174].

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[175] and this was followed in 2023 with guidance on developing Net Zero carbon roadmaps[176].

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 5.26).

airport carbon accreditation

[172] ACI-E (2024), What is Net Zero? – ACI-E Net Zero Resolution 2024

[173] 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.

[174] ACI-E (2022), Repository for airport net zero CO_2 roadmaps

[175] ACI-E (2022), Guidance on Airports' Contribution to Net Zero Aviation

[176] ACI-E (2023), Developing an Airport Net Zero Carbon Roadmap

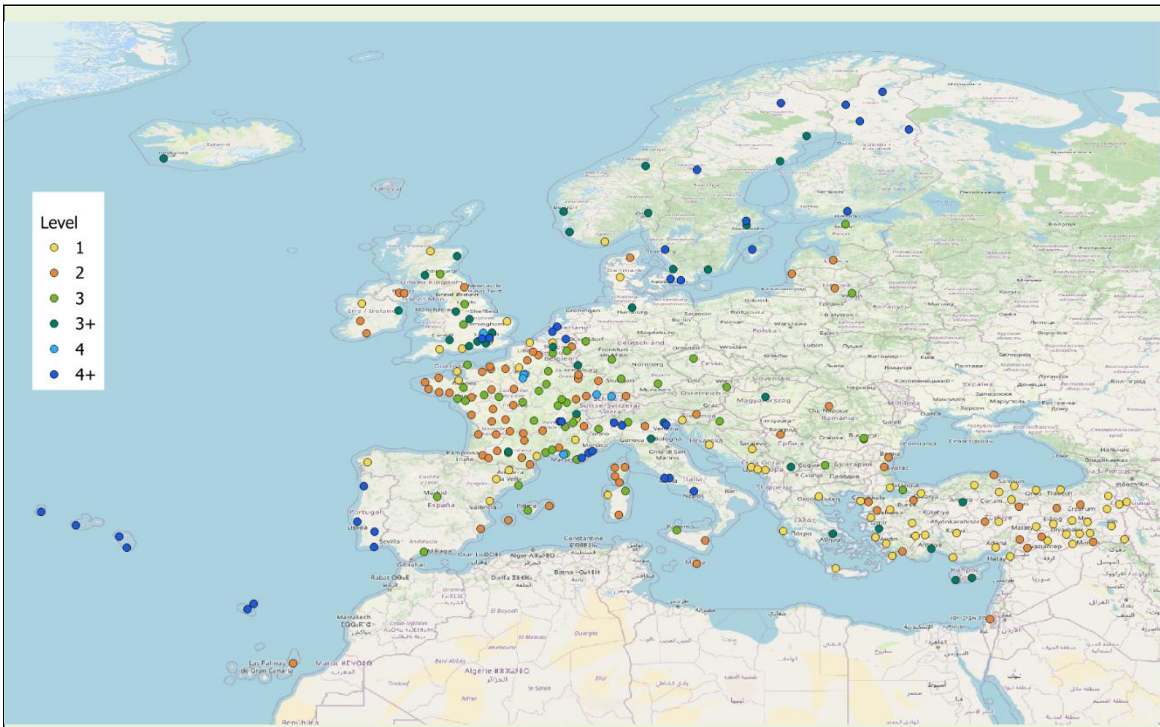

Figure 5.26 – European airports participating in the ACA programme

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[177]) and 4+ (Transition[178]) 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[179] 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

[177] 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.
[178] All Levels 1 to 4 plus offsetting of the residual carbon emissions over which the airport has control.
[179] ACA (2023), Offset Guidance Document

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[180] , 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.

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.

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 5.28). A total reduction in Scope 1 and 2 emissions compared to a three year rolling average[181] of **452,893 tonnes of CO_2** for all accredited airports in Europe was also reported (Figure 5.27). This represents about 20% reduction compared to the three-year rolling average.

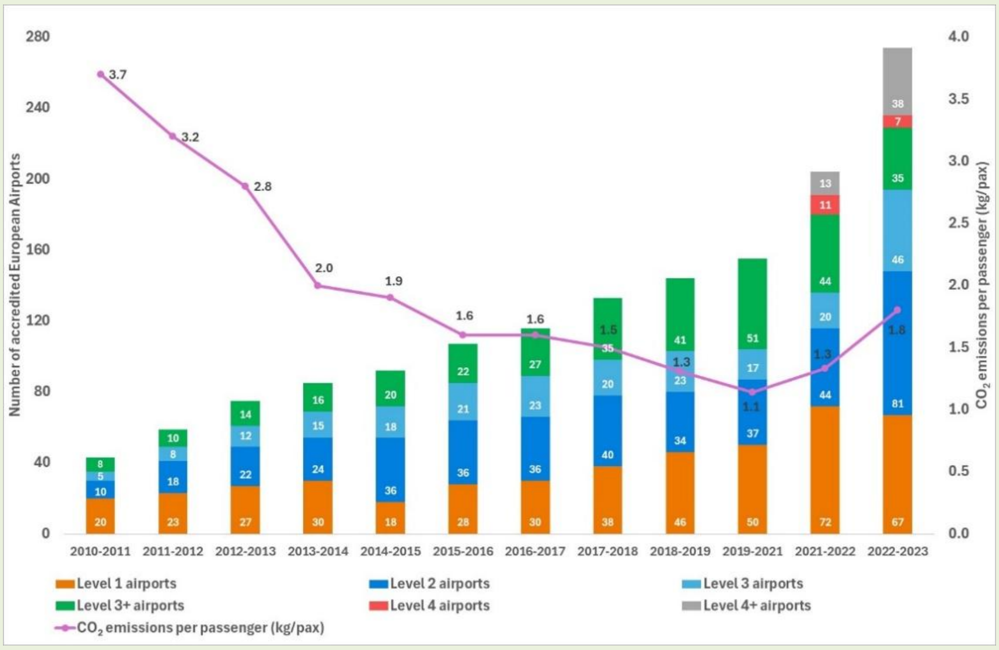

Figure 5.27 – Increasing number of accredited European airports and decreasing CO_2 emissions per passenger

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[180] GHG Protocol (2025), [Scope 2 and 3 Calculation Guidance]

[181] 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.

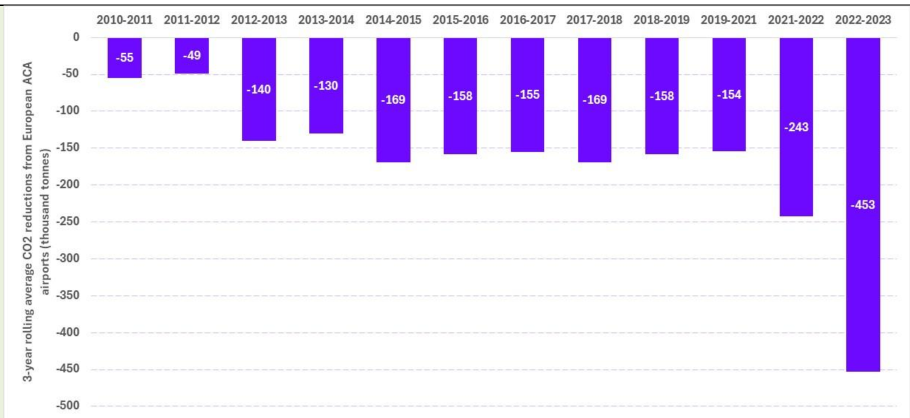

Figure 5.28 – Scope 1 and 2 emissions reductions in airport CO_2 emission

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.

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[182] 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

[182] Air Cargo Belgium (2024), Digital Green Lane

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'[183], 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[184]. This tool uses Carbon Disclosure Project[185] corporate emissions database and allows users to track the progress of a company's business air travel emissions

[183] STARGATE (2025), Digital Twin project
[184] Travel Smart (2025), Emissions Tracker
[185] CDP (2025), Carbon Disclosure Project

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[186].

5.5.3 AREAS OF INTERNATIONAL COLLABORATION

The aviation sector has a long-standing history of making use of International Cooperation through technical cooperation programmes to grow the capabilities of States in the areas of safety, security and ATM, and EU entities are trusted and experienced partners in those initiatives.

During the last decade, the number of technical cooperation programmes dedicated to environmental protection has grown in line with the increasing ambitions of States to mitigate the environmental impact of aviation. European entities have been key contributors to this having collaborated with 112 Partner States and committed an estimated €20 million in civil aviation environmental protection projects since 2022. At global level, ICAO has developed technical capacity building programmes, such as ACT-CORSIA and ACT-SAF, which offer a common umbrella to the capacity building efforts in environment. The contribution of the European Commission to these programmes amounts to €56.5 million[187], including €9.6 million in projects directly implemented by ICAO. The European States and the European industry are also contributing to these ICAO programmes.

These European projects, implemented by EASA, European States, European Industry or directly by ICAO with European funds, have supported capacity building in numerous regions covering various technical topics that are summarised in this section. Building on this, there is a commitment to continue engaging through International Cooperation initiatives to pursue sustainable aviation on a global basis.

5.5.3.1 CORSIA IMPLEMENTATION

The initiatives of EU entities, either through the ICAO ACT-CORSIA programme or through dedicated technical cooperation projects, have contributed to the increasing numbers of States volunteering to take part in CORSIA during the Pilot Phase (2021-2023) and First Phase (2024-2026) by facilitating the implementation of the Monitoring, Reporting and Verification (MRV) process and in some cases the development of their National accreditation process.

As described in detail within Chapter 4 on Market-Based Measures, CORSIA has now entered the First Phase (2024-2026) where, after the recovery of air traffic following the COVID-19 pandemic, the scheme is likely to lead to offsetting obligations for aeroplane operators flying between two volunteering States. CORSIA offers two ways to perform the offsetting, either by purchasing and

[186] Travel Smart (2025), Case Studies of company best practices
[187] Some of the projects covered environment among other activities but were not fully dedicated to environment matters.

cancelling CORSIA Emission Units (CEU) or by using CORSIA Eligible Fuels (CEF). In both cases, specific criteria and rules apply to CEU or to CEF production in order to deem them as eligible offsets. While CEU and CEF can be purchased worldwide, States are looking to benefit from the environmental and economic benefits of CORSIA by providing CEU and CEF on a domestic basis.

Mr Jame E. Empeno

Director, Philippines Accreditation Bureau

"The Philippine Accreditation Board (PAB) has worked hand in hand with EASA and with the Thai Industrial Standards Institute (TISI) to develop and implement the CORSIA Accreditation Process. The combination of expertise between the three parties, sponsored by the EU-SEA CCCA CORSIA Project, has provided the necessary conditions for us to embark into this new area as an organisation, and to achieve the first accreditation of a Verification Body in the Philippines. This collaboration between PAB, EASA and TI\TISI is an excellent example of sharing expertise and resources, thus enabling the growth of the accreditation and verification capabilities in ASEAN, which is a key area to ensure the sound and economical implementation of CORSIA within our region."

Increasing commitments of States under the Paris Agreement through their National Determined Contributions (NDC) may result in greater competition for the use of CEU within international markets. As such, technical cooperation is also playing an important role to facilitate the understanding of the complementarity of CORSIA with other carbon markets, enabling positive synergies to maximise their intended goals and avoiding potential double-counting of emissions and emission cancellations. The cooperation between European entities and Partner States in the period 2025-2027 is expected to focus on the sound implementation of the offsetting mechanisms under CORSIA and facilitating an increase in the availability of carbon projects providing CEU.

5.5.3.2 SAF DEVELOPMENT

The development of Sustainable Aviation Fuels (SAF) is the most cost-effective measure and has the biggest potential to significantly reduce the carbon footprint of air transport in the short- and long-term. The carbon reduction of SAF is on a life cycle basis.

The 3rd ICAO Conference on Alternative Aviation Fuels (CAAF#3) in 2023, called as part of the efforts to achieve the LTAG, resulted in its Member States adopting the "Global Framework for Sustainable Aviation Fuels (SAF), Lower Carbon Aviation Fuels (LCAF) and other Aviation Cleaner Energies" which includes an objective to reduce the emission of air transport of 5% by 2030 thanks to SAF and other cleaner energies[188]. As part of this Framework, it was acknowledged that support to States and industry to develop end finance SAF initiatives is essential to ensure that "No Country is Left Behind" in the decarbonisation efforts. As such, the ICAO ACT-SAF Programme was established to support States in developing their full potential in SAF, through specific training activities, development of feasibility studies, and other implementation support initiatives.

A rapid and geographically balanced scaling up of SAF production requires both significant investments and well-informed decision-making. In this regard, EU entities are advocating and supporting the development of SAF within 42 Partner States in Africa, Asia and Latin America through different International Cooperation initiatives.

The first stage of this support is to raise awareness, to exchange best practices and to develop technical capabilities on SAF. The second stage involves supporting the development of local capabilities to enable local SAF production.

As part of the first stage, EU funded projects have been facilitating SAF workshops and webinars around the world and has also funded, via projects implemented by ICAO, 7 SAF Feasibility Studies - for Kenya[189], Trinidad and Tobago[190], Dominican Republic[191], Burkina Faso[192], Zimbabwe[193], Côte d'Ivoire[194] and Rwanda[195]. Beyond Feasibility Studies, the technical cooperation initiatives from EU entities have facilitated bringing all relevant stakeholders together in order to develop a common understanding on SAF, the potential of SAF within their State and what their role could be in the development of local SAF production. This has covered the entire value chain of SAF including the different pathways for production, technoeconomic analyses, readiness studies and policy dialogues. Depending on the State profile, the support and collaboration has been tailored towards its specific potential for SAF production (e.g. analysing the activation of specific feedstocks, taking advantage of existing refining capabilities, potential use of electricity from renewable sources) and assessing at high level the technoeconomic viability of possible production pathways.

Similarly to the support provided on State Action Plans for CO_2 emissions, the most valuable contribution has been to facilitate a common understanding on SAF among the potential SAF actors in a State, and more crucially among different Governmental Departments (e.g. Ministries of Energy, Transport, Environment, Finance, Civil Aviation Authorities) and non-aviation stakeholders (e.g. gas

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188 ICAO (2023), ICAO Global Framework for Sustainable Aviation Fuels (SAF), Lower Carbon Aviation Fuels (LCAF) and other Aviation Cleaner Energies
189 ICAO (2018), Kenya – Feasibility study on the use of SAF
190 ICAO (2018), Trinidad and Tobago – Feasibility study on the use of SAF
191 ICAO (2018), Dominican Republic – Feasibility study on the use of SAF
192 ICAO (2018), Burkina Faso – Feasibility study on the use of SAF
193 ICAO (2023), Zimbabwe – Feasibility study on the use of SAF
194 ICAO (2023), Cote d'Ivoire – Feasibility study on the use of SAF
195 ICAO (2023), Rwanda – Feasibility study on the use of SAF

and oil industry, feedstock producers).

In the framework of the EU Global Gateway strategy, EU entities have now reached the start of the second stage with the funding by the European Commission of SAF projects in 15 Partner States: Cameroun, Cote d'Ivoire, Egypt, Equatorial Guinea, Ethiopia, Kenya, India, Madagascar, Mauritania, Morocco, Mozambique, Nigeria, Rwanda, Senegal, South Africa. These projects will be implemented by ICAO and by EASA and aim to support them in achieving local SAF production projects.

The funds are being committed under the EU Global Gateway strategy and contribute to ICAO's ACT-SAF programme and other technical cooperation projects that follow a similar approach. The support initiatives are discussed and agreed with the Partner States in order to map out the main areas of potential collaboration:

- **Developing and managing the SAF programme at State level**, including the definition of the SAF Roadmap, organising the stakeholder engagement and launching communication campaigns to explain the need of SAF for decarbonisation of air transport.
- **Designing and deploying the most adequate SAF framework**, as a set of State initiatives providing favourable conditions for SAF production projects to become viable (e.g. SAF policies, financial initiatives, capacity building), starting with having a good understanding of the State's potential in the form of a feasibility study.
- **Defining viable Direct Supply Lines (SAF production and supply projects)**, assessing the technoeconomic viability of different scenarios, identifying challenges and defining actions at State level (e.g. SAF policies or regulations, incentive schemes, research on sustainability of feedstocks) or at project level (e.g. adjusting technologies, establishing partnerships, securing feedstocks) for those production projects to become viable.
- **Facilitating access to finance**, enabling the bankability of the SAF production project by derisking investment and accessing dedicated funds (e.g. Development Banks, EU Global Gateway).

The initiatives are following and contributing to the development of ICAO's ACT-SAF programme framework, templates and tools. This collaborative work is providing a common and harmonised toolkit that helps both the Partner States and relevant stakeholders match needs and supporting resources in a more agile manner, and allows for more efficient cooperation, even with multiple and concurrent partners.

This coordination is deemed essential to maximise the output of the resources dedicated to the upscale of SAF production worldwide.

Mr Emile Arao

Director General, KCAA, Kenya

"SAF will be a key element in the ability of the aviation sector to increase its sustainability in mid to long-term. It is also an opportunity for countries to develop their green economy and to gain greater independence in a strategic area. However, the complexity of the product, the interdependencies with other economic sectors and the strategic decisions that are required to start producing SAF locally, requires coordination across a wide range of expertise in order for a Government to make the right decisions. The collaboration with international partners, such as the European Union, European States and Organisations, is crucial to maximise the use of available resources that can facilitate Kenya in its ambition to be one of the first countries in Africa to produce SAF at a commercial scale. Under the SAF Steering Committee, Kenya ensures an orchestrated collaboration among all partners, establishes clear leadership and milestones and allows for transparency in achieving this ambitious but exciting endeavour."

5.5.3.3 ENVIRONMENTAL MANAGEMENT SYSTEMS FOR AIRPORTS

As defined by ICAO, an Environmental Management System (EMS) provides a methodology and framework to systemically identify and cost-effectively manage significant environmental aspects in the operation of aviation organisations. It has been proven effective across a wide range of organisations, including airports, air carriers, manufacturers and government agencies. EMS is one of the tools available for managing environmental matters at an airport, along with sustainability plans, certifications and other processes.

Through the support from EU funded projects to the ASEAN Member States, Thailand, Laos PDR, Philippines, Indonesia and Vietnam have all developed technical capacity for the implementation of EMS in selected airports of their network. The support provided through a series of training sessions, and the exchange of experiences between airport officials, has facilitated the local implementation of the EMS and the progressive transformation of airport infrastructure to reduce its environmental impact.

As an example, Iloilo Airport in the Philippines was supported in developing and implementing their EMS, including associated manuals, processes and action plans, which led to certification against ISO14001 in 2023[196]. This attested to a well-established system and the commitment from airport senior officials to mitigate the impact of the infrastructure and its operation on the environment and surroundings. The environmental team from Iloilo Airport, together with the Civil Aviation Authority of Philippines (CAAP) and the support of EU Projects, has subsequently developed an EMS implementation package to support CAAP in progressively rolling out the EMS across the airport

[196] CAAP (2023), award of ISO14001 Certificate to Iloilo International Airport

network from 2024 onwards.

The implementation of EMS is location specific and faced different scenarios and environmental challenges at each airport. For example, Luang Prabang Airport in Laos PDR is an airport surrounded by UNESCO sites where the need to respect the local cultural heritage was essential during the implementation of their EMS.

All the expertise accumulated in the various EMS implementations is being shared among the ASEAN Member States in thematic workshops facilitated by EU funded projects, and in a dedicated workstream at ASEAN level led by the ASEAN Air Transport Working Group (ATWG).

5.5.4 GLOBAL GATEWAY

The European Commission is promoting the green transition externally, aiming to combat climate change and to minimise threats to the environment in line with the Paris Agreement together with Partner States. This includes notably the so-called Global Gateway strategy.

Global Gateway will foster convergence with European or international technical, social, environmental and competition standards, reciprocity in market access and a level playing field in the area of transport infrastructure planning and development. It will serve to enhance the recharging and refuelling infrastructure for zero-emission vehicles and foster the supply of renewable and low-carbon fuels. It will serve to strengthen aviation and maritime links with key partners, while also setting new standards to enhance environmental and social sustainability, create fair competition and reduce emissions in those sectors.

Air transport is acknowledged as a hard to decarbonise sector, while at the same time global air traffic is projected to continue growing, contributing to economic and social growth. This increase in air traffic will increase total aviation emissions if no action is taken. To face this challenge, acknowledging SAF as a cost-effective measure with the potential to significantly reduce the carbon footprint of air transport in the short- and long-term, increased availability and use of SAF outside of Europe has become a strategic objective for the EU. SAF also has a high potential to contribute to the economic development of States, notably in Africa, and to reduce their dependence on imported energy sources.

In December 2023, the European Council endorsed the list of Global Gateway flagship initiatives for 2024, including the global development and use of SAF[197] [58], in line with the strategy's pledge to enhance sustainable transport connections. This will support achieving the objectives of both the Long-Term Aspirational Goal of net zero CO_2 emissions from international aviation by 2050 and the ReFuelEU Aviation Regulation mandate that 70% of fuel supplied by 2050 must be SAF.

The recognition of SAF as a strategic priority provides the opportunity to access dedicated funds that can help reduce the investment gap for sound SAF production projects in Partner States.

5.5.5 AVIATION ENVIRONMENTAL PROJECT COORDINATION GROUP (AEPCG)

Mindful of the need to maximise the impact of the technical and financial resources made available to Partner States, the European Commission (EC) and the European Union Aviation Safety Agency (EASA) established the Aviation Environmental Projects Coordination Group (AEPCG) in 2020 as a forum to

[197] EU (2022), Global Gateway flagship projects

raise awareness and facilitate the coordination of international cooperation support being delivered by EU Entities.

The AEPCG meets twice a year with an increasing number of participants[198] and initiatives being discussed. While the initial intent of the group was to raise awareness and facilitate coordination, the discussions among the group identified synergies in the implementation of CORSIA and the development of SAF. For example, following the provision of technical support to Cambodia that was coordinated between DGAC France and an EU funded project (EU-SEA CCCA CORSIA Project), the Partner State decided to join CORSIA during its voluntary phase. Looking forward, similar synergies are being developed in the concurrent support of the EU and the Government of the Netherlands to the SAF development in Kenya through the ACT-SAF Programme.

This close coordination and collaborative spirit among support partners will be a key factor in successfully meeting future environmental goals.

[198] AEPCG participants currently include DG MOVE, DG CLIMA, EEAS-FPI, EASA, A4E, ACI-Europe, AEF, Airbus, DGAC-France, ECAC, ENAC, GIZ, Leonardo, Neste, RSB, AESA/SENASA, SkyNRG and UBA.

SECTION III

National actions in Poland

6. GENERAL OVERVIEW

This section is complementary to the section with measures taken collectively in Europe described in section II above and includes additional information on the participation of Poland and Polish aviation stakeholders in the EU aviation research and development programs and measures. Many activities and projects that intend to reduce the emission of carbon dioxide (CO_2) from civil aviation in Poland are based on extensive cooperation. Therefore, the national actions contribute to the European measures and remain part of the quantification included in Section II. The stakeholders involved are airports, air navigation services (ANS) providers, aircraft operators, research institutes and universities as well as governmental bodies and regional authorities.

Poland is determined to reduce emissions in a sustainable manner. On 2nd February 2021 the Council of Ministers have adopted the **Energy policy of Poland until 2040 (EPP2040)**[199]. The document presents an ambitious, consistent and responsible way of carrying out the energy transformation of Poland. The Energy Policy of Poland until 2040 takes into account changes in the energy mix, as well as the need to ensure, among others: energy security, sustainable development of the economy and strengthening its competitiveness with optimum use of Poland's own energy resources.

The EPP2040 is consistent with Poland's **National Energy and Climate Plan for the years 2021-2030**[200] (NECP, submitted to EC in December 2019, currently being updated), however, it also contains new goals, in particular regarding the limitation of coal use in residential sector and aimed at improvement of air quality.

Implementation of policies and measures included in the EPP2040 and the Polish NECP will put Poland on the low emission path in the long term and enable achieving climate neutrality according to national possibilities.

EPP2040 and NECP remain a solid base for **Civil aviation development policy in Poland until 2030 (with a perspective until 2040)**[201] that defines the main objectives, directions and methods of creating and implementing government policy related to civil aviation. The document, adopted in 2023, includes new thematic issues in order to ensure sustainable development of civil aviation, adapted to external and internal conditions and needs. The document sets out directions for interventions concerning, among others, the development of the sustainable aviation fuels (SAF) at Polish airports and creates conditions for ensuring a high level of environmental protection in air transport.

Poland is also fully committed to the development of regulatory standards in the environmental domain on **international level**. As a member of Committee of Aviation Environmental Protection (**CAEP**) Poland actively participates in the work of ICAO. Additionally, the Polish experts are deeply involved in the ReFuelEU Aviation MS Network on EASA level, work of the European Commission Sustainable Expert Group, as well as in the European Aviation and Environment Working Group (EAEG) at the European Civil Aviation Conference (ECAC) level.

199 https://www.gov.pl/web/climate/energy-policy-of-poland-until-2040-epp2040
200 https://www.gov.pl/web/climate/national-energy-and-climate-plan
201 https://www.gov.pl/web/infrastruktura/polityka-rozwoju-lotnictwa-cywilnego-w-polsce-do-2030-r-z-perspektywa-do-2040-r

7. BASKET OF MEASURES IN POLAND

7.1 AIRCRAFT TECHNOLOGY AND STANDARDS - The Łukasiewicz Research Network – Aviation Institute

The aviation industry in Poland is research oriented, with particular emphasis on technology and innovation processes and European targets.

One of the most modern research facilities in Poland is the Łukasiewicz Research Network – Institute of Aviation, with traditions dating back to 1926. The Institute closely cooperates with global aviation industry stakeholders, such as Boeing, GE Aerospace, Middle River Aerostructure Systems (MRAS), Airbus, Pratt & Whitney. In addition to the work of a commercial nature the Łukasiewicz Research Network – Institute of Aviation cooperates with a number of R&D and production sites and is currently participating in the following research projects:

- **AMBER (Innovative Demonstrator for hybrid-Electric Regional Application)**[202]
  The project is a demonstrator which aims to mature, integrate and validate key technologies necessary for a megawatt class hybrid electric propulsion system (~ 2MW) powered by hydrogen fuel cells.
- **OFELIA (Open Fan for Environmental Low Impact of Aviation)**[203]
  The project aims to demonstrate at TRL5 the RISE Open Fan architecture, for the SMR to achieve or surpass the Air Transport Action Group's goals on the way towards Carbon neutrality by 2050.
- **HERFUSE (Hybrid-Electric Regional Fuselage & Empennages)**[204]
  The main goal of the project is development of the innovative fuselage devoted for hybrid electric regional passenger aircraft, that will have positive influence on lowering greenhouse gas emission.

7.2 OPERATIONAL IMPROVEMENTS – Polish Air Navigation Agency (PANSA)

The primary goal of **PANSA (Polish Air Navigation Agency)**[205], the main Polish air navigation service provider, is to ensure safe, smooth and efficient air traffic. Where possible, PANSA also implements methods that limit the negative impact of air operations on the environment. Activities in the area of environmental protection are multi-threaded and bring measurable effects. The solutions used by PANSA reduce CO_2 emissions into the air. Every day, PANSA ensures sustainable development of navigation services while minimizing the negative impact of air operations on the environment.

One of the standard flight techniques performed by crews of aircraft flying to Warsaw Fryderyk Chopin Airport is the "green approach", or CDA (Continuous Descent Approach), provided by air traffic controllers.

CDA is an environmentally friendly technique for conducting an air operation that allows the aircraft

[202] https://www.clean-aviation.eu/research-and-innovation/clean-aviation/clean-aviation-projects/amber
[203] https://www.clean-aviation.eu/ofelia
[204] https://herfuse.eu/
[205] https://www.pansa.pl/srodowisko/

captain to perform a smooth descent to landing, preferably from cruising altitude. According to CDA, the air traffic controller, to the extent possible, gives the crew freedom to calculate the descent and approach profile to landing so that the aircraft can descend with minimal engine thrust and avoid flying at a constant altitude. The use of CDA thus minimizes fuel consumption and reduces aircraft noise, while also reducing air pollutant emissions.

Other operational activities of PANSA also allow for savings and environmental protection. The chain of dependencies can be reduced to the principle: the longer the aircraft crew has to keep the engines on, the longer the aircraft will emit pollutants into the air. Therefore, the shorter the flight route, the greater the fuel savings for the carrier, and at the same time the lower carbon dioxide emissions and cleaner environment. It is worth mentioning here the operational implementation of the A-CDM (Airport Collaborative Decision Making) system at Chopin Airport in Warsaw, which was possible thanks to the close cooperation between the airport and PANSA. A-CDM helps air traffic controllers effectively manage aircraft traffic while still on the airport apron and determine the optimal moment to start the engines so that the power units work on the ground for the shortest possible time. This action is equivalent to reduced fuel consumption, reduced pollutant emissions and reduced noise levels.

The Polish Air Navigation Agency also enables airspace users to submit flight plans for operations in the EPWW FIR, bypassing intermediate points. This means that the carrier can plan a flight route in a way that anticipates a flight along the shortest possible route. Here again, the activities of the Polish Air Navigation Agency bring tangible benefits.

It should also be noted that since February 8, 2019, the Free Route Airspace (FRA) concept, known as POLFRA, has been operational in Polish airspace. It gives carriers greater freedom in preparing flight plans. POLFRA allows planning a flight route through our airspace directly between defined navigation points (entry and exit), located on the FIR border, without the need to use the existing network of airways. Thanks to this solution, flights can be planned on routes that are closer to real trajectories, reducing flight time and reducing fuel consumption.

7.3. ADDITIONAL MEASURES OF POLISH AVIATION STAKEHOLDERS

Poland recognises the efforts of airports to manage and reduce their carbon emissions. There are currently 2 airports in Poland accredited at Level 1 of ACI Airport Carbon Accreditation programme: the Warsaw Chopin Airport (EPWA) and the Gdansk Lech Walesa Airport (EPGD).

With a reference to the environmental policy of the Polish Airport's State Enterprise[206], **the Warsaw Chopin Airport (EPWA)** has decided to provide incentives for airlines to use quiet and modern fleets. There is also a modern photovoltaic system of solar panels at the airport, utilizing clean and renewable energy. Additionally, the airport has adopted various energy-saving solutions, such as replacing conventional lighting with energy-efficient LED lights and optimising the operation of HVAC systems. The airport's vehicle fleet and machinery are being gradually modernized in order to meet the highest emission standards. The airport cooperates with PANSA to optimise the rules of air traffic.

[206] https://www.polish-airports.com/en/we-care-for-the-environment.html

The Gdansk Lech Walesa Airport (EPGD) is also committed to conducting a comprehensive analysis of its CO_2 emissions and establishing structured plans to reduce its carbon footprint. This achievement marks a significant step in its long-term goal of achieving climate neutrality by 2050. In August 2024 the Sustainability Commitment was signed[207], declaring that the airport constantly works on decreasing its environmental impact and increasing operating efficiency, beyond legal and regulatory requirements. The aim of the airport is to become Net-Zero in our greenhouse gas emissions from all operations by 2050. In its policy the airport follows principles and goals of United Nations in terms of sustainable development.

In the near future, the Centralny Port Komunikacyjny (CPK airport), scheduled to open in 2032, will serve as Poland's new central airport. The CPK airport would be a multimodal transfer hub to be located between Warsaw and Łódź, which will integrate air, rail and road transport. According to its Sustainability Statement[208], CPK airport will be technically prepared to operate, based on energy derived exclusively from renewable sources - from the first day of its opening. A large proportion of the energy necessary to heat, cool and power the airport's equipment and systems will be generated on-site and exclusively from renewable sources. The airport plans to use solar photovoltaics and various types of heat pump technologies, and possibly green hydrogen in the future. The collective long-term goal of the CPK airport is Net Zero travel.

7.4. EU ETS AND CORSIA

Poland, as a Member State of the EU, has implemented a regional emission trading system (the "EU ETS"), which is a cap-and-trade system that covers greenhouse gas emissions from aviation activities since 2012. It limits the overall emissions cap and allows emitters to buy and sell allowances to meet their obligations, thereby promoting a cost-effective emissions reduction.

The EU law, adopted in 2023[209], strengthened the EU ETS for emissions from all large airlines flying within the EEA, to Switzerland and to the UK. It also included provisions on the implementation of the global market-based measure CORSIA for emissions from airlines based in the European Economic Area. Every EU Member State, inluding Poland, has an obligation to implement CORSIA mechanism, however, as communicated to the ICAO Secretariat, and acknowledged by the Secretariat, the annual CO_2 emissions for all State pairs reported by Member States to the ICAO Secretariat as subject to offsetting requirements is without prejudice to the calculation of offsetting requirements and the quantity of CORSIA Eligible Units to be cancelled to demonstrate compliance.

For 2024, 5 Polish Aircraft Operators have been atributted to CORSIA mechanism, meanwhile 8 Polish AOs perform an aviation activity listed in Annex I to the EU ETS Directve.

[207] https://www.airport.gdansk.pl/airport/environmental-protection/sustainability-commitment-p119.html

[208] https://www.cpk.pl/wp-content/uploads/CPK_sustainability_statement_EN_final052023_small.pdf

[209] 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 (OJ L 130, 16.5.2023, p. 115-133)

8. SUSTAINABLE AVIATION FUELS IN POLAND

8.1 National SAF Council

The 41st ICAO Assembly adopted a *long-term global aspirational goal (LTAG*) for international aviation of net-zero carbon emissions by 2050, aligning governments and private sector towards net-zero carbon emissions by 2050. Poland fully supports common efforts to achieve a collective long-term global aspirational goal (LTAG) for international aviation of net-zero carbon emissions by 2050, including the goals established at the Third Conference on Aviation and Alternative Fuels (CAAF/3) regarding a 5% CO_2 reduction from international aviation in 2030. To fulfil the decarbonisation targets, a multi-approach national strategy should be pursued for the aviation sector in Poland, including an assortment of technological solutions. However, the most advanced and immediate viable option for reducing aircraft CO2 emissions and making progress towards the targets set at the European level are Sustainable Aviation Fuels (SAF). Therefore, there is a global effort to scale-up SAF.

As it was mentioned in Section II, by adoption of the ReFuelEU Aviation Regulation the EU had provided a strong push for the Member States towards the CO_2 emissions mitigation. Poland believes that the successful implementation of the ReFuelEU Aviation Regulation requires an enhanced collaboration of all the national stakeholders, in particular union airports, aircraft operators, fuel suppliers and public administration bodies.

Sustainable Aviation Fuels, depending on the feedstock and method of production, can reduce carbon emissions by up to 80% from a lifecycle perspective. They can be produced from biological sources, such as agricultural residues or used cooking oil, or non-biological sources, such as electricity. Therefore, SAF could be produced in Poland using existing technology and help reduce both the climate impact of aviation in the country and the reliance on foreign producers and suppliers.

In order to facilitate the development of a Polish national industry for sustainable aviation fuels (SAF) and the achievement of the aviation industry's goal of Net Zero Emission by 2050, the National Sustainable Aviation Fuel Council of Poland was launched in 2024. The objective of the National SAF Council is to initiate a systemic engagement among stakeholders to plan and identify the best path towards the development of a SAF industry in Poland through:

- raising awareness and fostering knowledge related to SAF development among key stakeholders;
- developing common methodology for evaluating the feasibility of the various production pathways of SAF in Poland;
- sharing best practices among industry stakeholders and identifying the possible actions necessary to favor and support the development of SAF;
- outlining possible steps for the implementation of a SAF development plan, addressing key bottlenecks and identifying first steps towards the scale-up of the national SAF industry;
- creating the necessary conditions to ensure the bankability of the SAF projects developed in Poland;

- recommending policies to facilitate the expansion and development of SAF through the most appropriate technological processes, and to achieve the objectives of climate neutrality, affordability and access to strategic national sources of SAF.

Among the Council Members, there are representatives of public administration entities (Ministry of Infrastructure, Ministry of Climate and Environment, Energy Regulatory Office, Civil Aviation Authority), airports (Polish Airports), air carriers (PLL LOT, Enter Air, Ryanair, Wizzair, IATA), fuel suppliers (Orlen, Air BP Aramco, Unimot), etc. The main aim of the Council is to discuss how the SAF business can develop effectively in Poland. Since the establishment, the National SAF Council met three times, discussing inter alia the regulatory barriers related to the application of the ReFuelEU Aviation Regulation in Poland and possible solutions to be provided. The National SAF Council has been also discussing the potential scope of SAF Roadmap for Poland, if any.

8.2 ORLEN

8.2.1 HVO

The HVO installation being built in Płock is a technology based on the hydrogenation of rapeseed oil, used cooking oil (UCO) or their mixture. The final product will be used as an additive to diesel oil or JET aviation fuel. The designed capacity of the HVO installation may amount to approximately 300 000 tons of hydrogenated oil per year.

8.2.2 HyFly

This project implements ORLEN's strategy to reduce CO_2 emissions and develop a new segment related to the implementation of low-carbon transport based on hydrogen, as well as to meet the targets resulting from ReFuelEU Aviation Regulation regarding the share of RFNBO and SAF in the produced aviation fuels. The project provides for the industrial implementation of a comprehensive technology for the production of synthetic aviation fuels (eSAF RFNBO). The purpose is to implement the production of synthetic fuels (eSAF) on a large scale based on the Fischer-Tropsch technology, using hydrogen generated in the electrolysis process powered by electricity from renewable energy sources (RFNBO) and CO_2 of biological origin (from the combustion of biomass and from municipal waste processing processes).

8.2.3 Optimization on the production of e-Fuel – NEON Program

ORLEN as part of the activities on optimization of production of e-Fuels is engaged in the dedicated program with the Narodowe Centrum Badań i Rozwoju (NCBR) called NEON. The aim of this program is to search for new solutions in selected issues, with the participation of Polish science and research institutions. The result of this program is the analysis of new solutions that can contribute to reducing CO_2 emissions within the scope of ORLEN's operations. The program may end with rescaling and building a given solution. One of the possible points on the program is the optimization on the production of syngas that can boost the production of e-SAF in the Fischer-Tropsch and decrease of CO_2 carbon footprint.

8.3 PLL LOT

The first SAF purchased by LOT to reduce its carbon footprint and minimize the environmental impact of operations was executed in 2023. LOT purchased SAF from SkyNRG and received an independently audited report to verify the environmental impact. This collaboration underscored the airline's unwavering commitment to reducing its carbon footprint and minimizing the environmental impact of aviation.

The agreement between Orlen and PLL LOT signed in 2022 has implied cooperative measures for the use of SAF according to ReFuel Aviation and CORSIA.

Responding to the growing challenges of mitigating climate change, LOT has adopted The Decarbonization Strategy based on Science Based Targets Initiative (SBTi) establishing GHG reduction targets. SAF is one of the many initiatives undertaken by LOT to reduce emissions from aircraft operations. To enhance the usage of SAF LOT intends to use it for all connections from airports in Poland where Orlen will deliver it.

8.4 Involvement in the Renewable and Low-Carbon Fuels Industrial Alliance (RLCF Alliance) activities

The alliance is an initiative that focuses on boosting the production and supply of renewable and low-carbon fuels in the aviation and waterborne sectors. It is a key flanking measure to the FuelEU Maritime and RefuelEU Aviation initiatives. Its aim is to ensure that air and maritime transport have sufficient access to renewable and low carbon fuels, while considering the future use of these fuels in road transport.

ORLEN is a member of the Programme and Monitoring Group of the Renewable and Low Carbon Fuels (RLCF) Alliance. The Programme and Monitoring Group is a key pillar of the renewed governance to drive the further work of the RLCF Alliance specifically and the development of renewable and low carbon fuels for the aviation and maritime sectors in general. The Alliance is focused on:

1. Building on the sustainable feedstock and production pathways eligible towards the decarbonisation targets put forward in FuelEU Maritime and ReFuelEU Aviation. The Alliance shall:
    - leverage on work done in other initiatives, identify transport fuels which are most economically and environmentally suitable (including consideration for the zero-pollution ambition) for scaling up along different timelines, and
    - evaluate strong and weak points of the value chain (including systemic, technological, geographical and workforce related ones) and assess investment needs.
2. Accelerating market entry of new innovative fuels and associated technologies. The Alliance will assess the enabling conditions, such as those relating to demand and supply side including local availability of feedstock, adequately trained workforce and industry knowledge base in Member States. It also identifies gaps in standardisation, safety assessments, and make sure all stakeholders in the value chains are aware of any downstream certification requirements .
3. Identifying and assessing existing relevant public and private financing opportunities as well as determining the suitability of additional instruments for de-risking investments for scaling up the production, while simultaneously reducing the price gap between fossil and renewable and low carbon fuels. This include crowding in private investments (in particular in relation to

cross-border projects, including possible Important Projects of Common European Interest) and drawing conclusions on their suitability.

4. Create of a pipeline of investment projects (including high TRL level and R&D activities) based on prioritisation established under points 1 and 2 and the self-assessment tools in order to increase their visibility and credibility. In the development of such pipeline, the Alliance will pay particular attention to focus on projects that are compatible with the transition to low- and zero-emission mobility. Ongoing processes to develop and subsequently deploy technologies for zero-emission vessels and aircraft shall not be negatively impacted.
5. Looking at creating synergies with different transport modes and ensuring availability of resources for renewable and low-carbon fuels for aviation and waterborne transport (notably in cooperating with the European Clean Hydrogen Alliance and ensuring consistency between hydrogen production capacity increases and different utilisation pathways in transport, such as for e-fuels).

As part of this Programme and Monitoring Group of selected stakeholders ORLEN will be contributing to the Alliance's Framework Work Plan and the objectives mentioned above, disseminating knowledge within the community and externally as well as establishing the RLCF project pipeline and mechanisms to drive the adoption of renewable and low-carbon fuel production especially e-Fuels.

8.5 First SAF delivery (Katowice)

In 2025, Unimot Aviation, member of the Unimot Group, has carried out Poland's first physical delivery of sustainable aviation fuel to a Polish airport. The fuel was delivered to the Katowice International Airport (EPKT), refuelling an Airbus A320 aircraft for the 23 April 2025 flight to Marsa Alam (HEMA), Egypt. It was the first refuelling with SAF in Poland, which is an important step towards decarbonisation of air transport in Poland[210].

8.6 ReFuelEU Aviation Regulation

According to the discussion at the Polish SAF Council, national regulations in Poland still require changes from the national legislator. The specification of the provisions of the ReFuelEU Aviation Regulation at the Member State level is crucial from the perspective of participants in the domestic aviation fuel market and air transport, from the point of view of legal certainty and predictability of obligations and sanctions.

National law has not yet been adapted to the ReFuelEU Aviation Regulation, however the amendments to 4 existing legal Acts have been prepared and consulted[211] and the law supporting the application of ReFuelEU Aviation Regulation is expected to be adopted in Q4 of 2025.

Nevertheless, the aviation fuel market also requires tighter supervision to avoid the risk of a grey zone in this segment. Polish SAF Council has identified that aviation fuel market participants in Poland still face additional challenges such as:

[210] https://bitumen.unimot.pl/en/news/unimot-with-first-delivery-of-sustainable-aviation-fuel-saf-to-poland
[211] Amendments to ordinary law: Aviation Law of 3 July 2002, Energy Law of 10 April 1997, Environmental Protection Law of 27 April 2001 and Act on biocomponents and liquid biofuels of 25 August 2006.

a) **Lack of regulations on extending the flexibility mechanism to include elements of the book and claim system.**

At this stage the European Commission has not decided to propose extending the flexibility mechanism to include elements of the "book and claim" system[212]. It has to be noted the lack of such a system may hinder logistics and settlement of regulatory obligations at the initial stage of market development, when not all countries produce SAF fuels and when not all Union airports will receive physical deliveries of SAF fuels (which is also assumed in Article 15 of ReFuelEU Aviation).

b) **Ensuring that the aviation fuel supplier can allocate the entire volume of SAF only to aircraft operators within the meaning of ReFuelEU Aviation, provided that SAF has been physically delivered to the given Union airport**.

SAF fuel delivered to a given airport is mixed in a shared logistics infrastructure with conventional JET fuel. In fuel supplier opinion, it is technically impossible to verify the product that is physically delivered to a specific aircraft at the airport and the proportion of SAF fuel contained therein, after mixing in a common logistics infrastructure. The aviation fuel supplier should not be deprived of the possibility of including this volume of SAF in the fulfilment of its obligation and should be entitled to issue documents confirming the sale of SAF only to entities covered by ReFuelEU Aviation, with which it has concluded appropriate aviation fuel sales agreements involving SAF for the volume of SAF that it has introduced to the market.

c) **National regulations should allow for the simultaneous fulfilment of obligations under the RED II/RED III, ReFuelEU Aviation or EU ETS directives by obliged entities.**

d) **It is necessary to finalize the work on UDB used for reporting. Simplification of reporting in UDB.**

The lack of this tool makes it difficult to implement, settle and report obligations, including in accordance with Article 10 of ReFuelEU Aviation Regulation. The scope of reported information under Article 10 should also be limited only to elements that affect the implementation of the ReFuelEU Aviation Regulation.

e) **Due to the exclusion of biofuels produced from 'food and feed crops' from the scope of the SAF definition, it will be necessary to use, among others, advanced biofuels from Annex IX, Part A of the Directive RED II and RFNBO fuels – currently rarely or not at all used in Poland.**

The widespread use of SAF fuels is not supported by the limited availability of advanced feedstock, and therefore the increased costs of obtaining such feedstock and fulfilling the SAF obligation[213].

f) **Excessively restrictive requirements for renewable hydrogen of non-biological origin (RFNBO) contained in the delegated acts to the RED II Directive, in particular temporal**

[212] Report from the Commission to the European Parliament and the Council. The ReFuelEU Aviation SAF flexibility mechanism of 27.2.2025, COM(2025) 59 final.
[213] 2024 Aviation Fuels Reference Prices for ReFuelEU Aviation, EASA, https://www.easa.europa.eu/en/document-library/general-publications/2024-aviation-fuels-reference-prices-refueleu-aviation

correlation and additionality.

The rapid development of the synthetic SAF fuel market will not be supported by the exceptionally restrictive requirements for renewable hydrogen of non-biological origin (RFNBO) contained in the delegated acts to the RED II Directive, in particular temporal correlation and additionality.

g) **Missing delegated act determining the rules for calculating GHG emission limits for low-carbon fuels.**

h) **Lack of appropriate support instruments: financial mechanisms are necessary to encourage investment in SAF production technologies (e.g. subsidies, tax incentives)**

Support instruments are necessary for the development of the SAF market and ensuring appropriate conditions for emerging projects. It is particularly important to cover the price gap between SAF and conventional fuel, the so-called green premium, for example by using contracts for difference.

Following best practice and recommendations from the European Civil Aviation Conference (ECAC) States, development of a national SAF strategy and implementation plan through identification and involvement of appropriate regulatory/executive body is being discussed. It seems to be crucial to share these initiatives and ensure that the European policy framework is aligned with the Polish priorities on renewable fuels and direct investments in SAF.

A need to take action to support the production and distribution of sustainable aviation fuels and financing activities related to the production of synthetic fuels (RFNBO) in Poland has started to be discussed at national level. The Polish SAF Council is analysing then all the points mentioned above in order to provide the effective application of the EU law concerning both the EU ETS and CORSIA mechanism as well as the ReFuelEU Aviation in Poland, having in mind a long-term global aspirational goal (LTAG) for international aviation of net-zero carbon emissions by 2050, adopted by 41st ICAO Assembly in support of the UNFCCC Paris Agreement’s temperature goal.