Bern, 21 February 2024

Carbon-neutral flying by 2050

Federal Council report

in response to postulate 21.3973 submitted by the National Council Environment, Spatial Planning and Energy Committee on 24 August 2021

Contents

Summary

Air traffic originating from Swiss airports is currently responsible for around 11% of Switzerland's greenhouse gas emissions. The aim of Switzerland's Long-Term Climate Strategy, the International Civil Aviation Organization (ICAO) and the global aviation industry is to reduce these emissions to net zero by 2050. The Federal Act on Climate Protection Goals, Innovation and Strengthening Energy Security (CIA) enshrines this target in law from 2025. The present report shows how carbon-neutral aviation can be achieved by 2050.

The primary measure for reducing CO_2 emissions is the use of sustainable aviation fuels (SAFs). Further increasing the efficiency of operations and the aircraft used will also play a role. By contrast, the potential of electric and hydrogen-powered aircraft is limited, at least until 2050. A combination of these technical measures will enable the aviation industry to reduce a large proportion of its fossil CO_2 emissions by 2050. However, it is expected that at least 10% of carbon emissions from aviation will have to be offset using negative emissions technologies (NETs).

Market-based measures, such as those already applying to domestic and international aviation from Switzerland, can make a significant contribution to reducing emissions. The impending expansion of the Swiss emissions trading system in particular may further strengthen such incentives. Measures that affect international aviation must be coordinated internationally.

The most effective tool for meeting aviation climate targets is a requirement to add SAFs to kerosene ('blending obligation'). There are also plans to promote technical measures, in particular the market ramp-up of SAFs. According to the dispatch and first reading in Parliament, both measures should be included in the CO_2 Act for the period after 2024.

In military aviation, the focus is also on improving efficiency and the use of SAFs. The Air Force already introduced SAFs in 2023 and intends to steadily increase their use. Military aviation will thus also be able to meet its climate targets, if necessary in combination with NETs.

Carbon neutrality in Swiss aviation can be achieved by 2050 if measures are taken promptly. The CO_2 Act for the period after 2024 will play a decisive role in this regard. Building on the existing instruments, the Act can now create the framework conditions to cut CO_2 emissions from aviation by over 70% in relation to transport performance by 2050. The remaining climate impacts will need to be addressed in subsequent revisions, by means of new or enhanced instruments.

1 Background

Postulate 21.3973, submitted by the National Council Environment, Spatial Planning and Energy Committee and adopted by the National Council on 17 March 2021, instructs the Federal Council to demonstrate "how flying can be made carbon neutral by 2050". This report in response to the postulate identifies technical and market-based measures as well as policy tools that Switzerland can use to achieve this goal.

1.1 Climate policy in aviation

In recent years, aviation has been included in efforts to reduce global warming through various international agreements and national targets. The United Nations Framework Convention on Climate Change (UNFCCC) provides a framework for the 198 parties to stabilise greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. In December 2015, the signatory states adopted the Paris Agreement based on the UNFCCC. This contains the internationally binding target of limiting the increase in the global mean temperature to well below 2 °C compared with pre-industrial levels. Efforts should also be made to limit the rise in temperature to 1.5 °C above pre-industrial levels. Switzerland ratified the Paris Agreement in 2017 and committed to a target of cutting greenhouse gas emissions in Switzerland by 50% by 2030, compared with 1990 levels. In accordance with the UNFCCC, greenhouse gas (GHG) emissions from international aviation are excluded. However, domestic aviation is covered by this target.

Also against the backdrop of Switzerland's obligations under the UNFCCC and the Paris Agreement, the Federal Council decided in 2019 to set a target of net-zero GHG emissions in Switzerland by 2050 at the latest. To this end, it adopted the guidelines for Swiss climate policy in 2021, in the form of Switzerland's Long-Term Climate Strategy (Federal Council 2021). Part of this strategy is to include emissions from international aviation in the net-zero target, provided this is scientifically and technically feasible.

The Federal Act on Climate Protection Goals, Innovation and Strengthening Energy Security (CIA) was approved in a popular vote on 18 June 2023. The CIA and associated ordinance are scheduled to come into force on 1 January 2025, thus transposing Switzerland's target of net-zero GHG emissions by 2050 into domestic law. The GHG emissions of international aviation originating in Switzerland are also included in the CIA in accordance with the climate strategy. Article 3 paragraph 4 CIA states that the reduction targets must be technically feasible and economically viable. They must be achieved as far as possible by cutting emissions in Switzerland. Table 1 lists Swiss climate targets relating to aviation.

Basis	Scope	GHG emissions vs 1990		
		2030	2040	2050
Draft CO_2 Act*	All sectors, domestic aviation only**	50%		
CIA	Transport, domestic aviation only		43%	0%
CIA	All sectors, domestic aviation only***		25%	0%
CIA	All sectors, including international aviation from Switzerland			0%

* According to the dispatch and first parliamentary reading

** In addition, an average reduction of 35% is to be achieved between 2021 and 2030.

*** In addition, an average reduction of 36% is to be achieved between 2031 and 2040 and an average reduction of 89% between 2041 and 2050.

Table 1 Swiss climate targets relating to aviation (reference year: 1990)

Achievement of the above climate targets is measured using the methods set out in the UNFCCC. In Switzerland, monitoring is conducted by means of the annually updated greenhouse gas inventory. For aviation, the relevant fossil CO_2 emissions are those generated by aviation fuel supplied in Switzerland for all flights. Depending on the target, a distinction is made here between flights bound for Switzerland and flights bound for abroad. Flights departing from EuroAirport Basel are not included, as the fuel supply for this airport is assigned to France. This report uses the same metric to delineate emissions. The terms 'net-zero CO_2' and 'carbon neutral' refer to this metric.

1.2 Economic importance of aviation

Swiss aviation is strongly oriented towards international travel, with 99.7% of passengers in 2019 flying abroad. Switzerland's excellent international connectivity is very important for the economy: according to the 2016 Federal Council report on Switzerland's aviation policy (Lupo 2016, BBl 2016 1847), aviation in Switzerland generates annual added value of over CHF 12 billion, rising to over CHF 24 billion if the induced effects are included (Federal Council 2016, 2014 figures). A key pillar of this is the aviation industry with its development, manufacturing and maintenance companies.

Good connectivity contributes to Switzerland's attractiveness as a business location (Federal Council 2016). This benefits international companies and organisations based in Switzerland, as well as Swiss tourism. Air freight is also very important for the export industry, with almost half of exports by value being transported by air (University of St Gallen 2020). In this context, aviation is the only mode of transport that largely covers its own infrastructure and operating costs (INFRAS 2015). However, there are also external costs of around CHF 1.5 billion per year,[1] comprising all the health and environmental damage caused, including noise, pollutants and climate effects (ARE 2022).

Until the COVID-19 pandemic, air traffic at Swiss airports increased steadily in line with economic development. Passenger-kilometres flown from Swiss airports (excluding EuroAirport Basel) rose by an average of 5.5% per year from 2009 to 2019 (FSO 2022). Since 1990, they have more than tripled. In 2019, the number of passenger-kilometres travelled by air from Swiss airports was similar to the number of kilometres travelled by road in Switzerland.[2] In addition, 300,000 to 500,000 tonnes of freight have been transported by air every year since 1990 (imports and exports, FSO 2022). In terms of weight, in 2019 this corresponded to less than 1% of imports and exports across all modes of transport (FSO 2021).

The COVID-19 pandemic had a dramatic impact on civil aviation, with passenger traffic at Swiss national airports dropping by 70% over the course of 2020 (FSO 2022). A significant proportion of freight services also fell away. The economic consequences for the entire industry were considerable. However, air traffic from Switzerland has been on the rise again since spring 2022. The European Union Aviation Safety Agency (EASA) expects the number of aircraft movements in 2024 to return to 2019 levels (EASA 2022). As the figures for Swiss aviation from 2020 and 2021 are not representative, this report is based on the data from 2019.

1.3 Climate impact of Swiss aviation

Flights from Swiss airports emitted 5.7 million tonnes of greenhouse gases in 2019. Of these, 98% were attributable to international aviation and 2% to civil aviation within Switzerland. GHG emissions from Swiss aviation increased by 75% between 1990 and 2019. According to the greenhouse gas inventory, GHG emissions from Swiss aviation account for around 11% of Switzerland's total GHG emissions. Globally, civil aviation is responsible for around 2.5% of human-induced GHG emissions, with Switzerland accounting for 0.5% of GHG emissions from global civil aviation. CO_2 is practically the only greenhouse gas covered by the UNFCCC to be emitted by aviation.[3]

Achieving carbon-neutral aviation from 2050 therefore means that fossil CO_2 emissions from aviation fuels supplied in Switzerland must be reduced to near zero. The remaining fossil CO_2 emissions must be offset through the use of negative emissions technologies, or NETs (see section 2.6). In addition, there are other climate impacts that are not directly caused by GHG emissions (see following box).

Non-CO_2 climate impacts

Aviation influences the climate not only through CO_2 emissions but also through effects that cannot be directly attributed to GHGs. These non-CO_2 effects are largely indirect. For example, under certain atmospheric conditions, the emission of soot particles leads to the formation of contrails and the resulting cirrus clouds, which generally have a cooling effect during the day but a warming effect at night. Consequently, it is not the amount of direct emissions that determines aviation's overall climate impact. To assess this impact, many other factors, which vary from flight to flight, must be taken into account. While scientists agree on the climate impact of one tonne of CO_2 emitted, there are major uncertainties regarding the measurement and evaluation of the climate impact of warming and cooling non-CO_2 effects (Neu 2021). Based on historical emissions, it has been estimated that the impact of non-CO_2 effects on the climate to date is around twice as great as that of CO_2 emissions (Neu 2021, Lee 2023). However, this estimate of the climate impact to date cannot be used for forecasts. The impact of CO_2 once emitted lasts for decades or centuries, whereas the non-CO_2 effects last only for hours or days. This means that they respond much more quickly to changes in traffic volumes and, in particular, to measures to reduce them. Switzerland's Long-Term Climate Strategy envisages a reduction in the climate impact of non-

[1] This estimate relates to the year 2019 (see source).

[2] According to the FSO (2022) and https://www.bfs.admin.ch/bfs/en/home/statistics/mobility-transport/passenger-transport/performance.html (accessed 12 January 2024)

[3] Aviation also emits traces of nitrous oxide (N_2O), and in net terms reduces the concentration of methane (CH_4) in the atmosphere.

CO_2 effects by 2050 (Federal Council 2021). The box in section 2.5 shows the potential for measures to achieve this goal.

1.4 Climate targets in the aviation sector

Between 2020 and 2022, a number of associations and organisations in the aviation sector set themselves net-zero CO_2 targets. In Switzerland, Aerosuisse, easyJet Switzerland, SWISS, the Swiss Business Aviation Association and the national airports published a declaration of intent in which they commit to the goals of Switzerland's Long-Term Climate Strategy and thus also to a target of net-zero CO_2 by 2050 (see section 1.1).[4] Internationally, in October 2021 the International Air Transport Association (IATA), the umbrella organisation for airlines, adopted a target of net-zero CO_2 by 2050 for the global air transport industry.[5]

In October 2022, the International Civil Aviation Organization (ICAO) adopted the goal that international aviation should strive for net-zero CO_2 emissions by 2050 (ICAO 2022b). Switzerland played a key role in developing this target and is supportive of it.

Emissions from airports

As well as aircraft, airports too cause significant greenhouse gas emissions. They are responsible for around 4% (Ecoplan 2021) of CO_2 emissions from Swiss aviation. These are not directly attributed to aviation, but are allocated to industry, buildings or land transport in the greenhouse gas inventory. Switzerland's international airports have committed to reducing these emissions to net zero by 2040, and even by 2030 in the case of EuroAirport Basel.[6] A range of measures are available to achieve this, including improved energy efficiency, the use of renewable energy sources and the electrification of the vehicle fleet. Like emissions, these measures are not directly attributed to aviation and so are not discussed further in this report.

2 Potential of CO_2 reduction measures

Various reports and strategies have been drawn up in connection with the aviation industry's net-zero CO_2 targets, in Switzerland and globally, setting out the means and path to achieving carbon-neutral aviation. As a basis for ICAO's net-zero CO_2 target, a comprehensive report was compiled with the involvement of several hundred international experts, to analyse the feasibility of meeting this target (ICAO 2022a).[7] The Air Transport Action Group (ATAG) also published a report on the achievability of climate targets in international aviation (ATAG 2020).

Similarly, the Aviation Outlook 2050 issued by the European Organisation for the Safety of Air Navigation (Eurocontrol) contains an overview of the feasibility of net-zero CO_2 emissions (Eurocontrol 2022). Associations representing the European aviation industry have also presented such a report (NLR 2021). For Switzerland, the Federal Office of Civil Aviation (FOCA), the Federal Office for the Environment (FOEN) and the Aviation Research Center Switzerland (ARCS) commissioned a study to identify a path to net-zero CO_2 emissions in Swiss aviation. The resulting Road Map Sustainable Aviation was developed in collaboration with industry and scientific experts and published in 2021 (Ecoplan 2021).

The Energy Perspectives 2050+ report commissioned by the Swiss Federal Office of Energy (SFOE) shows the expected development of energy consumption and CO_2 emissions from aviation without

4 https://www.arcs.aero/sites/default/files/downloads/Absichtserkl%C3%A4rung%20Sustainable%20Aviation.pdf (accessed 12 January 2024)
5 https://www.iata.org/en/pressroom/pressroom-archive/2021-releases/2021-10-04-03/ (accessed 12 January 2024)
6 https://www.aci-europe.org/downloads/content/ACI%20EUROPE%20RESOLUTION%202023.pdf (accessed 12 January 2024)
7 Only the data for the most ambitious scenario, IS3, is used in this chapter.

measures and a scenario in which net-zero CO_2 emissions are achieved by 2050 (Prognos 2020). However, the measures required for this are not discussed in detail. International aviation was largely excluded from this study.

ICAO and IATA reports in particular provide up-to-date and reliable studies on the feasibility of net-zero CO_2 targets in aviation. The available studies have different scopes (international, European, national). As aviation is a highly international industry, the results can be applied to Switzerland,[8] which is why no additional groundwork of this kind was undertaken for this report.

This chapter analyses the aforementioned reports and provides a consolidated summary with a focus on Swiss aviation. It also draws on the ICAO Action Plan on CO_2 Emission Reduction of Switzerland, which reports current and planned climate measures by Swiss aviation to ICAO on the basis of ICAO Resolution A37-19, and is updated every three years (FOCA 2021). This chapter is structured around the strategies relating to this topic. Sections 2.1 to 2.4 set out the technical measures taken by the aviation industry: more efficient aircraft,[9] more efficient flight operations, alternative energy storage systems and sustainable aviation fuels. Section 2.5 summarises the overall potential of these measures. Sections 2.6 to 2.7 address NETs for offsetting the remaining GHG emissions in accordance with the CIA and market-based measures that incentivise emission reduction.

Life-cycle considerations

In addition to the climate impact of flights, aviation also causes other environmental and climate impacts. These include indirect as well as upstream and downstream emissions, for example from fuel production or aircraft manufacture. These impacts may occur in Switzerland or abroad. Although emissions abroad are not covered by Switzerland's climate targets, they are still relevant in this context: certain measures may, for example, reduce emissions in flight but still have negative environmental effects overall.[10] For that reason, this chapter shows the overall impact of measures on the climate and on other environmental areas. The focus here is on aviation fuels, as these account for the majority of environmental damage and will continue to do so in the future (ARE 2022).

2.1 Energy efficiency of aircraft

The energy efficiency of aviation has improved significantly in recent decades. Per transport performance unit (measured in passenger-kilometres or tonne-kilometres), CO_2 emissions have fallen by around 50% since 1990 as a result of gradual optimisations.[11] This corresponds to an average increase in efficiency of around 2.3% per year. Engines account for the bulk of the improvements, followed by weight savings and aerodynamic improvements. This trend is set to continue in the coming decades. In some cases, improvements can also be made to aircraft that are already in service, through retrofitting. These optimisations are expected to deliver an increase in efficiency of around 1% per year (compared with 2019) up to 2035.

Efficiency increases beyond this are possible but would require innovative aircraft and engine designs, such as adapting the shape and arrangement of the fuselage, wings and engines. This could theoretically enable aircraft to become over 20% more efficient (compared with 2019). In some cases, adjustments to airports would also be necessary to enable them to handle these new types of aircraft. However, given the stringent demands of aviation safety, new developments generally take at least 10 to 15 years to be rolled out in the fleet. Such innovative designs would need to be manufactured and used in large quantities before they could make a significant contribution to reducing emissions. As only a small

8 The bulk of air traffic in Switzerland is international. In terms of technology too, the international arena is key, since the aircraft deployed are primarily foreign-made. Likewise, the aviation fuel used is almost entirely produced abroad, and this will remain the case in the future. Only just over half of air traffic from Switzerland is handled by Swiss aircraft operators. There are also several airports of international importance spanning the Swiss border, including EuroAirport Basel, a national airport on French soil. Accordingly, aviation policy is closely coordinated across Europe.

9 The term 'aircraft' in this report refers not only to aeroplanes but to all airborne vehicles, including helicopters.

10 This is possible, for example, where non-renewable energy sources are used for the production of alternative fuels, hydrogen or electricity for electric aircraft.

11 This applies both to Switzerland (FOEN 2023) and to Europe (EASA 2022).

proportion of the fleet is replaced each year, it would take decades for these emission reductions to materialise. Given that aircraft are designed with a service life of around 30 years, the global fleet will largely consist of the current aircraft types until after 2050.

The production, maintenance and decommissioning of aircraft have a comparatively low impact on the climate, with the resulting emissions estimated to account for around 2% of GHG emissions from Swiss aviation.[12] Nevertheless, there is scope for progress here too. Studies assume that the technical efficiency of the fleet as a whole will increase by between 10% and 21% by 2050 (see Figure 1). In the process, technological improvements will come ever closer to their physical limits.[13] At the same time, the high safety standards applying to aviation must be met. Such developments entail high innovation risks and costs for manufacturers. ICAO assumes that around USD 350 billion will need to be invested in this area by 2050. However, this will be offset by total savings of USD 740 billion by 2050 as a result of lower fuel consumption.

2.2 Energy efficiency of flight operations

However, the energy efficiency of aviation does not depend solely on the types of aircraft used. Emissions savings can also be made in the way these aircraft are operated. Possible measures here include optimised flight planning based on the shortest possible routes or adaptation to weather conditions (Ecoplan 2021). Aircraft operators can also avoid emissions by reducing weight, whether through lighter equipment or by carrying less fuel, water or food. Lower flight speeds and optimised weight distribution of the load (especially freight) in the aircraft can also help to reduce the impact on the climate. There is also scope to reduce fuel consumption during maintenance (Ecoplan 2021). Furthermore, there is great potential for more flexible air traffic management to reduce detours and holding times (ICAO 2022a). Flight capacity utilisation has a direct influence on emissions per passenger. This has increased by around 20% since 1990 and currently stands at around 80%. Finally, optimisation is also possible on the ground. For example, taxiing movements could potentially be electrified in the future.

In order to realise the potential described in this section, a number of hurdles must be overcome. These mostly involve additional administrative expenses for civil aviation authorities, air navigation service providers and airlines. International cooperation between these parties has proved to be particularly challenging in this regard. Airspace is highly fragmented, especially in Europe. In addition, the robustness of the system must be maintained in the event of any changes, and the high level of safety performance must not be compromised. Some of the incentives hitherto have been misguided, penalising rather than rewarding efficiency gains. Examples include conditions for holding slots at airports and fee systems that encourage aircraft to make detours and so increase CO_2 emissions. There are a number of initiatives aimed at improving these framework conditions. In particular, Switzerland is participating in the Single European Sky initiative, which aims to optimise airspace and its management. However, the hoped-for improvements have so far only materialised to a limited extent.

Reports assume a total increase in operational efficiency of 6–11% by 2050 compared with today (see Figure 1). ICAO anticipates a total investment requirement of around USD 180 billion by 2050, which will primarily be borne by the airlines (ICAO 2022a).[14] However, this will be offset by total savings of USD 490 billion by 2050 as a result of lower fuel consumption.

[12] https://www.sccer-mobility.ch/export/sites/sccer-mobility/capacity-areas/dwn_capacity_areas/Jemiolo_Thesis_Final.pdf (accessed 12 January 2024)

[13] An overview of innovative technologies that may increase efficiency can be found in the IATA Technology Net Zero Roadmap 2050, available at https://www.iata.org > Programs & Policy > Sustainability > Net Zero Roadmaps (accessed 12 January 2024), and in Appendix M3 to the ICAO report on the net-zero CO_2 goal (ICAO 2022a).

[14] For an overview of measures that can be implemented in the short term, see the 2021 document by Aerosuisse, available (in German) at https://www.aerosuisse.ch/fileadmin/documents/Klima/20210319_AG_Aerosuisse_CO2_Massnahmen_Luftverkehr_Version2_final.pdf (accessed 12 January 2024), and Appendix M4 to the ICAO report on the net-zero CO_2 goal (ICAO 2022a).

2.3 Sustainable aviation fuels

Sustainable aviation fuels have the potential to significantly reduce fossil CO_2 emissions from aviation. They may not be produced from fossil resources, but only from renewable sources, and must meet specific sustainability criteria[15] (FOCA 2022). Only then are they classed as sustainable aviation fuels (SAFs). In principle, SAFs do not cause any fossil CO_2 emissions during flights. However, there are some emissions associated with their production. Currently, these amount to around 20% of the life-cycle emissions of fossil kerosene (jet fuel). This could be reduced to below 10%, at best, in the future (FOCA 2022). However, these values cannot be achieved in every case. Sustainability criteria therefore always specify a minimum reduction.

There are already various production pathways for the manufacture of SAFs. Nine of these had been certified by 2021 and more will be added in the coming years (EASA 2022). Some of these pathways utilise biogenic sources, in which case the origin of the biomass used is a key factor in determining the fuels' sustainability. Different countries and organisations apply different criteria here. Switzerland currently regulates these criteria via the Federal Act on the Protection of the Environment (EPA, SR 814.01) and the Mineral Oil Tax Act (MinOTA, SR 641.61). According to the dispatch, they are to be revised as part of the revision of the CO_2 Act, based on the practically equivalent provisions of the EU (see section 3.2). For example, no food or animal feed may be used in the production process.

Sustainable aviation fuels can also be produced without using biomass as an energy source, in which case they are referred to as 'synthetic SAFs'. The energy for their production must come from renewable sources such as hydropower, solar or wind energy. SAFs from biomass are already being produced on an industrial scale, whereas the production of synthetic SAFs is still comparatively modest.

Pure SAFs are usually free from aromatic hydrocarbons (aromatics). Besides carbon-neutral combustion, this has the advantage that the exhaust gases contain significantly fewer harmful combustion residues (especially particulate matter). SAFs can already be used in today's aircraft and with the existing infrastructure at airports. For technical reasons, they currently still have to be mixed with at least 50% fossil kerosene.[16] The aircraft industry has pledged to deliver aircraft able to operate using 100% SAFs by 2030.[17] Aircraft already in use today could also be retrofitted to this end. In terms of safety, SAFs are at least equivalent to fossil kerosene.

Global SAF production in 2023 has been estimated at 480,000 tonnes, double the amount produced in 2022.[18] This corresponds to 0.2% of current aviation fuel consumption and is therefore only a small step towards meeting the targets. Various roadmaps conclude that SAFs are the most promising measure to reduce fossil CO_2 emissions from aviation. Their contribution is expected to account for 50–56% of the net-zero CO_2 target, or even as much as 70% according to some studies (see Figure 1). The challenge here lies in production capacity, which has scarcely been realised to date. Even the currently planned production capacity will still be insufficient to realise this potential in time.[19] In order to build up such capacity, considerable investments will need to be made quickly at a global scale and renewable energy generation significantly expanded at suitable locations. Furthermore, this expansion will be competing with the demand for renewable energy in other sectors. As SAFs are more expensive to produce than fossil fuels, their final selling prices are correspondingly higher. ICAO expects that USD 3,110 billion will need to be invested in SAF production globally by 2050 (ICAO 2022a).

Further information on SAFs can be found in the FOCA's report on fostering the development and uptake of sustainable aviation fuels (FOCA 2022). This shows, in particular, that Switzerland does not have sufficient resources and renewable energy to meet its SAF requirements cost-effectively through domestic production. Production in more suitable areas abroad would be economically and environmentally more advantageous.

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[15] In the revision of the CO_2 Act (see section 3.2), aviation fuels from renewable sources are referred to as 'renewable aviation fuels' for short.

[16] This is due to individual materials in the aircraft that still require a minimum proportion of aromatics in the fuel, see https://www.icao.int/environmental-protection/GFAAF/Pages/Conversion-processes.aspx (accessed 12 January 2024).

[17] https://iccaia.org/wp-content/uploads/2023/09/Public-Statement-100-SAF-Commitment-Final.pdf (accessed 12 January 2024)

[18] https://www.iata.org/en/pressroom/2023-releases/2023-12-06-02/ (accessed 12 January 2024)

[19] https://www.icao.int/environmental-protection/Pages/SAF-Projections.aspx (accessed 12 January 2024)

2.4 Hydrogen-powered and electric aircraft

CO_2 emissions in flight can be avoided if no carbon-containing fuels are used. Either hydrogen or electric batteries can therefore be considered as alternative energy storage systems. Hydrogen or battery-powered operation requires a modified aircraft design, with the kerosene tank replaced by hydrogen tanks or batteries, and the engines either adapted or replaced by electric motors. Battery-powered aircraft use electric motors, while hydrogen-powered aircraft require either fuel cells for converting hydrogen into electricity and electric motors, or an internal combustion engine adapted to run on hydrogen. Both types of propulsion entail greater technical risks than conventional aircraft. The biggest challenge, however, is the additional volume and weight of hydrogen tanks and batteries (ICAO 2022a).

There is already a small battery-powered aircraft type that is certified for operation, and further hydrogen and electric aircraft are being developed by various manufacturers (EASA 2022). However, none of the prototypes can compete with conventionally powered aircraft in terms of range, payload and speed. Table 2 shows the findings of a study concerning the aircraft categories for which the use of hydrogen and electric aircraft is conceivable and from what point in time (ATAG 2020). For long- and medium-haul flights, which together account for 73% of CO_2 emissions, this suggests that no alternatives to propulsion with gas turbines and kerosene-like fuels or SAFs will be available by 2050.

Category	Year						
	2020	2025	2030	2035	2040	2045	2050
Commuter up to 15 seats and 1 hr flight time <1% of CO_2 emissions	SAF (→ 2050)						
		Electric aircraft (→ 2050)					
Regional up to 100 seats and 1.5 hrs flight time ~3% of CO_2 emissions	SAF (→ 2050)						
			H2/electric aircraft (→ 2050)				
Short haul up to 150 seats and 2 hrs flight time ~24% of CO_2 emissions	SAF (→ 2050)						
				H_2 (potentially)	H_2 aircraft (→ 2050)		
Medium haul up to 250 seats and 2.5 hrs flight time ~43% of CO_2 emissions	SAF (→ 2050)						
							H_2 (potentially)
Long haul 250+ seats and 2.5 hrs flight time ~30% of CO_2 emissions	SAF (→ 2050)						

Table 2 Overview of the potential use of hydrogen (H_2) and electric aircraft by category and year (adapted from ATAG 2020).

The use of alternative energy storage systems would also require the existing infrastructure at each airport served to be significantly adapted. Electric aircraft require high-performance charging stations and hydrogen aircraft a local supply of hydrogen (ATAG 2020). The necessary adjustments to infrastructure and energy supply entail additional CO_2 emissions and costs. In order to actually reduce emissions, renewable sources would need to be used for hydrogen and electricity production. Taking this aspect into account, even hydrogen and electric aircraft and their use can never be completely carbon neutral over their life cycle.

In view of these challenges, it is unlikely that alternative energy storage systems will be able to make a major contribution to carbon-neutral flying by 2050. Studies generally assume a contribution to emission reductions of 0 to a maximum of 3% (see Figure 1). Some studies assume higher values (NLR 2021), but these are not reliable due to the low maturity level of the technologies (see Table 2). The costs of deploying alternative energy sources are still highly uncertain, but ICAO estimates the investment required at approximately USD 180 billion (ICAO 2022a). ICAO assumes that the potential of these technologies will be greater after 2050. This leaves more time to develop technical solutions and provide the necessary infrastructure and fleet. The EU's Clean Aviation research programme, for example, aims to explore and implement the potential of all sustainable energy sources in aviation.[20]

2.5 Overall potential of technical aviation measures

The foregoing sections have shown the potential of technical measures in the aviation sector to reduce its GHG emissions. These measures can and must be combined if carbon-neutral flying is to be achieved. Figure 1 illustrates the potential of these technical measures. As demand for air transport in 2050 is still uncertain (see sections 2.7 and 3.3), the chosen presentation is independent of the trend in demand. The potential reduction in the carbon intensity of aviation, i.e. emissions per transport performance unit, relative to the 2019 baseline is shown. Currently, it can be assumed that a 77% reduction in fossil CO_2 emissions is possible by 2050 by means of technical measures in aviation. Increased energy efficiency of aircraft and flight operations account for 22%. However, the bulk of the reduction, 55%, comes from sustainable aviation fuels.[21]

This means that carbon-neutral flying by 2050 cannot be achieved by technical measures in aviation alone. The complete replacement of fossil aviation fuels will definitely take longer than this. At least 10% of fossil CO_2 emissions must be offset by NETs (see section 2.6). As regards the remaining 13%, the referenced studies are at variance. Depending on the study, the emissions in this uncertainty range could either be reduced by technical aviation measures or would need to be offset by additional NETs. The decisive factor here will be developments in the coming years, in particular the economic viability of the various measures.

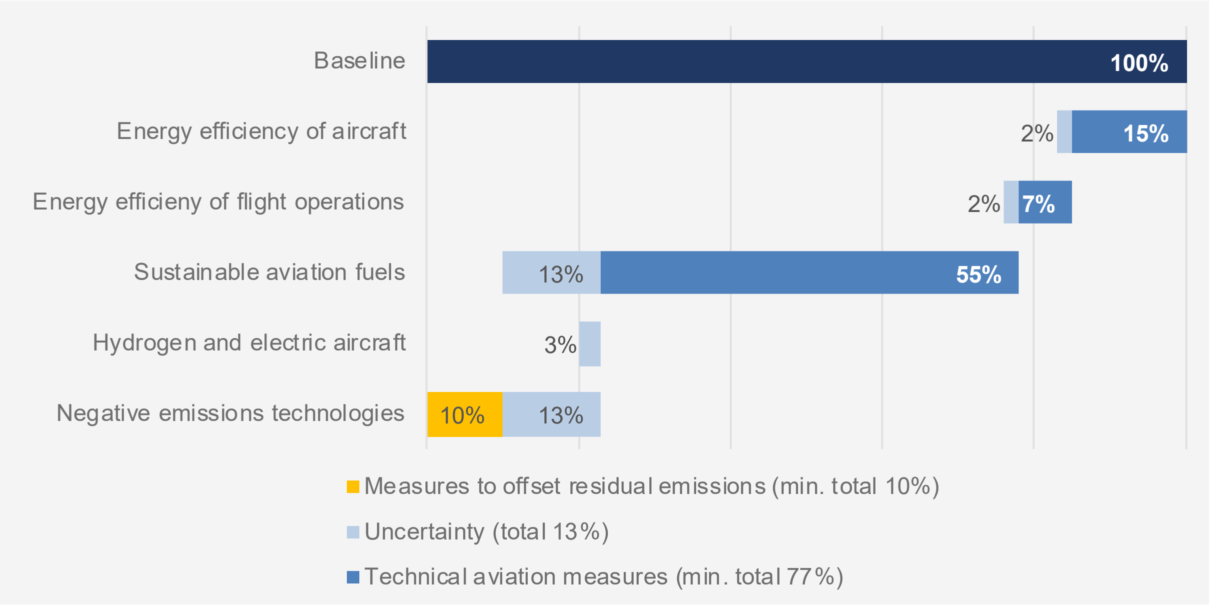

Figure 1 Possible contributions to carbon-neutral flying by 2050, in relation to transport performance,[22] compared with 2019

Carbon-neutral flying could therefore be achieved by 2050 using all the available aviation technical measures combined with NETs. In order to realise the potential shown, four key challenges must be overcome:

1. **Energy and resource requirements**

Swiss aviation accounts for around 10% of final energy consumption in Switzerland. In view of the climate targets for all sectors, providing this amount of energy from renewable sources represents a major

[20] https://clean-aviation.eu/sites/default/files/2022-01/CAJU-GB-2021-12-16-SRIA_en.pdf (accessed 12 January 2024)

[21] Efficiency-enhancing measures already reduce fuel consumption and thus CO_2 emissions by at least 22%. An SAF share of 70% (based on the planned blending obligation, see section 3.3) would reduce the remaining emissions by 70%, which corresponds to 55% of total emissions.

[22] Data collated from ICAO (2022a), ATAG (2020), NLR (2021), Eurocontrol (2022) and Ecoplan (2021)

challenge. The bulk of the energy required by Swiss aviation is, and will continue to be, met by imports (see section 2.3). The high demand for energy means a correspondingly large need for resources.

2. Ambitious time frame

Technologies take time to become established in the aviation industry. Prior to initial deployment, new technologies must first undergo extensive certification processes to prove that they meet the stringent safety requirements stipulated by law. As aircraft are in use for several decades, it also takes decades for new technologies to fully penetrate the market. The same applies to the necessary infrastructure and, in particular, the production of fuels. If carbon-neutral flying by 2050 is to be achieved, the required technologies must be scaled up quickly. This applies to technical aviation measures as well as to NETs (see section 2.6).

3. Overall environmental and economic impact

The central goal of Swiss climate policy in the area of aviation is to achieve net-zero GHG emissions, measured in terms of direct emissions from aviation fuels used in Switzerland. When it comes to implementing measures, however, reducing CO_2 emissions in flight is not the only consideration. All measures result in further impacts on the climate. These include, for example, upstream GHG emissions from the production of all fuels. As such fuels are mainly produced abroad, most of these emissions do not fall within Swiss climate targets. This makes the criteria for SAF authorisation all the more important (see section 2.3). Non-CO_2 effects (see box below) and other environmental impacts also need to be considered.

According to Article 3 paragraph 4 CIA, reduction targets (or measures to achieve them) must be economically viable. Accordingly, economic and social effects must be taken into account.

4. Investment requirements

Scaling up the required technologies in a timely manner will entail a high level of investment. Overall, ICAO anticipates an annual investment requirement of around USD 120 billion worldwide between 2020 and 2050 (ICAO 2022a).[23] Based on its share of air traffic, this would mean around CHF 600 million for Switzerland. By way of comparison, the annual global turnover of commercial airlines is USD 838 billion.[24] It should be noted that the overall costs incurred, particularly in operations, will also be offset by cost reductions, for example through reduced fuel consumption as a result of increased efficiency.

If the sector continues to grow rapidly, these challenges will be particularly pronounced (ICAO 2022a). Lower growth would favour achievement of the target, as it would result in lower demand for energy and resources (ICAO 2022a, IEA 2021, IEA 2023, Sacchi 2023). The technologies involved would have to be scaled up less quickly, the impact on the environment and economy would be smaller and the investment requirements would be lower. Sections 2.7 and 3.3 discuss the development of demand and ways of influencing it.

Influencing non-CO_2 effects

The overall impact of non-CO_2 effects on the climate cannot yet be precisely determined (see box in section 1.3). It is also highly uncertain how measures will change non-CO_2 effects. In principle, a reduction in CO_2 emissions should also lead to a reduction in non-CO_2 emissions. These include measures for more efficient aircraft or more efficient aircraft operations. Certain measures are also expected to have an additional effect: SAFs emit significantly less particulate matter on average, meaning an improvement in local air quality and a potential reduction in non-CO_2 climate impacts (EASA 2022). Thanks to their additional impact on the climate, these measures are therefore even more effective than if CO_2 alone is considered.

Conversely, other measures, while reducing non-CO_2 effects, could potentially increase CO_2 emissions. In the case of modifications to engines, for example, there is a trade-off between emissions of CO_2 and

[23] ICAO's report on the feasibility of a net-zero CO_2 goal includes a detailed breakdown of the cost items by stakeholder (ICAO 2022a).

[24] As at 2019; available at https://www.iata.org/en/iata-repository/publications/economic-reports/airline-industry-economic-performance-june-2020-data-tables/ (accessed 12 January 2024)

nitrogen oxides (NOx). Flying around zones that are critical to cloud formation usually leads to an increase in CO_2 emissions. Battery-powered flying may entirely eliminate non-CO_2 effects in flight, but indirectly generate more CO_2 emissions (see section 2.4). The non-CO_2 effects of hydrogen-powered aircraft are still uncertain. Measures entailing such conflicting objectives should only be undertaken once there is a reliable understanding of the trade-offs involved (Lee 2023). Work on this is currently under way, for example in the EU, which aims to include non-CO_2 effects separately from CO_2 emissions in its emissions trading system (see section 3.2).

2.6 Negative emissions technologies

Article 3 paragraph 1 CIA states that, in order to achieve the net-zero target, the impact of the remaining GHG emissions must be offset by the use of NETs in Switzerland and abroad. However, reducing GHG emissions takes priority under Article 3 paragraph 1 letter a CIA. NETs should only be used where emissions are unavoidable or difficult to avoid (Federal Council 2022). Article 2 letter a CIA defines NETs as "biological and technical processes for removing CO_2 from the atmosphere and permanently sequestering it in forests, soils, wood products or other carbon stores". The Federal Council report 'Carbon capture and storage (CCS) and negative emission technologies (NETs). How they can gradually contribute to the long-term climate target' identifies the requirement for NETs in various sectors (Federal Council 2022). It does not analyse the requirement in aviation. With the expected developments as shown in Figure 1 and the development of demand as set out in the box in section 2.7, this would result in an annual requirement of approximately 1–2 million tonnes. The Federal Council report on postulate 18.4211 contains an overview of the technologies currently available (Federal Council 2020).

The report makes the following statements on the potential of NETs: "Many fundamental questions regarding the implementation of NETs, such as costs, environmental impacts and conflicting objectives, have been insufficiently clarified at both national and international level. Accordingly, it is almost impossible to make reliable statements about the *sustainably realisable* potential of individual NETs in Switzerland. Furthermore, all the processes discussed have either not yet been tested in practice or are not ready for use to the extent required to achieve the climate targets. In order to counter these knowledge deficits, research and development activities on NETs would have to be massively ramped up" (Federal Council 2020). It is already clear that the overall potential for NETs is limited both in Switzerland and abroad. Deploying NETs requires energy, resources and investment. Cost estimates for different technologies vary widely and are highly uncertain (Federal Council 2020).

The difference between the now standard practice of offsetting CO_2 emissions and NETs is key. Offsetting emissions involves trading in certified emission reductions. The reduction is compared with the initial state and credited accordingly. Unlike with NETs, it is not usually a question of negative emissions. In the context of net-zero targets for all sectors, such traditional offsetting is unlikely to remain available to any great extent by 2050.

2.7 Market-based measures

Environmental market-based measures have been developed to achieve environmental goals at the lowest possible cost and with a high degree of flexibility. In principle, they provide market-based incentives for aircraft operators to reduce emissions. A number of market-based measures relating to CO_2 emissions are in force in the Swiss aviation sector. Under Article 16*a* of the Federal Act on the Reduction of CO_2 Emissions (CO_2 Act, SR 641.71), aircraft operators have been obliged to participate in Switzerland's emissions trading system (ETS) since 2020. The ETS provides for a cap on emissions from domestic flights and from international flights from Switzerland to the European Economic Area and the United Kingdom. In the opposite direction, the respective flights are covered by the EU and UK emissions trading systems. In 2023, this cap was around 1.2 million tonnes of CO_2. It has been reduced by 2.2% each year since 2021. Aircraft operators must purchase emission allowances for their CO_2 emissions on the included routes. At an average market price of around CHF 90 per tonne of CO_2 in 2023, the market value of these allowances was over CHF 100 million. Of these emission allowances, 82%

are currently freely allocated, 15% are auctioned and 3% are assigned to a reserve. The Swiss ETS is linked to the EU ETS by a linking agreement,[25] with both parties also agreeing to develop their ETS in line with that of the other party. In the EU ETS, the auctioning revenues from all sectors are earmarked for a specific purpose from 2021 to 2030. They are channelled into a fund that supports innovative technologies for meeting climate targets. A revision of the ETS was adopted in the EU on 10 May 2023. This also has implications for the current design of the Swiss ETS (see section 3.2).

Another market-based system is ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).[26] This is intended to help achieve ICAO's goal of carbon-neutral growth in international aviation from 2020 onwards. From 2027, it requires offsetting of emissions that exceed 85% of 2019 emissions. The proven use of SAFs will (proportionally) reduce the offsetting obligation. Switzerland is already participating in this system on a voluntary basis, meaning that, since 2021, emissions have to be recorded and offset as soon as they exceed the limit value. However, due to the effects of the COVID-19 pandemic and the associated decline in air traffic, the first offsetting is not expected until 2024. The costs are estimated at less than CHF 10 per tonne of CO_2.[27]

Market-based measures can incentivise the reduction of emissions.[28] Per tonne of CO_2, the incentive from CORSIA is significantly smaller than that of the ETS. Market distortions vis-à-vis companies and countries that are not involved are also an obstacle. The linking of the Swiss and EU ETSs avoids market distortion only between Switzerland and surrounding countries. The situation is different beyond the borders of the European Economic Area, with flights from Switzerland to destinations outside the European Economic Area and the United Kingdom not subject to the ETS. CORSIA, on the other hand, is the first market-based measure with a global scope and covers virtually all emissions from international civil aviation. No significant market distortion is to be expected here. This effect is also small in the case of national instruments that do not affect international flights (see section 3.1).

Development of demand

The complex dependence on social and economic developments makes it difficult to produce reliable forecasts concerning demand for air travel up to 2050. After the COVID-19 pandemic, existing forecasts of demand for air transport were mostly revised downwards, at least after reaching 2019 levels. ICAO assumes annual growth of 2.3% to 3.1% for passenger traffic in Europe (around 10% less than before COVID-19)[29] while EASA predicts annual growth for Europe of -0.3% to 1.7%, some 40% less than before COVID-19 (EASA 2019, EASA 2022). The forecasts are therefore well below the annual growth in Swiss air traffic of 8.5% between 1990 and 2019. Capacity at Swiss airports is already limited due to operating times (general ban on night flights) and restrictions in operating regulations. In the long term, the limited infrastructure also restricts growth potential. There are therefore major obstacles to any further increase in capacity.

A reduction in demand for air transport could be achieved, for example, by shifting certain flights to rail. However, this only applies to intra-European flights of less than 1,000 km. These flights account for 14% of CO_2 emissions from aviation in Europe (T&E 2020). One study concludes that the potential for reducing emissions from air traffic from Europe by shifting it to rail is relatively low, at a maximum of around 3% (T&E 2020, Eurocontrol 2021). For many destinations in this distance class, no competitive rail connections exist (FOT 2023). Developing these would require an expansion of infrastructure, primarily abroad (FOT 2023).

[25] Agreement of 23 November 2017 between the Swiss Confederation and the European Union on the linking of their greenhouse gas emissions trading systems (SR 0.814.011.268)

[26] https://www.bazl.admin.ch/bazl/en/home/themen/umwelt/klima/oekonomische-massnahmen/corsia.html (accessed 12 January 2024)

[27] https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Newsletter_Nov_2021.pdf (accessed 12 January 2024)

[28] As market-based measures do not directly reduce emissions per transport performance unit, their contribution does not appear in Figure 1.

[29] https://www.icao.int/sustainability/Documents/Post-COVID-19%20forecasts%20scenarios%20tables.pdf (accessed 12 January 2024)

3 Implementation concept for Switzerland

3.1 Existing instruments

A number of market-based measures relating to aviation are already in force in Switzerland, including the ETS and CORSIA (see section 2.7). CORSIA applies to international aviation, the ETS to domestic and some international aviation.

For aviation within Switzerland, the mineral oil tax is an instrument with implications for the climate impact of air transport in Switzerland. Under Article 12 MinOTA, per 1,000 litres of aviation fuel a mineral oil tax (currently CHF 439.50) is levied, with a mineral oil surtax of CHF 300. In accordance with Article 37*a* of the Federal Act on the Use of the Earmarked Mineral Oil Tax and Other Funds Earmarked for Road and Air Transport (MinOA), part of this revenue is used for safety and environmental measures in aviation. This is known as 'special aviation financing'. The MinOTA therefore has multiple, albeit minor, beneficial impacts on the climate: firstly, the tax incentivises a reduction in fuel consumption on domestic flights, and secondly, the special aviation financing can be used to promote climate measures. In addition, aircraft operators can apply for tax relief if they use SAFs on domestic flights. The fuel used must meet the criteria set out in Article 12*b* and *c* MinOTA. The tax relief is currently limited to the end of 2024, but according to the first parliamentary reading of the CO_2 Act for the period after 2024, it is to be extended until the end of 2030.

For domestic flights, there is also a compensation (offsetting) obligation for fuel importers under Article 26 of the CO_2 Act. This means that a certain proportion of CO_2 emissions from transport must be compensated by attestations, the costs of which must not exceed five centimes per litre of fuel. The implementing provisions are contained in Articles 86 to 92 of the Ordinance on the Reduction of Carbon Emissions (CO_2 Ordinance, SR 641.711).

3.2 International context

In 2021, the European Commission presented the 'Fit for 55' package. This contains measures for meeting the EU's climate target of reducing CO_2 emissions by 55% by 2030 compared with 1990 levels. Some of these measures have a direct impact on Switzerland. It has already been decided to make the ETS more stringent,[30] with the cap on permissible CO_2 emissions set to be reduced further, namely by 4.3% per year from 2024 and by 4.4% from 2028. The free allocation of emission allowances will be scaled back, and stopped altogether from 2026. At the start of 2024, the outermost regions of the EU were brought within the scope of the EU ETS. In addition, from 2024 to 2030, a total of 20 million emission allowances (with an estimated equivalent value of almost EUR 2 billion in 2023) will be used to incentivise the uptake of SAFs by reducing the price differential compared with kerosene. There are also plans to include non-CO_2 effects in the EU ETS from 2028. The foundations for this are to be developed in the coming years. The European Commission envisages levying a tax on aviation fuels, including for international aviation within the EU, through an amendment to the Energy Taxation Directive, another measure of the Fit for 55 package.[31] Member states would also be able to tax aviation fuels for flights outside the EU. The consultations on this are still ongoing and it remains uncertain whether the amendment will be adopted and, if so, when it will come into force.

The most significant piece of Fit for 55 legislation as regards the climate impact of aviation is the ReFuelEU Aviation Regulation.[32] This regulation introduces an obligation to add SAFs to kerosene ('blending obligation'). This will begin with a mandatory blending of 2% SAFs from 2025, rising to 70% by 2050. In order to promote early uptake of synthetic SAFs, a sub-quota for these fuels will be introduced from

[30] 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. 134

[31] Proposal for a Council Directive of 14 July 2021 restructuring the Union framework for the taxation of energy products and electricity (recast)

[32] 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), OJ L, 2023/2405, 31.10.2023, ELI: http://data.europa.eu/eli/reg/2023/2405/oj

2030. The use of hydrogen can also be counted towards these targets. The ReFuelEU Aviation Regulation also includes a restriction on tankering, i.e. the carrying of excess fuel, so that the blending obligation cannot be circumvented on return flights to destinations outside the EU. Similar regulations are under development or already in force in a number of countries worldwide.[33]

3.3 Instruments planned by 2030

The existing measures provide initial incentives to increase the efficiency of aviation and result in the offsetting and reduction of part of its fossil CO_2 emissions. However, in view of the challenges (see section 2.5), other measures will be needed in the near future to enable carbon-neutral flying by 2050. The ambitious time frame requires the rapid creation of framework conditions for SAF market ramp-up. By joining the EU's harmonised blending obligation, Switzerland intends to help achieve this. In addition, the Federal Council plans to subsidise the development and uptake of innovative technologies to reduce the climate impact of aviation. The further development of internationally supported market-based measures should also contribute to making carbon-neutral flying a reality. For example, Switzerland will mirror the adjustments to the EU ETS in its own ETS, based on the linking of the two systems. With the free allocation of emission allowances set to disappear from 2026, the overhauled ETS will create a greater incentive to enhance the efficiency of aircraft and operations, but will also increase costs for aircraft operators.

The Federal Council proposed an SAF blending obligation for Switzerland in the dispatch on the revision of the CO_2 Act in September 2021. The latter contains the principle that the blending obligation should be based on the relevant EU regulations, thereby avoiding market distortion. Since the publication of this dispatch, implementation in the EU has been fleshed out, and the legislation adopted by the European Parliament. The provisions of the ReFuelEU Aviation Regulation and the Swiss CO_2 Act essentially correspond. The Federal Administration therefore proposed adopting this regulation as part of the air transport agreement between Switzerland and the EU,[34] as this approach would be more favourable for Switzerland than implementing it itself via the CO_2 Act. In particular, it would significantly simplify enforcement and directly prevent distortions of competition. EU experts have signalled to Switzerland that the EU would welcome adoption of the regulation as part of the air transport agreement. The National Council has endorsed this approach and the Council of States is scheduled to discuss it in the 2024 spring session. The quotas specified in the ReFuelEU Aviation Regulation will make it possible to reduce fossil CO_2 emissions by up to 70% by 2050, with the overall impact on the environment being taken into account through stringent sustainability criteria.

The Federal Council wants to make additional funds available to encourage the market ramp-up of SAFs and other technologies for achieving carbon-neutral flying. The dispatch on the revision of the CO_2 Act therefore includes funding of CHF 150 million by 2030. Similarly, the Council of States introduced earmarking for the Swiss ETS in the revision of the CO_2 Act. This means that auctioning revenues should generally be used to promote measures in the same sector. In addition, the Federal Council may provide for a mechanism similar to the EU ETS with compensation for the uplift of SAF. Finally, if the EU blending obligation is adopted, any funds from sanctions should also go towards market ramp-up. These new resources must be implemented in a coordinated way, by means of an instrument. The focus here is on providing the most effective support possible for measures that are already close to market maturity. These include innovative Swiss technologies that could enhance environmental and economic impacts. A promotion strategy, including a roadmap for scaling up the necessary optimisations in technology and flight operations, is currently being developed under the leadership of the FOCA, with the aim of ensuring that the measures can have a targeted impact as soon as possible after they take effect. The FOCA, ICAO and European Civil Aviation Conference (ECAC) reports on this topic provide the basis for effective promotion of the SAF market ramp-up (FOCA 2022, ICAO 2022a, ECAC 2023).

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33 For an overview, see https://www.icao.int/environmental-protection/GFAAF/Pages/Policies.aspx (accessed 12 January 2024).

34 Agreement between the Swiss Confederation and the European Community on Air Transport of 21 June 1999 (SR 0.748.127.192.68)

Influencing demand

In recent years, a number of parliamentary procedural requests have called for the scrapping of the exemption from mineral oil tax on aviation fuels used for international aviation in order to reduce the demand for air transport.[35] However, Switzerland has little legal room for manoeuvre here: the tax exemption for aviation fuels used for international aviation is established worldwide. Specifically, Switzerland's bilateral air transport agreements contain this provision, in line with EU recommendations based on the Chicago Convention. Changing this practice unilaterally is therefore not possible; this would have to be done internationally. The Federal Council stated the following in its opinion on the motion submitted by Nadine Masshardt (20.3523 'Amend the 1944 Chicago Convention and tax air transport at last'): "If there is room for manoeuvre internationally on the issue of general taxation of aviation fuels in global transport, the Federal Council will support efforts to this end" (see section 3.2).

One way of influencing demand would be to levy taxes on flight tickets. Switzerland's neighbouring countries impose modest taxes on air passengers, averaging EUR 5–20 for international flights (European Commission 2019). However, the impact of a national tax instrument for international aviation would be questionable: a Swiss regime with significantly higher taxes than at airports in neighbouring countries would automatically lead to a distortion of competition. Avoidance through rerouting would be likely, entailing an increase in CO_2 emissions and thus calling into question the effectiveness of high taxes. Low taxes, on the other hand, have virtually no appreciable impact on demand due to low price elasticity (Ecoplan 2021).

In its dispatch on the revised CO_2 Act, the Federal Council does not, in principle, envisage any new or higher taxes or levies. Since the popular vote on the latest revision of the CO_2 Act, Parliament has also rejected all procedural requests for additional taxes or levies on air traffic. The Confederation thus maintains the distinction between national and international instruments. National measures, specifically the compensation obligation and the mineral oil tax, apply only to aviation within Switzerland. Here, a direct impact can be achieved and there is no risk of market distortion. The instruments for international aviation, specifically CORSIA and the ETS, are internationally harmonised. The Confederation is actively involved in further developing and, in the case of the ETS, substantially strengthening these instruments (see section 3.2).

3.4 Looking ahead to 2050

Article 12 paragraph 1 CIA states that federal enactments in various areas, including aviation, should be designed and applied in such a way that they contribute to the achievement of climate targets. Section 3.3 shows the need for this. Over 70% of fossil CO_2 emissions from aviation can be reduced by 2050 by means of the existing and planned instruments. To this end, these instruments must be retained and further developed, in particular the blending obligation coupled with targeted promotion, the ETS (in line with the EU) and CORSIA.

Even with the planned legislative changes, there are still insufficient incentives to reduce the remaining emissions. This need can be met by further developing existing instruments (blending obligation, ETS, CORSIA) or with new instruments. However, the effectiveness of the planned measures and instruments must first be confirmed. This can be done within the time frame of the CO_2 Act revision for the period after 2030. Were the relevant decisions to be adopted any later, it would either jeopardise the timely achievement of the net-zero CO_2 emissions target or entail economically unacceptable consequences. This applies particularly to NETs. In this area, the Federal Council envisages targeted scaling-up from 2031 onwards (Federal Council 2022). Clear framework conditions must be created for this, with financing based as much as possible on the polluter pays principle and coordination between all sectors with

[35] Interpellation 19.3508 by Ursula Schneider Schüttel 'The exemption of kerosene from the mineral oil tax is outdated. Amend the Chicago Convention', motion 20.3383 by the Green Group 'The Federal Council must advocate internationally for the introduction of a kerosene tax', motion 20.3523 by Nadine Masshardt 'Amend the 1944 Chicago Convention and tax air transport at last'.

corresponding needs. The Federal Council will examine specific proposals on this by the end of 2024 (Federal Council 2022).

With all instruments, a holistic view must be taken of all the economic and environmental impacts, including upstream emissions and non-CO_2 effects. The international nature of aviation must also be considered, including the economic and environmental consequences of market distortions caused by national instruments. This necessitates a clear focus on international coordination. Developments in the EU post-2030 must be taken into account, and developments in ICAO monitored and influenced. There are some major decisions around the corner, with the implementation of ICAO's goal of net-zero CO_2 emissions and a possible extension of or successor to the CORSIA scheme, which is scheduled to end in 2035. The Confederation can play an active role here, thereby generating impact beyond Switzerland. The same applies to the Swiss aviation industry, which could send out a clear signal beyond Switzerland that there is a demand for more efficient technologies.

4 Carbon-neutral flying in the DDPS

4.1 Background

The Swiss Air Force consumes around 2% of all kerosene uplifted in Switzerland. It accounts for around 0.3% of the CO_2 emissions from all fuels used for energy in Switzerland. In 2022, the aviation fuel uplifted by the Swiss Air Force caused around half of the approximately 200,000 tonnes of CO_{2eq} currently reported annually by the Federal Department of Defence, Civil Protection and Sport (DDPS). A 2019 Federal Council decree tasks the DDPS with reducing its CO_2 emissions by at least 40% by 2030 compared with 2001 levels.

In 2021, the DDPS enacted the Energy and Climate Action Plan.[36] In addition to the 2030 reduction target, this includes other objectives such as increasing self-sufficiency through the use of renewable energy sources and developing energy storage options. Innovative solutions on fuels and propulsion systems are also to be promoted in the years ahead.

Following the adoption of the CIA on 18 June 2023, the central Federal Administration must reduce its GHG emissions to at least net zero by 2040. The statutory CO_2 reduction target applicable from 1 January 2025 is therefore more stringent than the DDPS's vision of net-zero GHG emissions in 2050, as currently stipulated in the Energy and Climate Action Plan. According to Article 10 paragraph 3 CIA, the Federal Council may "provide for exemptions in connection with national security and the protection of the population". The implementing provisions for the CIA are still being finalised.

4.2 CO_2 reduction measures for military aviation

In principle, the Swiss Air Force has the same technical measures at its disposal as civil aviation to achieve carbon-neutral flying: more efficient aircraft, more efficient flight operations including training, the use of SAFs, the deployment of hydrogen and electric aircraft and the adoption of NETs.

Replacing old aircraft with new, more efficient models is one possible way to reduce CO_2 emissions. The service life of Air Force aircraft is often longer than those used in civil aviation, meaning that the Air Force may benefit less quickly than civil aviation from technological innovations and more efficient aircraft. The requirements of the new DDPS procurement strategy of 1 February 2023 will be implemented for the procurement of new aircraft (DDPS 2023). This strategy stipulates that economic, environmental and social aspects must be taken into account throughout the entire life cycle and the entire procurement process, and that procurement procedures must be open to innovative solutions.

The Air Force's CO_2 emissions can be kept low by minimising flight hours. To this end, simulators are already being used in flight training where possible. Furthermore, the aircraft movements and flying

[36] https://www.vbs.admin.ch/de/aktionsplan-energie-klima (accessed 12 January 2024)

hours required depend on the fleet. For example, the new F-35A fleet will have a lower flight hour requirement and around 25% lower annual kerosene consumption than the current fighter aircraft fleet.

As with civil aviation, SAFs are also certified for military aviation, up to a maximum admixture of 50%. They are already being used in the military sector by several countries, including Switzerland. It is assumed that manufacturers of military aircraft systems will allow the use of 100% SAFs in the longer term.

The use of hydrogen and electric aircraft in the military sector is challenging for various reasons. Aircraft using these propulsion technologies cannot achieve the performance levels or perform the range of tasks required of fighter aircraft. There may be some potential for use in training or as unmanned aerial vehicles (drones). Overall, it is unlikely that these types of propulsion will be able to make a significant contribution to carbon-neutral military flight operations in the near future.

DDPS climate protection measures must be designed in such a way that fulfilment of the Armed Forces' mission is not compromised. Accordingly, implementation of the CIA is likely to entail offsetting some of the DDPS's climate impacts by means of NETs.

4.3 Measures up to 2030

The DDPS Energy and Climate Action Plan commits the Air Force to making a substantial contribution to reducing the DDPS's fossil CO_2 emissions by 2030. SAF uptake and fleet replacement, in particular the gradual roll-out of the F-35A fleet, will contribute to this goal. The Air Force's current aircraft fleet is expected to be fully replaced by 2040. Improving processes on the ground and in the air should also help to reduce fuel consumption.

In 2023, the Defence Group began blending SAFs with fossil kerosene. From 2023 to 2027, approximately 700 tonnes of SAFs (premixed with fossil fuel) are to be procured annually, which equates to around 2% of the Air Force's kerosene consumption. From 2027, the plan is to increase the share of SAFs to around 10% by 2030, i.e. around 4,000 tonnes per year.

In the period 2020–30, the remaining GHG emissions will be fully offset by attestations, in accordance with the Federal Council decree on the climate package.

4.4 Looking ahead to 2050

The Swiss Air Force will need to take measures beyond 2030 in order to comply with the requirements of the CIA, and thus also support the goal of carbon-neutral flying by 2050. Fleet replacement is also expected to generate efficiency gains in the future. The main measure to reduce fossil CO_2 emissions is likely to be the use of sustainable fuels. Any remaining emissions will have to be offset with NETs. The specific potential of the individual measures to reduce fossil CO_2 emissions between 2030 and 2050 cannot yet be quantified, as it depends on the development of various technologies. The pending certification of military aviation systems for the use of 100% SAFs is particularly crucial.

4.5 Cost implications

When it comes to reducing the DDPS's fossil CO_2 emissions, the challenges lie not only in the availability but also in the financing of technology. SAFs are currently difficult to obtain and they are expensive. The blending of 2% SAFs from 2023 to 2027 is expected to result in additional annual costs of between CHF 1.1 million and CHF 2.2 million. Approximately 10% SAF blending from 2030 will entail additional costs of CHF 5 million to CHF 10 million. With the introduction of the ReFuelEU Aviation Regulation, the situation regarding availability and price will become more unpredictable. The use of SAFs is likely to substantially increase the financial resources required by the Air Force by 2050.

5 Conclusion

The aviation sector can largely avoid fossil CO_2 emissions, and so also reduce its external costs, by 2050 by using innovative technologies. The most important measure for achieving this is sustainable fuel. However, it will take longer than 2050 to completely replace fossil fuels, meaning that it will not be possible to avoid a certain proportion of fossil CO_2 emissions by that time, likely between 10% and a maximum of 23%. NETs will therefore be needed to offset these remaining emissions. With a combination of these measures, aviation from Switzerland can achieve carbon neutrality by 2050.

There are several challenging aspects here. Firstly, both SAFs and NETs entail a high demand for raw materials and energy from renewable sources. This means that aviation will be competing with demand from other sectors. Overall, the potential for NETs is limited as things stand. Another challenge is the ambitious time frame. The scaling-up of technologies required for SAF production and the necessary progress on technical and operational measures will have to be achieved quickly at the international level. This will have various environmental and economic impacts, which will need to be minimised. Timely and sufficient financing of measures is also key to enabling carbon-neutral flying.

Several market-based measures are already in force in the Swiss aviation sector, in particular the ETS and CORSIA, which cover international aviation. While these already provide certain incentives to increase efficiency, they are not sufficient by themselves to achieve carbon-neutral flying. The CO_2 Act for the period after 2024 contains (before the resolution of differences procedure in Parliament) enhanced and newly developed instruments that address the greatest challenges. The blending quotas for SAFs are intended to create a binding, long-term framework for the scaling-up of these fuels. This includes the subsidiary and time-limited use of additional subsidies to reduce the investment risk in new technologies. The ETS is also being tightened. With these instruments, the Confederation is paving the way for a reduction of over 70% in fossil CO_2 emissions from aviation.

These measures will enable the aviation sector to partially internalise its external costs, which will make flying correspondingly more expensive. This is expected to have a secondary effect of curbing the rising demand for air transport, which will favour the achievement of climate targets. In this context, international harmonisation of measures will prevent market distortions. To reduce or offset the remaining emissions, provisions to this end must be included in the revision of the CO_2 Act after 2030. Given the international dimension of Swiss aviation, here too attention must be paid to international alignment.

Military aviation has essentially the same measures at its disposal as civil aviation to achieve carbon-neutral flight operations. Owing to the range of applications of military aircraft, SAFs are particularly important for military aviation. Technological advances to reduce GHG emissions from military flight operations may not progress as quickly as in the civilian sector.

Carbon neutrality in aviation is heavily dependent on innovative technologies in all areas. As many of these are still at the research and development stage, their potential and costs are still uncertain. This report should be updated as soon as there is more clarity in this regard. Similarly, the impact of the measures planned today and introduced over the coming years will become apparent, as will the development of other international instruments. By then, the effectiveness of measures to reduce non-CO_2 effects will also be known more precisely, so that they too can be factored in.

Annex: Updated opinion on the Green Group's postulate of 6 May 2020 (20.3384 'Aviation masterplan. New rules for the aviation sector')

The Green Group's postulate of 6 May 2020 (20.3384 'Aviation masterplan. New rules for the aviation sector') called for the development of measures to make aviation compatible with the Paris climate targets. The Federal Council requested that the postulate be rejected. In its opinion, it referred to the existing measures and the revision of the CO_2 Act. The postulate was withdrawn on 9 May 2022, with the proviso that the Federal Council address the eight central considerations of postulate 20.3384 in the report on the postulate of the National Council Environment, Spatial Planning and Energy Committee (21.3973 'Carbon-neutral flying by 2050'). This section fulfils that requirement in summary form with regard to developments since submission.

Involvement of airlines and airport operators in meeting the Paris climate targets based on target agreements

With the entry into force of the CIA, there is a legal obligation for all companies to achieve net-zero GHG emissions by 2050 in accordance with Article 5. This also applies to Swiss airlines and airport operators. The Federal Council therefore considers that this concern has been met.

Requirements for the promotion and use of synthetic fuels and more efficient aircraft, especially in the case of fleet renewal

Requirements for the use of sustainable fuels, and in particular sustainable synthetic fuels, are already in progress with the blending obligation. Technological advances and the high proportion of fuel costs within airlines' operating expenses mean that there is ongoing modernisation of the aircraft fleet operating in Switzerland and thus the deployment of more efficient aircraft.

A proactive role in international negotiations on the introduction of a CO_2 tax on kerosene and the integration of aviation into a future climate agreement

In the international aviation sector, the introduction of a tax on aviation fuels is currently unlikely as there is no support for such a move among a majority of countries. This is examined in more detail in sections 2.7, 3.1 and 3.2. As a member of the Friends of Fossil Fuel Subsidy Reform, Switzerland is committed to the elimination of fossil fuel subsidies within the framework of the UNFCCC. If there is room for manoeuvre internationally on the issue of general taxation of aviation fuels in global transport, the Federal Council will examine the relevant initiatives and support them where appropriate. The Federal Council stated this in its response to the interpellation by Ursula Schneider Schüttel (19.3508 'The exemption of kerosene from the mineral oil tax is outdated. Amend the Chicago Convention').

A moratorium on the expansion of airport infrastructure until it can be demonstrated that this is compatible with the necessary reduction in the sector's greenhouse gas emissions

The development of airport infrastructure is dealt with in the Sectoral Aviation Infrastructure Plan (SAIP). At present, there are no plans for airport expansions in Switzerland that would significantly increase peak capacities. The upgrades currently planned by airports are aimed at ensuring more punctual operations. Any expansions with an impact on capacity would be reviewed for their environmental compatibility at the sectoral planning stage and in the relevant planning approval procedures. Consequently, in the Federal Council's view, this concern has already been sufficiently addressed.

The introduction of a night flight ban of at least eight hours

The night flight regulations at Swiss airports are already strict in order to protect the population from flight noise at night. The 2016 aviation policy report (Lupo 2016) states: "Further restrictions on the operating hours of national airports should only be considered if extended night-time curfews that go beyond the existing regime in Switzerland also become established in Europe" (Federal Council 2016). The Federal Council has confirmed this several times, notably in its response to the motion submitted by Marionna Schlatter (20.3275 'Rebooting aviation. A ban on night flights'). Assuming that capacity remained the same during the day, an extension of night-time curfews would result in an overall reduction in capacity. The climate impact of such a measure is questionable (see also section 3.3) as it would likely result in a significant diversion of traffic to neighbouring countries, while also generating economic disadvantages.

Shifting commercial transit and other domestic flights to rail

Domestic commercial feeder flights account for less than 1% of CO_2 emissions from Swiss aviation. Other domestic flights also make up around 1%. In the case of the latter, it cannot be assumed that there are equivalent rail services available, especially as a significant proportion of these flights are by helicopter. The shift to rail is discussed in section 2.7.

A support package for rail, in particular for the development of international services and night trains

According to the dispatch, promotion of cross-border rail transport is included in the revision of the CO_2 Act. Thus, between 2025 and 2030, a total of CHF 180 million from aviation ETS revenues is to be used to raise the funding ceiling. This issue is also addressed in the Federal Council's report 'Fossilfreien Verkehr bis 2050 ermöglichen' ('Enabling fossil-free transport by 2050').

The establishment of a training and retraining fund to offer employees prospects in climate-compatible public transport sectors

This report demonstrates how the aviation sector itself can become climate-compatible. Retraining staff to work in other sectors would not be conducive to this. It is therefore not examined any further in this report.

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List of abbreviations

ARE	Federal Office for Spatial Development
FOEN	Federal Office for the Environment
FOCA	Federal Office of Civil Aviation
SFOE	Swiss Federal Office of Energy
FSO	Federal Statistical Office
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
EASA	European Union Aviation Safety Agency
ECAC	European Civil Aviation Conference

ETS	Emissions trading system
Eurocontrol	European Organisation for the Safety of Air Navigation
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
CIA	Federal Act on Climate Protection Goals, Innovation and Strengthening Energy Security, Climate Protection Act
Lupo 2016	Bericht 2016 über die Luftfahrtpolitik der Schweiz (2016 Federal Council report on Switzerland's aviation policy) (BBl 2016 1847)
MinOTA	Mineral Oil Tax Act (SR 641.61)
MinOA	Federal Act on the Use of the Earmarked Mineral Oil Tax and Other Funds Earmarked for Road and Air Transport (SR 725.116.2)
NET	Negative emissions technology
SAF	Sustainable aviation fuel
UNFCCC	United Nations Framework Convention on Climate Change
EPA	Federal Act on the Protection of the Environment (SR 814.01)
DDPS	Federal Department of Defence, Civil Protection and Sport